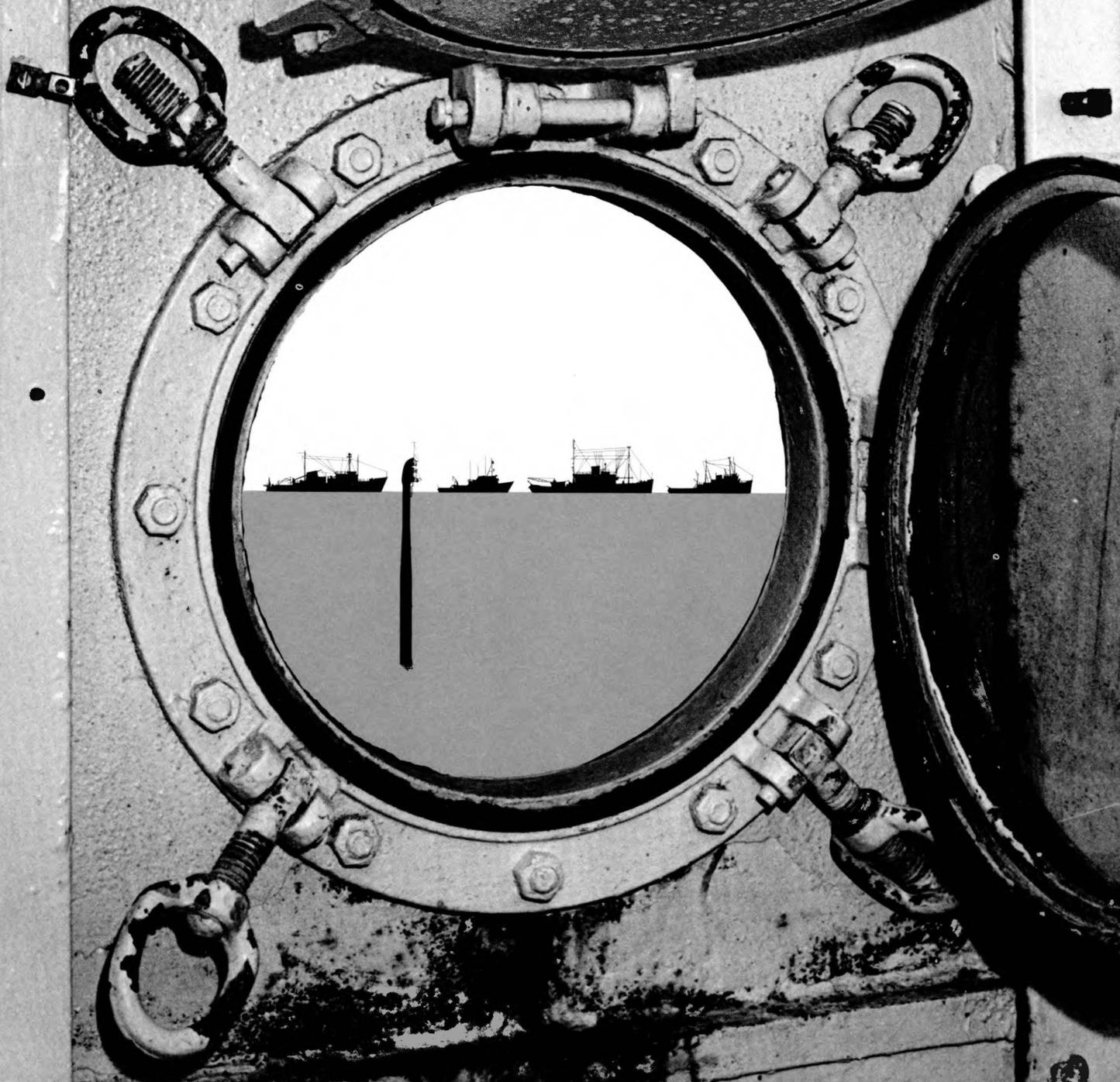


UCSD

SIO 1968

SCRIPPS INSTITUTION OF OCEANOGRAPHY
ANNUAL REPORT FOR THE YEAR ENDING
JUNE 30, 1968

THE UNIVERSITY OF CALIFORNIA AT SAN DIEGO





Dr. Francis P. Shepard, right, pioneer in field of submarine geology, descends from Diving Saucer with pilot, Ron Church.

(Photo courtesy of Ron Church)

sio 1968 SCRIPPS INSTITUTION OF OCEANOGRAPHY
ANNUAL REPORT FOR THE YEAR ENDING JUNE 30, 1968

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

Pictures not individually credited have been provided courtesy of the Scripps Institution of Oceanography campus Photographic Laboratory.



UCSD

Published at San Diego, California

Volume II, Number 2, June, 1969

A series of administrative publications of the University of California, San Diego, P. O. Box 109, La Jolla, California 92037

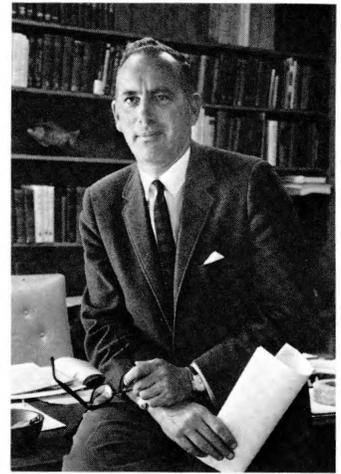
Second-class postage paid at La Jolla, California.

Four issues a year: two issues in June; one in July and one in October.



*Table
of
Contents* *Page*

<i>Introduction</i>	<i>4</i>
<i>Featured Events</i>	<i>6</i>
<i>Seagoing Operations</i>	<i>8</i>
<i>The Graduate Department</i>	<i>14</i>
<i>Research Activities</i>	<i>16</i>
<i>Shore Facilities and Collections (and map)</i>	<i>35</i>
<i>Publications</i>	<i>38</i>
<i>Staff</i>	<i>49</i>
<i>Appendix A: Organization Chart</i>	<i>53</i>
<i>Appendix B: Sponsors</i>	<i>54</i>
<i>Appendix C: Awards and Honors</i>	<i>54</i>
<i>Appendix D: Research Vessels</i>	<i>55</i>
<i>Appendix E: Ph.D. and Master's Degrees</i>	<i>57</i>
<i>Appendix F: Amazon Expedition Participants</i>	<i>57</i>
<i>Appendix G: University Officers and Regents</i>	<i>60</i>



*Dr. William A. Nierenberg, Dean and Director,
Scripps Institution of Oceanography, UCSD.*

INTRODUCTION

The review of a year's accomplishments of a great laboratory is not easily encompassed in an annual report. Even the voluminous Scripps Annual Contributions, which are a good measure of the research output of the Institution, do not tell the entire story. They omit, for example, external interactions and our educational program.

The Institution did continue its steady growth; in fact, in fiscal terms, the growth was more than 20 percent. The most significant event to me, however, was the retirement of the research vessel *Horizon* from active service. This great vessel marked the beginning and end of an era for Scripps. The ship entered service with Scripps in 1948, and took the Institution from one operating in largely local waters to one capable of operating anywhere in the world. This transformation was accomplished largely through the efforts of my distinguished predecessor, Roger Revelle. During these

many years, the oceanographers have had to do with hand-me-down vessels heroically modified to meet the needs of the scientists. With the recent introduction of research vessels designed from the keel up for the purpose, the *Horizon* has outlived her usefulness to Scripps. Although the vessel logged 610,522 miles for research that took her all over the world, she was no longer able to compete with the new class of vessels in economy of operation.

In the early days of the *Horizon*, a major expedition absorbed the efforts of Scripps' entire staff. We now operate three or four major expeditions a year and perhaps a dozen of one-month's duration, with most of the laboratory staff not involved in more than one of these efforts. This new era is also being signaled by the introduction of the computerized vessel and the mid-ocean buoy fields that are producing more and better data for the oceanographer.



Dr. Warren S. Wooster, left, was elected president of the Scientific Committee on Oceanic Research (SCOR) when the group met on campus. At right is Dr. Klaus Voigt, German Academy of Sciences, Warnemunde, German Democratic Republic, SCOR secretary. SCOR past-president, Capt. Luis R. A. Capurro of Argentina, faculty member at Texas A&M University, is in center.

In this nostalgic vein, I should mention that the Institution, as the fifth oldest unit of the University of California, helped celebrate the 100th anniversary of the University by sponsoring two special events. The first was a symposium for the people of San Diego in recognition of their contribution to the community and the Institution, and the second was the designation of the 'round-the-world cruise, *Circe*—utilizing the research vessel *Argo*—as the Centennial Expedition by having the ship carry to her ports of call a brochure about the University and the work of the expedition. Both these events are mentioned later on in this report.

Beyond this nostalgia, however, these pages record steady progress in all research areas in which Scripps is engaged. The major programs that were projected in the last annual report are all successfully underway, including, among others, the North Pacific Study and the JOIDES Deep Sea Drilling Project.

In other matters, the Institution is being caught between a great public demand for accelerating programs in developing the oceans and severe budget strictures, both from the federal government and the State of California. Nevertheless, we have been able to enlarge our research programs in scope and depth, thanks, in part, to many federal and private sources which are listed in Appendix B. We look forward with confidence to a future of continuing steady growth. The principal discouraging note, however, is our inability to increase our student population because of budgetary strictures.

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography



Scripps Director William A. Nierenberg escorts Crown Prince Vong Savang of Laos, right, and Princess Manilay on tour of Scripps campus.

FEATURED EVENTS

Two programs of more than passing interest that involved Scripps Institution faculty and staff members during the year were formal and informal in nature, yet both added to man's knowledge of the science of the sea.

On the formal side was the Institution's Centennial Symposium—"The Ocean 1968—A New World"—held on February 1 and 2. The less formal, but certainly as stimulating to the high school boys and girls who came from 15 states to work and study during the summer at Scripps, was the annual National Science Foundation science training program. Both programs are outlined below.

CENTENNIAL SYMPOSIUM

More than 400 scientists, government leaders, educators, and civic and business leaders gathered in La Jolla for the Centennial Symposium. Sponsored by Scripps Institution, the symposium marked Scripps' participation in the 100th anniversary of the establishment of the University of California.

Distinguished specialists in major fields of marine research, representing Scripps, the University of California, San Diego, and scientific, business, and governmental communities from the United States and abroad spoke to interested audiences. Co-chairmen for the symposium were Dr. Fred B Phleger, professor of oceanography and director of the Scripps Foraminifera Laboratory, and Prof. John D. Isaacs, professor of oceanography and director of Scripps' Marine Life Research Group.

Space limitations preclude reporting the substance of the 13 lectures that comprised the program. The nation's press, however, carried news stories and editorials based on information that flowed from the symposium. The La Jolla *Light-Journal*, for example, editorialized that La Jolla "should look with pride on this grand old-young institution which lends a distinguished name to our community. We say, 'Hats Off' for this symposium, another first in the stride for knowledge of the oceans." And the *Christian Science Monitor*, commenting editorially upon Dr. Edward D. Goldberg's lecture on the chemistry of the ocean, remarked that "His report adds to the many similar warnings scientists have given recently. Their message is



Scripps Director William A. Nierenberg, left, checks Centennial Symposium program with UCSD Chancellor John S. Galbraith, center, and University of California President Charles J. Hitch.

clear. Man's population has grown so huge even ordinary processes of living pollute our environment on a global scale."

Distinguished guests who participated in the symposium were Willard Bascom, president, Ocean Science and Engineering, Inc., Washington, D.C., "Minerals From the Ocean;" Dr. John P. Craven, chief scientist, Deep Submergence Systems Project Office, Department of the Navy, Chevy Chase, Maryland, "Military Oceanography;" Dr. Donald L. McKernan, special assistant for fisheries and wildlife to the Secretary, Department of State, Washington, D.C., "Food From the Ocean;"

Also, Dr. Jerome Namias, chief, Extended Forecast Division, Environmental Science Services Administration, Silver Spring, Md., "The Ocean and the Atmosphere;" Dr. Frank Press, chairman, Department of Geology and Geophysics, Massachusetts Institute of Technology, Cambridge, Mass., "Structure Beneath the Ocean;" and Sir Maurice Yonge, C.B.E., D.Sc., F.R.S., research fellow, Department of Zoology, The University of Glasgow, Scotland, "Biology of the Ocean."



Dr. Theodore Walker and NSF students study marine organisms taken during cruise aboard R/V Thomas Washington.

The symposium included these speakers from Scripps Institution and UCSD:

Dr. Charles S. Cox, professor of oceanography, "Physics of the Ocean;" Dr. Edward D. Goldberg, professor of chemistry, "Chemistry of the Ocean;" Dr. Douglas L. Inman, professor of oceanography, "Beaches;" Professor Isaacs, "Ocean Science and Ocean Technology;" Dr. Henry W. Menard, professor of geology, and acting director, University of California's Institute of Marine Resources, "The Pacific Basin;" Dr. Walter Munk, professor of geophysics and director of the La Jolla Laboratories of the University of California's Institute of Geophysics and Planetary Physics, "Ocean Tides and Waves;" and Dr. Harold C. Urey, professor of chemistry-at-large, University of California, "The Primordial Ocean."

NSF SUMMER SCIENCE TRAINING PROGRAM

Nearly 15 years ago, an exciting and unique seagoing program for high school boys was initiated at Scripps Institution by Dr. Norris Rakestraw, at that time Scripps' dean of students and presently professor of oceanography emeritus. This special program was de-

signed primarily to enable selected boys to get oceanographic experience at sea, aboard Scripps vessels. Scripps funds were set aside for the project, which has since been continued annually, in modified form. The National Science Foundation (NSF) has funded the project since 1959.

Although in recent years the emphasis on seagoing experience has been somewhat reduced, the program has gradually evolved to the point that its broader goals encompass all aspects of the marine sciences. The youth are on campus eight weeks during the summer, and participation is open to highly qualified high school girls and boys between the ages of 16 and 19.

For the past two years, the program has been directed by Dr. Theodore J. Walker, associate research oceanographer, who has broadened the scope of the project to include classroom lectures, laboratory research, and a variety of extra-curricular activities. Nearly 1,000 high school students throughout the United States applied for the 53 available positions in the summer of 1967. Those who were selected represented 15 states.

Under Dr. Walker's guidance, each student was assigned a co-worker—a member of the Scripps staff or faculty—with whom he conducted laboratory and field research. Work carried out by NSF students included such diverse operations as preparing topographic and geophysical maps and models of the Mid-Atlantic Ridge, based on data obtained from earlier Scripps research; measuring waves and currents in the surf zone off the Scripps campus; analyzing core sediments; studying the metabolism of fish tissue under high oxygen pressure; and training electric fish and honeybees.

In addition to conducting their laboratory work, the students listened four nights a week to experts in a variety of oceanographic fields. The combination of lectures and visits to ocean-oriented industries in the San Diego area exposed the young people to a wide range of subjects related to oceanography.

Extra-curricular activities included field trips to Mexico, attendance at performances of the San Diego Symphony, a one-day cruise aboard the Scripps research vessel, *Thomas Washington*, to learn how oceanographic data are collected at sea, and visits to local points of interest.



R/V Thomas Washington



R/V T-441

SEAGOING OPERATIONS

NIMITZ MARINE FACILITY AND THE FLEET

The Scripps Institution of Oceanography fleet of research vessels in the fiscal year 1967-68 consisted of *Argo*, *Alpha Helix*, *Alexander Agassiz*, *Horizon*, *Thomas Washington*, *FLIP*, *Ellen B. Scripps*, *Oconostota*, *T-441*, and *ST-908*. Ship operations were supported by the Institution's Nimitz Marine Facility on San Diego Bay.

During the year the fleet operated at sea for a total of 1,474 days and traveled a distance of 169,472 miles. (See Appendix D for complete ship information.)

Under construction at Defoe Shipbuilding Co., in Bay City, Michigan, and launched in early July, 1968, was the *Melville*, the first of a new generation of Navy-sponsored oceanographic research vessels. This 245-foot, 2,075-ton ship—scheduled to arrive in San Diego in mid-1969 to join the Scripps fleet—will be equipped for research in biological, geological, physical, and chemical oceanography.

Maxwell Silverman and James G. Pollock, Scripps marine engineers, worked closely with naval architects in designing the *Melville*, which will feature a propulsion system that will enable the ship to proceed forward, backward, or sideways, or to remain stationary over a fixed position in 35-knot winds and heavy seas. The vessel, which will have a maximum capacity of 60 scientists, technicians, and crew members, will be a welcome addition to the fleet.

Noteworthy operations during the year involved the *Alpha Helix*, *Alexander Agassiz*, *Argo*, *Horizon*, and *Thomas Washington*.

The beginning of the fiscal year found *Argo* enroute from Honolulu to Suva, Fiji, on Leg III of Nova Expedition which had departed San Diego April 17, 1967. Under the direction of Dr. Harmon Craig, hydrocasts, coring and heat flow measurements were accomplished on this leg. Subsequent legs of Nova Expedition included Leg IV, in July and August, Suva, Fiji to Noumea, New Caledonia, dredging, heat flow, seismology,

and coring, under Dr. Edward L. Winterer; Leg V-A, also in August, Noumea to Brisbane, Australia, dredging, heat flow and seismology, Dr. Henry W. Menard; Leg V-B, in September, Brisbane to Auckland, New Zealand, seismology, Dr. Menard; Leg VI, also in September, Auckland to Suva, dredging, coring, and heat flow, Dr. Craig; Leg VII-A, in October, Suva to Tonga Island, bottom topography and dredging, Dr. Robert L. Fisher; Leg VII-B, in October, Tonga Island to Pago Pago, American Samoa, bottom topography and dredging, Dr. Fisher; Leg VIII, in October and November, Pago Pago to Suva, bathymetry and heat flow, Prof. Victor Vacquier, and Suva to Pago Pago, dredging, Dr. Albert E. J. Engel; Leg IX, in November and December, Pago Pago to Hilo, Hawaii, bottom geology, Dr. George G. Shor; and Leg X, in December, Hilo, Hawaii, to San Diego, bathymetry, Dr. Menard. The ship returned to San Diego on December 19, 1967, having completed Nova Expedition. This expedition logged a total distance of 41,675 miles, 28,155 miles of which were traversed in fiscal 1967-68. Some of the findings of Nova are outlined later in this section under Major Expeditions.

Argo was overhauled and re-outfitted at Nimitz Marine Facility in January and February, 1968, including installation of an IBM 1800 computer. The vessel departed on an around-the-world expedition, designated *Circe*, on March 6, 1968. *Circe* coincides with the centennial anniversary (1868-1968) of the University of California, hence the acronym for "Circumnavigation" of the globe and "Centennial." Dr. George G. Shor carried out work which involved continuous seismic reflection profiling and wide-angle reflection with sonobuoys enroute from San Diego to Honolulu in March. Work by Daniel Karig during April involved seismic reflection and rock dredging studies between Honolulu and Penang, Malaysia. Seismic reflection and sediment studies, conducted by Dr. Joseph R. Curry in May, terminated at Colombo, Ceylon, on June 1. Dr. Charles S. Cox carried out magnetic heat flow studies and rock dredging from Colombo during June, 1968.



R/V Ellen B. Scripps

During the year the ship was underway or working on station 288 days and traveled a total of 50,351 miles.

Alpha Helix began the year enroute from Manaus, Brazil, to a camp-site at Gavião Amazonas Junction, busily engaged in Phase C of the Amazon Expedition which had commenced with departure of the ship from San Diego February 3, 1967. Phase C, from July 5 to August 11, 1967, was led by Dr. Carroll M. Williams, of Harvard University, and involved study of insect physiology. Phase D, which was conducted on the Rio Negro and Amazon Rivers from August 20 to October 7 centered on plant physiology research under Dr. Jacob Biale of UCLA. Phase D terminated at Belem, Brazil, on October 7. *Alpha Helix* departed Belem on October 12 for the homeward cruise. Enroute to Panama, plankton sampling was conducted by Dr. Abraham Fleminger of Scripps. Between November 12 and December 4, zoological collecting was conducted by Dr. Malcolm Gordon of UCLA in the Galapagos Island area. The ship arrived in San Diego on December 16, 1967. Some of the expedition's findings are outlined later in this section, under Major Expeditions.

After overhaul and re-outfitting at Nimitz Marine Facility, *Alpha Helix* departed on the Bering Sea Expedition on February 9, 1968. Program A, led by Dr. Per F. Scholander and Dr. H. T. Hammel, of Scripps' Physiological Research Laboratory, originated at Dutch Harbor, Alaska, March 6 and terminated at Kodiak, Alaska, on April 30. This program involved studies of the temperature sensitivity of arctic fishes, diving reflexes in seal and walrus pups, physical chemistry of fishes in ice areas, and adaptation of birds, walruses, and seals to temperature variance. Program A was conducted in part with the U. S. Coast Guard Cutter *Northwind* in heavy ice in the vicinity of Nunivak Island. Program B, under Dr. Kjell Johansen of the University of Washington, involved metabolic, circulatory and gas exchange studies of seals, walruses, and sea otters, fishes and larger invertebrates. This work, also conducted in ice, terminated at Dutch Harbor, on June 4. The vessel was re-outfitted at Kodiak during



R/V Oconostota

the remainder of June in preparation for Program C. During 1967-68, the ship was underway or working on station at sea 312 days and logged 19,607 miles.

For the first nine months of the year, *Alexander Agassiz* was on inactive status undergoing overhaul and a major conversion involving installation of two bow propulsion units. After being fitted out, the ship departed San Diego on Phase I of Styx Expedition on April 2, 1968. Studies of deep-flow water characteristics, topography, and sediments in the Central Pacific Ocean were carried out by William R. Riedel, Thomas J. Walsh, and Joseph L. Reid during the remainder of the year. The ship was underway or working on station at sea 93 days and traveled a total of 10,414 miles in 1967-68.

Horizon began the year at Suva, Fiji, after having completed Leg II of Nova Expedition. The ship continued this expedition as follows: Leg III, bathymetry, dredging and coring and returning to Suva under Dr. Henry W. Menard; Leg IV, Suva to Noumea, New Caledonia, bathymetry, coring, dredging and heat flow, Dr. Menard; Leg V, Noumea to Brisbane, Australia, to Auckland, New Zealand, coring, dredging and seismology, under Dr. George G. Shor; Leg VI, Auckland to Pago Pago, American Samoa, to San Diego, seismology, Daniel Karig. The ship returned to San Diego on October 14, 1967, having completed Nova Expedition. This expedition logged 31,439 miles, 17,404 miles of which occurred in fiscal year 1967-68. Following overhaul and re-outfitting at Nimitz Marine Facility the ship was employed by the Marine Life Research Group in December, 1967, and January, 1968. *Horizon* went out of service on January 27, 1968. In May, 1968, plans for her disposal were deferred pending further employment of the vessel for about two months in the fall of 1968. During the year, the ship was underway or working on station at sea 146 days and logged 24,334 miles.

In spite of limitations placed on the vessel pending replacement of the ship's main propulsion and service generator diesel engines, *Thomas Washington* carried



R/V Argo



R/V Alpha Helix

out several significant programs during 1967-68. These included: Eastropac Expedition in August and September, 1967, under Dr. Warren S. Wooster; TOW-MAS in November and December, 1967, under Dr. Fred N. Spiess; deep water biological operations in January, 1968, under Dr. Carl Hubbs; Eastropac Expedition, February, March and April, under Dr. Wooster; and TIP TOW, in May, under Dr. Spiess. The vessel commenced a four-month shipyard period on June 15, during which her propulsion and service diesel engines were to be replaced. The vessel operated a total of 214 days and steamed 29,343 miles in fiscal 1967-68.

FLIP spent a large fraction of the year in a major overhaul, including the addition of a deckhouse which provides increased laboratory and ship-control space, quarters for two additional men and other facilities. Lack of shipyard availability and the extensive nature of the work delayed completion until February, 1968. During the remaining months of the year, local operations were conducted in support of the acoustic signal processing investigations of Dr. V. C. Anderson and in preparation for the mid-Pacific sound propagation experiment, Parka. These involved, during the 1967-68 fiscal year, a total of 13 flipping operations and towed transit of somewhat over 2,000 nautical miles.

Ellen B. Scripps was employed mainly in operations of short duration in California and Mexican coastal regions. The vessel's versatility was demonstrated repeatedly through rapid equipment changes to suit new program requirements in minimum turn-around time. Use of the vessel for offshore work included tests of Applied Oceanography Group equipment by Dr. William MacLeish; deep-sea capsule work by Frank E. Snodgrass; and the establishing of taut-wire moorings and handling of experimental buoys by Dr. Charles S. Cox. Several programs of three to four weeks' duration included, in July, 1967, a Marine Life Research Group cruise; in November, 1967, and February, 1968, geological and geophysical studies off Baja California, by Dr. Henry W. Menard; and in May, 1968, studies of spectral radiant energy measurements in water, by John

E. Tyler. *Ellen B. Scripps* operated 165 days and logged 19,588 miles in fiscal 1967-68.

Oconostota was employed largely by the Marine Physical Laboratory for work by C. S. Pepper involving magnetometers. Drs. Charles S. Cox and Myrl Hendershott utilized the vessel for handling, launching, and retrieving experimental buoys. The vessel operated 130 days and traveled 11,549 miles.

T-441 was out of service most of the year and operated one-day, near-shore trips for 60 days; she traveled 2,513 miles. The *T-441* was declared surplus to Scripps' needs and will be turned over to the University of Connecticut in the near future.

The *ST-908* regularly carried out small-craft work formerly accomplished by *T-441*. *ST-908* operated 66 days and covered 1,773 miles.

MAJOR EXPEDITIONS

As is clearly indicated above, Scripps Institution research vessels are key factors not only in cruises of short duration and for work relatively near home port, but also in expeditions to far-flung places around the world.

The Institution's two major expeditions in 1967-68 involved the *Argo* and the *Horizon*, during the 73,114-mile Nova Expedition, and the *Alpha Helix*, which logged 17,610 miles during the Amazon Expedition.

NOVA EXPEDITION

Dr. Henry W. Menard led a major part of, and coordinated planning for, the Nova Expedition that worked in a 5-million-square-mile area of the Central and southwest Pacific.

Dr. Menard reported that a sedimentary "snow fall" of fossils from microscopic shells whose intense weight accumulated for more than 15 million years has pushed islands 900 feet below the surface of the Pacific Ocean at an inch every 2,000 years.

The discovery he cited was among several made by an international team of scientists during the eight-month expedition funded by \$1,500,000 in contracts



R/V Alexander Agassiz

and grants through the U. S. Office of Naval Research and the National Science Foundation.

More than 25 scientists from Australia, New Zealand, New Caledonia, France, England, Japan, and Switzerland and from several universities in the United States participated in *Nova*, whose prime goals were to study the origin of island and land masses and possible continental drift in the Pacific.

Argo sailed from San Diego April 17, 1967, to join her sister ship, *Horizon*, which took part in *Nova* for six months before returning home in mid-October, 1967. *Argo*, with Capt. Laurence Davis and Alan W. Phinney in charge, and *Horizon*, captained by Noel Ferris and Terry Hansen, logged 31,439 miles and 41,675 miles, respectively. *Argo* returned to San Diego December 19, 1967.

The ships' ports of call included Noumea, Suva, Auckland, Brisbane, Pago Pago, Honolulu, and Hilo, as well as the remote islands, in the Melanesian region, of Tonga, Rotuna, and Futuna, and the Explorer Islands.

Because of the length of the expedition and nature of work involved, *Argo* crews were rotated home in July and September and *Horizon* crews in April and June. *Horizon* had put to sea earlier on February 7, and concluded Scripps' two-month Carmarsel Expedition in the Pacific just before teaming up with *Argo* for the *Nova* research.

One of *Nova's* major accomplishments was the successful tabulation of data while both ships were cruising and the resultant preparation of new maps within the first several weeks. The new maps were distributed to scientists and crews of the two vessels for use during the ensuing months.

The "snow fall" of fossils was discovered along a 600-mile line of submerged volcanoes, or guyots, about 500 miles east of Australia along the north-south Lord Howe Rise.

"The intense pressure from the incredibly large amounts of falling sediment had gone on long enough that it was sufficient literally to push the gigantic volcanoes below the ocean surface," Dr. Menard reported.



FLIP

"The remarkable fact about the line of guyots was their uniform depth. We were able to pinpoint the age of the area by dredging an outcropping of rock on the Lord Howe Rise exposed by swirling deep-ocean currents that had disturbed the thick sedimentary ooze."

Another major discovery during the expedition was an explanation as to why the ocean area under study is so curiously shallow.

For example, it was found that the Fiji Plateau is higher than it was originally thought to be because the earth's mantle is pushing it up from below. Also, the ocean bottom has a thick crust elsewhere in the area and that makes for shallower water. There is also more sedimentary ooze than originally thought, and this contributes toward a shallower region.

The scientists also discovered an extremely large area on the Fiji Plateau in which the outward flow of heat from the earth was more than twice the earth's normal heat flow. The Fiji Plateau is the highest ocean plateau in which such a high heat flow has been recorded. It is somewhat comparable to the rate of heat flow discovered by Scripps scientists west of Japan in 1966 during the Institution's Zetes Expedition.

As to sea-floor spreading, the scientists learned that there have been a great many earthquakes on the ocean bottom west of Fiji. Many narrow, deep trenches 500 miles long and separated by ridges were found. These trenches are the locus of the quakes, and the area appears to be a place in which the sea floor is spreading, ever so slightly, just as it is doing in the Atlantic Ocean along the Mid-Atlantic Ridge.

Participating as scientific leaders in the 16 legs of *Nova* from Scripps Institution and the University of California, San Diego, in addition to Dr. Menard, were, Drs. Harmon Craig, Edward D. Goldberg, George G. Shor, Edward L. Winterer, William G. Van Dorn, Robert L. Fisher, and Albert E. J. Engel; Prof. Victor Vacquier, T. E. Chase, Stuart M. Smith, Perry Cramp-ton, and Daniel Karig.

Nova plans were coordinated with related expeditions of the U. S. Coast and Geodetic Survey, Lamont



R/V Horizon

Geological Observatory of Columbia University, the Hawaii Institute of Geophysics, and several organizations in the southwest Pacific.

AMAZON EXPEDITION

Eighty-six scientists from 12 countries and representing 39 institutions comprised the four international research teams which conducted Brazilian Amazon Basin investigations in four broad areas.

Their work was conducted primarily at the confluence of the Rio Negro and Rio Branco Rivers, some 200 miles up-river from Manaus—itsself 1,000 miles up the Amazon from Belem. Investigations were conducted aboard the *Alpha Helix* and in a laboratory-equipped shore camp.

Fields of research and their leaders were (1) behavioral studies of fish and animal life, directed by Dr. Theodore H. Bullock, professor of neurosciences, University of California, San Diego, School of Medicine; (2) evolutionary transitions experienced by fish moving through various environments, headed by Dr. Knut Schmidt-Nielsen, Duke University, Durham, N.C.; (3) studies of insects and the insect-repelling qualities of plants, under Dr. Carroll M. Williams, biologist from Harvard University, Cambridge, Mass.; and (4) research into tropical fruits and their commercial potentialities, directed by Dr. Jacob Biale, botanist and plant physiologist, University of California, Los Angeles.

The research generated 109 field reports ranging from the infrared sensing abilities of the boa constrictor to the nature of condensation nuclei in the Amazon atmosphere. In all, the investigations provided a marked contrast between the wet tropics of the Amazon Basin and the arid tropics of Australia's Great Barrier Reef, locale of the first expedition in which the *Alpha Helix*

participated after joining the Scripps fleet in 1966.

Homeward-bound from the Amazon, scientists investigated deep-sea marine life in the Galapagos Islands area, during studies led by Dr. Malcolm Gordon, UCLA zoologist.

Commanded by Capt. James Faughn and Robert Haines, the *Alpha Helix* logged 17,610 miles during the Amazon Expedition. She sailed from San Diego February 3, 1967, and returned home December 16.

"Results of the exciting, basic research conducted aboard the *Alpha Helix* and at the shore camp far exceeded our expectations," Dr. Per F. Scholander, expedition coordinator and director of Scripps' Physiological Research Laboratory, reported.

"The cooperation of the Brazilian government and of Brazilian scientists was all that could be asked for. We were especially grateful for the excellent work of Navy Cmdr. Manoel Pérez, himself a physical chemist, who was the Brazilian liaison officer with the expedition."

The 86 scientists, including some ten graduate students from Scripps, who took part in the expedition represented the United States, Brazil, England, Canada, Germany, Norway, France, New Zealand, Sweden, Australia, Japan, and Russia. (See Appendix F for names of participants and affiliated organizations.)

The expedition was funded by a \$600,000 grant from the National Science Foundation.

Lack of space precludes enumerating the many types of research conducted in the Amazon Basin and Galapagos Islands. These few preliminary findings may be of interest.

Dr. Williams reported that hormones he brought back from the Rio Negro may be used as the basis for insecticides that could either destroy any insect or be



R/V ST-908



(Photo courtesy Alan C. Jones)

R/V Argo docks at Pago Pago, American Samoa, during Nova Expedition.

adapted to destroy one particular specie.

Dr. Bullock discovered that boa constrictors and anacondas have highly sensitive heat receptor systems in their lips and can sense bodies warmer or colder than surrounding objects, an ability that helps them find food. Peter Hartline, a UCSD graduate student, also discovered that boas can hear airborne sounds. He obtained readings from electrodes placed in the boa's brains after they had been insulated against earth vibrations.

Dr. A. B. Steinbach of Rockefeller University learned that some types of electric eels function best in water that is neither too salty nor too soft (as in the Rio Negro).

Working with the so-called vicious piranha fish, Dr. Hubert Markl, an ethologist from the University of Frankfurt, West Germany, discovered that most species are somewhat timid, will attack an abnormal-looking object, such as a sick fish, rather than a normal one, and hesitate to attack anything larger than themselves.

In studying the cicada, Dr. David J. Aidley, of Oxford University, England, learned that these relatives of the American seven-year "locusts" have drums on both sides of the abdomen that are sounded by rapid tightening and releasing of the membrane, a rhythm generated in the muscle, not the brain.

Dr. Scholander and Commander Pérez studied the sap pressures measured in the "drowned" forests under flooded conditions that existed when they were working on the Rio Negro. During the *Alpha Helix's* 1966 expedition to Australia's Great Barrier Reef, Dr. Scholander learned that mangroves were able to develop enough negative pressure or suction to desalt the water, whereas on the Rio Negro, the hydraulic systems of

plants in fresh water provided contrasting conditions.

Studying sloths, Dr. Robert B. Livingston, chairman of the Department of Neurosciences of UCSD's School of Medicine, and Dr. Donald B. Lindsley of UCLA learned that the slowness of the three-toed sloth is related to its central processes but not enough to explain the animal's entire slow-motion system.

Dr. Kenneth Norris of UCLA discovered that the Amazonian pink, fresh-water dolphins have higher-pitched voices than their salt-water contemporaries. Once thought to be silent, they actually make yelps and barks.

Dr. Biale and his colleagues researched problems connected with the ripening and preservation of fruits, studied the time sequences occurring in their development, and discovered what appears to be a new strain of cacao.

In the Galapagos Islands operation, some ten specimens of a rare, deep-sea, scorpion fish, *Ectreposebastes imus*, were identified aboard ship by Dr. Richard H. Rosenblatt, Scripps' curator of marine vertebrates. The only previous similar specimens taken from the Pacific were collected by the U. S. Fish Commission's Albatross Expedition in 1891. Dr. Rosenblatt also collected small shore fishes of many kinds and determined the thermal tolerance ranges for several which have evolutionary relationship with tropical or subtropical mainland groups.

Dr. Malcolm Gordon of UCLA measured the metabolism rate, at different temperatures, of red and white muscles from six species of inshore and free-swimming fishes, and noted a higher rate of oxygen uptake by the red muscles than the white.

Drs. Frank Carey and John Teal of Woods Hole Oceanographic Institution, Woods Hole, Mass., studied various aspects of respiratory physiology in diving marine iguanas.

In order to better understand the adaptation of deep-sea fishes to their environment, the effects of pressure on the oxygen consumption in fish muscle were researched by Dr. Alexei Kuznetsov, a member of the Soviet Academy of Sciences from Moscow's Institute of Oceanology.

Dr. Fred White, of the UCLA School of Medicine, studied the heart rate and temperature adaptation of marine iguanas sunning themselves on the Galapagos rocks and again after they slithered into the ocean. Dr. Kenneth Norris, UCLA zoologist, continued his work on porpoise echo-location problems; that is, how porpoises transmit sound to their inner ear. This is not achieved by the usual "hole" in the ear, and Dr. Norris was trying to determine whether the sound is transmitted through the animal's lower jaw or the fatty lump in its head.

THE GRADUATE DEPARTMENT

As indicated in the previous annual report, graduate education is administered through the Department of the Scripps Institution of Oceanography. Within this Department, curricular programs are offered in biological oceanography, marine biology, marine chemistry, physical oceanography, marine geology, and geophysics. Each curricular group has its own special requirements for admission (in addition to those applying to the Department as a whole), and its own course requirements and policies.

Clearly in the rapid evolution of modern oceanography, growth is often most vigorous at the boundaries of established disciplines, so that the interests of a given student may fall somewhere between the limits of two curricular programs. It was the intent of the unification of the educational activities at Scripps to provide the maximum of flexibility in meeting the specific interests of individual students. To date the structure has been successful in responding to such problems.

CURRICULUM IN APPLIED OCEAN SCIENCES

During the year, a new curriculum in applied ocean sciences was established. The impetus for this curriculum came from the increasing demands of society for people with sound professional education in this area, and from establishment of the office of Sea Grant Programs in the National Science Foundation. This office has made available funds for the support of faculty and students in this curriculum, and additional faculty provisions have been furnished by the University.

The program in applied ocean sciences is being developed jointly by the Graduate Department of Scripps and two engineering departments on the San Diego campus of the University; namely, Aerospace and Mechanical Engineering Sciences and Applied Physics and Information Science. The goal is to create a flexible program directed toward the useful intervention by man into the sea through the applied physical sciences. An attempt will be made to produce modern engineers with a substantial training in oceanography, and oceanographers with a significant ability in modern engineering, competent to undertake instruction, research, and professional activities in areas such as those outlined below:

- Support of Ocean Science: Concept and design of instruments, ships, platforms, tools, and equipment (examples, FLIP, and autonomous instruments, automated ship handling, deep moored stations, fixed arrays, drilling ships).
- Methodological Contributions of Ocean Science: Research in mixing, turbulence, air-sea interaction, structure and similitude laws of organisms.
- Support of Ocean Industry: Concept, research, and design in transport, harbors, mining production, recreational facilities, beach erosion control, fish acquisition methodology, disposal and pollution, under-sea warfare, mine countermeasures, amphibious warfare.
- Guidance of Marine Development: Delineation and appraisal of resources, such as planetary power, food,

fuels, transport, water problems, minerals, recreation, aesthetics; concept and consideration of basic innovation.

- Development of the Technological Base: Delineation and acquisition of basic technical information, analysis of limiting conditions, combers, near-bottom velocities, turbidity flows, earthquake overpressures, tsunamics, bottom conditions, effects of organisms, engineering nature of bottom materials, electrolysis, pressure effects, effects of explosions.
- Generalized Technical Development: Concept and developments for enhancement of freedom from wave motion, pressure, distance, consideration of fundamental entries (examples: stable platforms, true marine aircraft, surface effect vehicles, improved load handling at sea, air-sea and satellite-sea linkages; evaluation of Claudé systems).
- Large-Scale Intervention and Forecast: Co₂ greenhouse problems, Bering Straits dam, Red Sea dam, thermal-gradient-driven upwelling.

Although this list naturally covers a considerable range of intellectual challenge, none of the items is trivial and in fact their full exploration would occupy a much larger faculty for a number of years.

GRADUATE STUDENTS AND DEGREE RECIPIENTS

In the fall of 1967, 49 new students began their graduate studies. Of these, eight were in marine chemistry, five in marine geology, two in geophysics, 25 in marine biology, four in biological oceanography, and five in physical oceanography. They came from these states and countries: California, 17; Connecticut, 2; District of Columbia, 2; Florida, 1; Hawaii, 2; Illinois, 4; Massachusetts, 1; Michigan, 3; Minnesota, 1; Missouri, 1; New Jersey, 1; New Mexico, 1; New York, 4; Ohio, 1; Pennsylvania, 1; South Dakota, 1; Wisconsin, 1; Canada, 1; Germany, 1; India, 1; Israel, 1; Taiwan, 1. Enrollment at the start of the year totaled 184.

During the year, eight Master of Science degrees and 14 Doctor of Philosophy degrees were awarded by UCSD to students having completed their advanced studies at Scripps. The names of degree recipients and the titles of doctoral dissertations are listed in Appendix E. The following abstracts of dissertations by Thomas A. Clarke, Herbert Lynn Windom, and Robert L. Zalkan are indicative of the varied subjects chosen by candidates for the doctoral degree.

Clarke's dissertation was entitled, "Territorial Behavior and Population Dynamics of the Garibaldi." After leaving Scripps, he became assistant professor of oceanography in the Department of Oceanography, University of Hawaii. The abstract of his dissertation follows:

The ecology of the garibaldi, *Hypsypops rubicunda*, was investigated to determine how aspects of the life history, particularly territorial behavior, affect the dynamics of local populations.

The garibaldi inhabits the rocky subtidal region from 0-25 m and ranges between Point Concepcion, California, and Magdalena Bay, Baja California. Adults have a restricted home range and defend it

as a territory the year around. Most aspects of the garibaldi's territorial behavior seem primarily related to reproduction. The adult male cultivates and tends a patch of living red algae at the nest site. After courting a female and allowing her to spawn in the nest, the male chases her away and guards the eggs. After hatching, the larvae go into the plankton and subsequently settle out in shallow water. Some juveniles move deeper as they mature. Age estimates from scales indicate that juveniles assume adult coloration at age five or six years and that adults live 13 and possibly 17 years. Garibaldi have no apparent competitors and no known predators or diseases. Mortality is very low, about 10 percent of the adult population per year. The principal food of the garibaldi in the areas studied was soft siliceous sponge supplemented by other sessile organisms.

In the the areas studied, from 57 percent to 69 percent of the adults were males; of these, 16 percent to 49 percent were bachelors, and 20 percent to 72 percent nesting males. The nests tended to be evenly distributed unless sites suitable for nest culture were strongly aggregated. The nesting males also held territories in the more favorable sections of any given area.

When some fish were removed, the vacated territories were usually filled rapidly. Reoccupants tended to be the same sex as the original residents, and their sizes were positively correlated with those of the original inhabitants. The fish that moved into vacated territories were usually from neighboring non-nesting territories. Territories were reoccupied as units with the same boundaries, forage areas, and shelter. Bachelor males that reoccupied vacated territories of nesting males usually used the same nest site. The probability of spawning success was nearly constant for a given site and was unaffected by a change in residents.

In most areas, adult density is limited by the local supply of some requisite and regulated by factors operating within the area and not by outside events, such as larval or juvenile mortality. In some cases, density was well below the estimated carrying capacity of the resources. It appeared that the males' defense of an area required for spawning denied resources to other fish and thus both limited and regulated density. In other cases, density appeared to be limited by the abundance of some resource such as food or shelter. There is evidence that, in such cases, density could be regulated by emigration from and avoidance of overcrowded areas. However, it is likely that territorial defense, by excluding individuals, also plays a part in regulation. There is no evidence that these effects have been important in the evolution of territorial behavior. All aspects of the behavior appear to be consequences of the garibaldi's method of reproduction; the effects on density are probably incidental.

Windom is affiliated with the Georgia Institute of Technology's Skidaway Institute of Oceanography, at Savannah. The title of his dissertation at Scripps was "Atmospheric Dust Records in Glacial Snowfields:

Implications to Marine Sedimentation." The abstract of his dissertation follows:

This study considers the contributions of atmospherically transported solids to marine sediments by an investigation of the dust accumulation in glacial snowfields. Seven snowfields, including the Antarctic and Greenland ice sheets and five associated with temperate glaciers, were studied. Lead-210 geochronology was used to ascertain rates of snow accumulation and of dust fallout. Semiquantitative mineralogical and size analyses were carried out on the particulate matter in the ice samples. The results indicate that the dust comes from material derived from local and distant (global) sources. The composition of the global component is dependent on sources under its wind system, while that of the local component is dependent on the regional geology and physiography of the sampling area.

The accumulation rates of the global dust component range from 0.1 to about 1.0 mm per 10³ years. Comparison of the accumulation rate, mineralogy, and size distribution of the globally transported dusts with those of the adjacent marine sediments of the North and South Pacific and Central Atlantic oceans, suggests that these areas receive as much as 25 percent to 75 percent of their detrital phases from atmospheric dust fallout.

Zalkan, who studied for his advanced degree at Scripps under U. S. Navy sponsorship, returned to active duty with the Navy upon receiving his doctorate and is now serving at the U. S. Naval Nuclear Power School, Mare Island, San Francisco. Title of his dissertation at Scripps was "Observation of High Frequency Internal Waves in the Pacific Ocean." The abstract of his dissertation follows:

Observations of high frequency internal waves were made from December 1 to 14, 1966, in the deep sea off Baja California. The fluctuations of the depth of an isotherm were measured with a three-element horizontal array attached to a stable platform.

The waves are characterized as a broad band phenomenon with a continuous distribution in frequency. For short intervals of time, a narrow frequency band within the continuum is adequately described as a horizontally plane wave of a single vertical mode. Furthermore, this simplified structure is stationary over time spans of several days. High modes are present in the low frequency waves. Above four cycles per hour, however, the first mode predominates.

The spectral shape is consistent with the shear limited equilibrium spectrum proposed by Phillips (1966). In addition, the predominance of the first mode at high frequencies further emphasizes the importance of shear instability in internal wave propagation.

The horizontal properties of the wave field indicate well-defined directions of narrow-beamed propagation. These directions and the dispersive properties of the propagation have led to the identification of local topographic features as generating areas of internal waves.



(Photo courtesy of Leigh Weiner)

IBM 1800 computer, first of its kind to be installed on a research vessel, is hoisted aboard the *Thomas Washington*.

RESEARCH ACTIVITIES

One of the most frequent questions asked by visitors to Scripps Institution—and even by those inquiring by mail—is, “What’s going on at Scripps?” Obviously, in the space allotted, it is impossible to pinpoint here the far-ranging scope of research programs undertaken during this year. One of the highlights, however, was a major step forward in use of digital computers on board Scripps ships. Although the utilization of such equipment is still in a developmental stage, experience obtained in their shipboard applications has led to speeding the work of seagoing scientists and freeing shore-based personnel for efforts that have, in times past, been devoted to analysis of data sometimes months after they have been recorded at sea, and that simply awaited the arrival of the ship in home port before the information could become available for interpretation.

Two groups installed digital computers aboard Scripps ships during the year. The first was the deep-tow group of the Marine Physical Laboratory, while the second was formed by the Scripps Shipboard Computer Panel, with Dr. C. S. Cox, chairman, as part of a program to provide the capabilities of general purpose digital computers to shipboard research activities.

The Marine Physical Laboratory group began use of a PDP 8 computer on board the *Thomas Washington* in the fall of 1966 in connection with deep-towed instrument work. The primary purpose in having the computer on board was to speed the calculations associated with acoustic transponder navigation and to provide a digital data logging capability for both the magne-

tometer and the precision echo sounder which are included in the deep-tow package.

Capability to carry out these functions was developed gradually so that by May, 1968, data logging was operative and the navigational capability was complete. Acoustic travel time information for up to six transponders can be inserted and will result in a plot (on 30-inch flatbed unit) of successive positions for both the ship and the towed body. The combination of transponders and computer provides a real time local tracking capability for the towed FISH (near bottom in 1500 fathoms or more), showing individual position uncertainties of less than 100 meters. FISH is the acronym for Fully Instrumented Submersible Housing. Further improvement of accuracy can be obtained, if needed, by increasing program sophistication, as is done in subsequent shore processing in which residual range uncertainties of about five meters are achieved.

Prior to introduction of the computer, manual means for determination of fixes resulted in routine production of FISH and ship fixes from three transponders with a delay of about 15 minutes behind the time of availability of data. This delay has now been reduced to only 30 seconds, most of which is associated with reading of the original travel time information.

In connection with the work of the Computer Panel Group, an IBM 1800 Data Acquisition and Control System was checked out in a campus laboratory. It was transferred in June, 1967, to the R/V *Thomas Washington*, and installed aboard ship in accordance with a joint research project agreement between IBM and the University entitled “Investigation of Capabilities of an Electronic Computer Aboard an Oceanographic Research Ship.”

The first expedition of the *Washington* utilizing the IBM 1800 was Eastropac, during August and September, with Dr. Bruce Taft as chief scientist. The computer was maintained and operated by IBM and Scripps personnel. It gathered data directly from several scientific and ship’s instruments, including expendable bathythermographs, gyrocompass and electromagnetic log. Data from the salinity-temperature-pressure sensor, Nansen casts, chemical analyses, and navigation were reduced, correlated, and displayed, usually graphically, with a digital plotter.

As a result of this and other cruises of the *Washington*, the Shipboard Computer Panel selected an IBM 1800 computer for installation aboard the R/V *Argo* for the Circe Expedition. The Panel also recommended that the Shipboard Computer Group be expanded to provide for design and construction of direct computer interfaces and associated computer programming for many additional instruments.

The Office of Naval Research purchased a computer for the *Argo* and its utilization during the early legs of

the Circe Expedition was expanded to include automatic gathering of magnetometer and navigational data, including inputs from a Magnavox navigational satellite receiver.

Operation of the satellite receiver was poor initially, but it improved to the point that an average of four navigational "fixes" per day were obtained. These normally were in error by less than one-half mile. The data were acquired by the computer, extensive computations performed, and the results printed without operator intervention.

The computer initially placed on the *Washington* was subsequently installed ashore to support sea-going systems, and another computer has been ordered for the *Washington*. Preparations for the first voyage with this computer and continuing development of the *Argo* system are producing a number of instrument interfaces and a library of programs which will allow the computers to be increasingly useful to Scripps scientists in upcoming voyages as they make on-the-spot decisions regarding the progress of their work without having to wait until a cruise is over to process their data.

DEEP SEA DRILLING PROJECT

Scripps Institution's Deep Sea Drilling Project, a part of the National Science Foundation's Ocean Sediment Coring Program, is now almost at its full operating capability. Drilling and coring of sediments from the floor of the Gulf of Mexico and the Atlantic Ocean, in water depths of up to almost 18,000 feet, have been accomplished with gratifying success.

On March 23, Mrs. William A. Nierenberg, wife of the director of Scripps, christened the drilling ship, *Glomar Challenger*, with a bottle of seawater mixed from the Atlantic and Pacific Oceans and symbolic of the far-flung operations scheduled for the scientific program.

The *Glomar Challenger* was constructed for Global Marine Inc., of Los Angeles, by the Levingston Shipbuilding Co., in Orange, Texas. In less than a year, the project moved from the signing of the contract for the drilling ship to the collection of the first samples from deep beneath the floor of the oceans.

The 400-foot, 10,500-ton, self-propelled, drilling ship is the first commercial vessel to use the heretofore classified satellite navigation system developed by the U. S. Navy. The vessel is outfitted with some of the most sophisticated equipment in the offshore industry. She works at water depths of 5,000 to 20,000 feet and takes sediment cores to a depth of 2,500 feet into the sea floor.

The *Challenger* is the first of its size and type to have "dynamic positioning," a system of four tunnel thrusters in the bow and stern and its own propellers—all controlled by an electronic computer to maintain its posi-



Glomar Challenger slides down the ways in launching ceremonies at Levingston Shipbuilding Co., Orange Texas.

tion continuously within prescribed limits when waves, currents, or wind try to move it away from the drilling site.

Kenneth E. Brunot was appointed project manager, succeeding Dr. William Rand, to carry the project to its present accomplishments. The scientific program is being led by Dr. Melvin N. A. Peterson, project chief scientist, of Scripps.

The program receives impetus and backing from the JOIDES organization and a panel structure that involves many of the nation's leading scientists. The original JOIDES institutions—Scripps, Lamont Geological Observatory of Columbia University, Woods Hole Oceanographic Institution, and the University of Miami's Institute of Marine Sciences—have been joined by the University of Washington.

Early in the program, Dr. Elizabeth L. Gealy was appointed executive staff geologist. More recently, Dr. N. Terence Edgar was appointed coordinating staff geologist, and Dr. T. A. Davies was appointed information officer. William R. Riedel is curator for the project. Other scientists and technicians are being brought into the permanent staff to participate in the drilling cruises, in the collection of data, and in the final report production.

Co-chief scientists for the first leg, which started in the Gulf of Mexico and ended at New York, were Dr. Maurice Ewing and Dr. J. Lamar Worzel of Lamont; for the second leg, ending at Dakar, Africa, Drs. Peterson and Edgar of Scripps; and for the third leg, Dr. Arthur E. Maxwell and Dr. Richard von Herzen of Woods Hole. Eminent scientists from across the nation and abroad participate in the shipboard and shore-based studies of the core material and other information recovered from the program.

Early results from the first leg included the demonstration that small knolls found on the floor of the central Gulf of Mexico, called the Sigsbee Knolls, are salt domes having typical caprock and accumulations of oil and gas, all of which are of potentially great economic interest. Sediments in the undisturbed abyssal plain of the Gulf of Mexico, both from the foot of the Sigsbee Scarp and near the Sigsbee Knolls, show the importance of deposition by turbidity currents, which are

(Photo courtesy of Gann's Studio)

intermittent flows along the bottom carrying sediment in suspension.

Information derived from the first leg operations has important implications for the remainder of the Deep Sea Drilling Project, and for the future of deep-ocean drilling in general.

GEOLOGICAL RESEARCH DIVISION

The Geological Research Division was formed this year of individual investigators and groups of investigators who work on geological, geophysical and stratigraphic aspects of oceanic research. It includes a broad spectrum of research projects from the shore line to the deep sea; the sediments, and their geochemistry, fauna, and flora; and the evolution of the earth's crust, continents, and ocean basins. A few of the many types of research projects are described briefly here.

Dr. Fred B Phleger was one of the organizers of the International Symposium on Coastal Lagoons in Mexico City, sponsored by UNESCO and the National University of Mexico, and is co-editor of the symposium volume which is now in press. His recent work on foraminiferal populations from marine marshes in England, Holland, Australia, New Zealand, Brazil, Argentina, and Chile, has given insight into faunal patterns in marine marshes, some of the physical and chemical characteristics of these environments, organic productivity, relative rates of sedimentation, and the dynamics of adjacent coastal lagoons.

Dr. Wolfgang Berger's analysis of planktonic foraminiferal populations from a frontal area in the California Current suggests that the empty shells settling to the bottom are largely derived from displaced populations, with local reproduction and predation also contributing factors. The estimated flux of empty shells was about 6 percent of the living standing crop per day, by volume. Data from this area and from previous work suggests that turnover rates of a few days are possible. The effect of solution in modifying a foraminiferal assemblage accumulating on the bottom has been investigated.

A continuing study of Late and Middle Tertiary stratigraphy of deep-sea cores using planktonic foraminifera, has been conducted by Miss Frances L. Parker. She is also studying the distribution of recent species in the South Pacific surface sediments. The two studies, taken together, give interesting data on changes in the distribution of species since Middle Miocene times. These changes may be due to changing oceanic circulation and/or increasing glaciation.

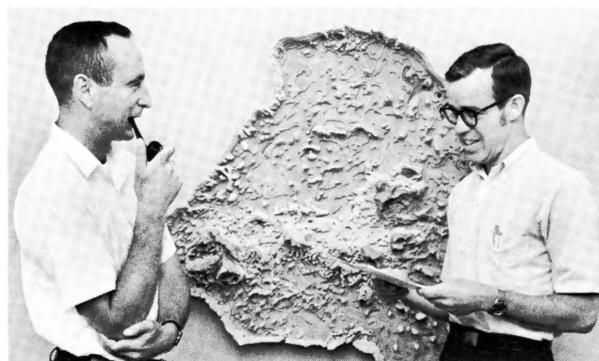
Dr. M. N. Bramlette continued his studies of fossil coccolithophorids and their application to biostratigraphy, especially for age assignments. Preliminary preparations, with Dr. David Bukry of the U. S. Geological Survey, La Jolla, for age determinations of core

samples from the Deep Sea Drilling Project have required much attention, and that work will receive major attention during the next year.

In addition to extensive work with the Deep Sea Drilling Project, William R. Riedel has revised the family classification of radiolaria in a manner which improves their stratigraphic applicability. To facilitate the continuing revision of this group, at the level of genera and species, a catalogue containing all published information on radiolarians is being prepared, in a form suitable for mechanical handling. Investigations of Late Cenezoic calcareous nannoplankton by Riedel, Dr. Bramlette, and Miss Annika Sanfilippo, and of foraminifera by Miss Parker, are forming a link between the biostratigraphy of calcareous planktonic microfossils and that of the radiolarians.

Dr. William A. Newman, in collaboration with Dr. V. A. Zullo, Marine Biological Laboratory, Woods Hole Oceanographic Institution, completed the chapter on Cirripedia for the "Treatise on Invertebrate Paleontology," for the Geological Society of America, and with Arnold Ross, of the San Diego Museum of Natural History, the distributional charts and text for the "Antarctic Map Folio Series," for the American Geographical Society.

Data and samples obtained last year from Micronesian Islands by Drs. Francis P. Shepard, Joseph R. Curray, and Newman, with a group of visiting geologists, continue to reveal the complex nature of the near-surface features of oceanic reefs, atolls, and islands. The submarine Karst topography in the lagoon floor at Truk, Caroline Islands, indicates the entire island and its surrounding reefs had been exposed at least 37m above the present level. Thus, while the gross morphology of the reef structure is the result of subsidence in the Darwinian sense, Pleistocene fluctuations of the sea have had pronounced effects, as Daly had proposed. The detailed morphology appears to be a complex of Pleistocene subaerial erosion forms and subsequent reef growth. A relief map of Truk reveals not only sub-



Dr. William A. Newman, left, and Dr. Joseph R. Curray discuss relief map of lagoon floor at Truk, Caroline Islands. Map indicates submarine topography and drowned river valleys.

marine Karst topography but also drowned river valleys extending out to the margin and deepest portions of the lagoon. These do not align with deep passes in the existing reef.

Dr. Shepard devoted most of this past year to completing manuscripts of earlier work on the topography and sediments of the submarine fan off La Jolla and its fan-valley, and working on a book with Harold R. Wanless, of the University of Illinois, on coastal changes in the United States. Wanless spent six months at Scripps Institution. Aerial photographs taken on different dates are being used to show the changes in recent years on many coastal lowlands, especially in eastern and southern United States. Cliff erosion is shown by comparing old photographs with new ones taken at the same spot or as close to it as erosion allows. Various coastal areas were re-photographed as near the old sites as possible.

Studies of the fan of sediments flooring the Bay of Bengal, Indian Ocean, on the Circe Expedition in May, 1968, were made by Dr. Curray, working with Dr. Edward D. Goldberg of Scripps and Dr. D. G. Moore, U. S. Naval Undersea Warfare Center. This is the largest deep-sea fan in the world, with a length of almost 3,000 kilometers, a width of 1,000 kilometers and thicknesses which may reach as great as 10-15 kilometers at the northern end. Most of the sediments of the fan have come from the Himalayan Mountains, via the Ganges and Brahmaputra Rivers, and have been spread out as turbidity currents. A vast system of channels leads these turbid masses of sediment and water to all portions of the fan surface. Dr. Curray also continued his investigations of the continental shelves and slopes off western Europe and central California, and completed a study of beach ridges along the coastline of western mainland Mexico. The chronology and depositional pattern of the Mexican beach ridges suggests that a cooler and stormier period occurred there between 3,600 and 1,500 years ago and resulted in realignment of the coastline of the region.

Dr. Goldberg's group has been analyzing noble gases in seawater from the North Pacific, North Atlantic and Antarctic Oceans, using the omegatron, a highly sensitive mass spectrometer. Their analysis indicates that many waters show measurable deviations from saturation. The deep waters of the North Atlantic appear to be supersaturated in argon to an upper limit of around 3 percent while their counterparts of the North Pacific are undersaturated to a smaller figure. Individual stations show supersaturation in the thermocline region for argon and krypton, a phenomenon relating to the mixing processes in this zone.

Excess helium levels in the Atlantic deep waters are less than those for the Pacific, a result related to the relative ages of these two water masses. Recent carbon-

14 data indicate that the deep waters of the Pacific are on the order of three to four times older (1,000 versus several hundred years) than those of the Atlantic.

Dr. Goldberg's group has also studied the geochemical behavior of fluorine in the major sedimentary cycle through a new analytical technique, photon activation analyses, using the 15 million electron volt linear accelerator. They have also investigated differentiation of barium sulfate (barite) precipitated on the continents and in the oceans, with results suggesting that isotopic compositions of strontium and sulphur are diagnostic of the zone of precipitation.

Further studies on the distribution of clay minerals in the world oceans demonstrate three modes of entry by these solid phases from the lands to the seas: by glaciers, by rivers, and by atmospheric winds. Fluorinated hydrocarbons of pesticides accompany these river- and wind-borne constituents into the world's oceans.

Dr. Gustaf Arrhenius' group has continued work on the stratigraphic distribution of barium as a guide to hydrothermal and tectonic processes occurring along the East Pacific Rise. Their results, which are consistent with a model of sea-floor spreading from the East Pacific Rise, show that very rich sediments, originally deposited near the crest of the Rise, are progressively buried by younger sediments of lower barium content as they are conveyed from the crest.

Efforts of this group in mapping the sediment distribution in the world ocean, with about 24,000 data points, have led to the discovery of some previously unknown features in the facies of boundaries. Other work has also continued on investigation of the distribution of transition elements in deep-sea sediments and ferromanganese nodules; the development of high-resolution techniques for determination of crystal structure in marine sediments; and the study of properties of the system Mg-Si-O, including olivine and enstatite polymorphs. These later studies are particularly pertinent to space research problems but apply also to meteorite chondrules and deep-sea sediments.

Results from the Nova Expedition in the Central and southwest Pacific have been of primary concern to Dr. Harmon Craig's group during the past year. Research during two expedition legs enabled them to obtain a complete longitudinal profile from Hawaii to New Zealand for ocean and atmospheric sampling for deuterium and oxygen-18, and for the initial work in the development of two important new tracers for oceanic circulation studies: silicon-32, and He^3/He^4 ratios in dissolved helium in the sea.

The Si^{32} study is a collaborative effort with scientists of the Tata Institute in Bombay, India. Si^{32} is a radioactive isotope formed in the atmosphere by cosmic ray activity, and introduced into the sea at the surface. Its

half-life, of about 800 years, is much less than that of radiocarbon, so it should be most important for deep-water studies where radiocarbon shows almost no variation with depth (below about 2,000 meters). The formidable sampling task of processing thousands of liters of seawater, to obtain enough sample, has been solved by use of large open mesh samplers filled with processed sponges which absorb silica from seawater. A study of dissolved nitrogen, argon, neon, and helium, from the Pacific, was completed, showing that nitrogen and argon are very close to solubility equilibrium in the Pacific. Small deviations from solubility equilibrium characterize the North Pacific and Antarctic intermediate waters, indicating that these waters probably form by subsurface mixing in the manner postulated by Reid on the basis of temperature and salinity studies.

Gas chromatograph measurements for such studies will be facilitated in the future by development of a sea-going gas chromatograph which was used very successfully on the Nova Expedition for a detailed study of the Cromwell Current and for a general oceanic study of total CO₂, nitrogen, and argon variations at all depths.

Dr. Craig is spending part of this year at Montecatini, Italy, working on a gas chromatographic isotope separation and a theory to explain observed variations in nitrogen isotope ratios inflow through sandstones.

Members of Dr. Henry W. Menard's group did much of the preparation for, and led several legs of, the Nova Expedition. The digitizing and data processing system was put to a test and all navigation, soundings, and magnetic profiles were processed for 15 months of ship time within 45 days of the return of *Argo*. New soundings have been combined into a new bathymetric map of Melanesia. The group also mounted Gam I and II, which were short topographic and magnetic surveys off Mexico. They established that the Gulf of California was opened by sea-floor spreading during the last few million years.

Dr. Robert L. Fisher and his colleagues carried out a geological-geophysical exploration of a well-developed portion of the deep Tonga Trench, along the eastern border of Melanesia. Station work included extensive bottom photography of the trench floor at 9,970 meters and of both walls of the trench, and rock dredging from the nearshore trench wall.

Both Dr. Fisher's Indian Ocean work, begun in 1960 as part of the International Indian Ocean Expedition, and the Tonga Trench sampling have provided critically needed tests of the hypothesis of worldwide sea-floor spreading, transformed faulting, and continental drift. The recovery of unweathered, ultrabasic intrusives (dunites and peridotites) near the base of the volcanic Tonga arc, and mafic volcanics on the nearshore flank nearer the islands, provided the first direct data on the

composition of such an arc's foundations. The simple composition and purity of the coarse-grained ultramafics pose serious doubt to the oft-stated notion that the near-shore flanks of island arc-trench associations consist of strongly deformed and metamorphosed sediments carried there from far off shore by a rapidly moving oceanic crust. This occurrence, and the lack of deformation in outer-flank and trench floor sediment layers, as attested by seismic reflection records, requires a re-examination of the sea-floor spreading hypothesis in its simplest, most far-reaching form, particularly at the continental margins and island arc boundaries.

Dr. Manuel N. Bass spent most of the past year establishing a pre-continental drift reconstruction of the Gulf of Mexico region at the end of the Paleozoic era. The refitting indicates that the Jurassic salt was deposited in the initial narrow rift basins which formed an integrated system as the Gulf opened. In the Greater Antilles, Paleozoic crust is found only in western and central Cuba. The remainder of those large islands were built by Mesozoic and Early Tertiary volcanism in some of the widening rifts.

Counterparts of the volcanism can be identified in the Cretaceous time onward, by relating the zones of volcanism to those blocks, and by reconstructing the tectonic activity which appears to have lifted oceanic second layer above sea level in the peninsulas of western Costa Rica and Panama. The ridges of western Panama appear to be tectonic continuations of the same elements of Central America which turn southward into the Pacific Ocean in Costa Rica and western Panama, rather than follow the axis of isthmian Panama. The isthmus may be elevated oceanic crust. Petrographic and chemical analysis are now in progress on the volcanic and metavolcanic rocks, and an attempt will be made to identify those submarine conditions and depths favoring weathering.

Dr. J. W. Hawkins, Jr., has continued studies concerning the evolution of continental granite rocks from eugeosynclinal rocks in the Cascade Range of Washington. Particular emphasis was placed on the origin of mimatites from metamorphosed sedimentary and volcanic material. In addition, a study of basaltic rocks in San Diego County has begun. These rocks are of particular interest in that their chemistry, petrology, age, and tectonic setting all suggest an affinity to volcanic rocks of the East Pacific Rise. Their geologic history appears to be related to Late Tertiary interaction between the Rise and the continental margin.

During 1967-68, Drs. Albert E. J. and Celeste Engel explored, mapped, and dredged the westerly extension of the Clipperton Fracture Zone in the Central Pacific at about 180°W. In this region, just northwest of the Phoenix Islands, one fault trench of the Clipperton is over 8,400 meters deep and is bounded by rocky scarps

over 5,500 meters high. The crust is largely tholeiitic basalt and metatholeiite, with rock ages in excess of 80 million years. They also continued their studies of early ocean basins now preserved only in the stable continental nuclei. The remnants of pre-three-billion-year-old ocean floors in southeast Africa are strikingly like the crust exposed along some faulted segments of contemporary oceanic ridges. These ancient oceanic crusts grade downward into a fossil mantle composed of peridotite lava and ultramafic stratiform sheets.

MARINE BIOLOGY RESEARCH DIVISION

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 Marine Biology Research Division represent interests in physiology, microbiology, photobiology, developmental and systematic biology, and ecology in the sea.

Throughout the year, some 40 lectures were presented on campus during marine biology seminars. Twelve visiting lecturers represented institutions and organizations in the United States; others were from Nova Scotia and British Columbia, Canada; Chile, Germany, the U.S.S.R., Mexico, Israel, The Netherlands, Italy, and Great Britain. Work of the Division is described below.

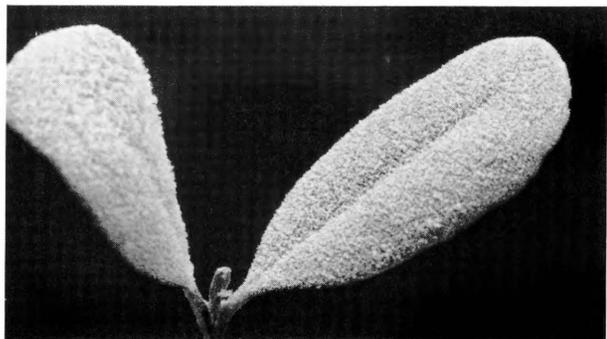
An investigation of spontaneous bioluminescence as related to sonic scatterings was undertaken off Fuerteventura, in the Canary Islands, by Dr. Brian P. Boden. The apparatus used is described in "Observations of Bioluminescence on SONDA, 1965 Cruise—R. R. S. *Discovery*." A definite increase in the magnitude of luminescence at scattering-layer depths is demonstrated. It is shown that the amount of luminescence forward of, and in the net of, an Isaacs-Kidd mid-water trawl is very much greater than that either above or below it. A frequency is disclosed within a single flash, and it is hypothesized that this may be a specific property.

Dr. Elizabeth Kampa Boden has been working with the eyes of oceanic crustaceans that perform extensive diurnal 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. In the Gulf of California, two genera of the galatheid crustaceans live in adjacent areas. One, *Pleuroncodes*, performs extensive diurnal migrations and has one of the most complex eyes yet found among crustacea. The other, *Munidopsis*, does not migrate and has been listed systematically as "blind." Its eye, devoid of filter pigment, has a structure indicating that the animal has evolved in a deep, dark environment, perhaps because of adverse factors in its development.

A program to study pathways and mechanisms of the biological transport of water, gases, electrolytes, and other substances in intact animals and tissue preparations is being conducted by Dr. Theodore Enns.

Urea excretion studies in the kidneys of the horn shark, *Heterodontus francisci*, indicate urea retention by active transport and possibly the formation of a urea complex to which the tissues are impervious. Further evidence of urea complex formation is obtained from urea transport studies in the gills of the same shark species. Carbonic anhydrase activity has been demonstrated in liquids containing rabbit red cells, indicating enzyme activity in the cell membrane. The enzyme has been measured by G. Bowes in the marine algae, Rhodophyceae, Chlorophyceae, and Phaeophyceae.

In the section devoted to studies in marine and comparative biochemistry, Dr. Denis L. Fox, his students, and colleagues have continued their investigations into the comparative metabolic fractionation of colored molecules by animals; e.g., of carotenoids, by flamingos, anemones, sponges, certain pelagic, oceanic barnacles, a species of gorgonian coral, and several brightly colored species of nudibranch molluscs. Long-term experiments include a cooperative project with the San Diego Zoo, wherein a group of American flamingos has been quartered, administered a carotenoid-free diet over several months until the plasma carotenoids have fallen to a minimal level, and the diet then supplemented with generous amounts of a single carotenoid, B-carotene, in order to follow the gradual elevation of kinds and amounts of carotenoids to be encountered in the body. A unique discovery has been that of a dihydrobin-like polyene acid, incorporated as bright orange-yellow soap of calcium and magnesium within the microspicules of the fan-coral *Eugorgia amplexa*. Two doctoral dissertations were completed and filed in June, 1968. (See Appendix E.)



Close-up of salt hairs extruded from salt glands in the leaves of tropical mangrove trees.

(Photo courtesy of Dr. A. A. Benson)

The structure and function of membranes which perform the essential functions of transporting nutrients, salts, and electrons between the environment and the cytoplasm of the cell have been studied in the laboratory of Dr. A. A. Benson and his colleagues. The lipid

and protein components of these lipoprotein membranes have been re-associated with restoration of their biological function. Their quantitative studies have suggested how biological membranes may adapt to the stresses of pressure and cold of marine depths, and to the heat and acidity of volcanic hot springs. Unique adaptations in marine organisms to their environment are reflected in the lipid and protein interactions within their membranes.

Dr. Francis T. Haxo continued work on the improvement of apparatus for automatic recording of photosynthetic action spectra. Such determinations have been made on a variety of cultured algae and a few natural populations.

Particular attention is being devoted to comparative studies of the role of peridinin, chlorophyll c and an ultra-violet absorbing pigment in dinoflagellates. In all species examined, peridinin contributes significantly to *in vivo* light absorption and to photosynthesis; whereas the contribution of chlorophyll c appears to be less important in this regard. By contrast with dinoflagellates such as *Amphidinium carterae*, where photosynthetic activity drops progressively with cell absorption from 400 to 300 nm, photosynthesis in *Gonyaulax* sp. is markedly depressed throughout this region due to absorption by an unidentified masking pigment. Whether or not the presence of this pigment is significant in the photoecology of dinoflagellates remains to be determined.

Measurements of gas exchange under ice (70 cm of ice and 10 cm of snow), indicated no net photosynthesis even during a clear day. When light penetration was increased about three-fold, by removal of the snow cover, net photosynthesis was readily measured in all three seaweeds.

Measurements of photosynthesis and respiration were made on cold-adapted seaweeds at Nunivak Island during the first phase (mid-March to mid-April, 1968) of the Bering Sea Expedition. Studies included measurements of the temperature dependence of photosynthesis under saturating light in the laboratory and field measurements of gas exchange in algae samples lowered below the sea ice. Appropriate light measurements were included. Attached algae studied included *Halosaccim* (red algae) *Fucus* and *Laminaria* (brown algae).

Notable features of the temperature dependence curves were (1) the marked deviation of the temperature and maximum photosynthesis rate (20-25° C) from the ambient seawater temperature (-1.6° C) and (2) the appreciable photosynthesis rate recorded at the latter temperature, about 1/5 to 1/10 that of the maximum rate.

Work by Dr. R. A. Lewin and his colleagues was divided between studies of gliding microbes and of photosynthetic algae. A monograph on flexibacteria was completed and submitted for publication. Relation-

ships are being sought among anaerobic members of this order, isolated, respectively, from marine mud and from the human mouth. Some unusual diatoms have been isolated from brackish, marine, and highly saline waters, and their tolerance to different salinities has been determined. Male and female strains of a filamentous brown alga, *Ectocarpus siliculosus*, have been isolated in pure culture; their physiology is being studied in order to find optimum conditions for controlling the sexual cycle.

Two professors on sabbatical leave have worked in these laboratories during the past year. Dr. Ralph Mitchell (Harvard University) isolated strains of bacteria capable of attacking marine and freshwater flagellates in the genus *Chlamydomonas*; and Dr. H. William Davies (Purdue University) is currently examining the micro-flora of littoral sand.

In August, 1967, Miss I. Mitskevich, from the Academy of Sciences in Moscow, and Dr. Lewin were invited to give an intensive course in Baltic shore microbiology at Tvärminne, Finland, under the auspices of the Nordic Council for Marine Biology and of UNESCO. The course, which lasted three weeks, was attended by selected advanced students from Sweden, Norway, Denmark, Finland and Thailand.

Dr. B. E. Volcani and his colleagues are investigating the metabolic and structural processes by which diatoms transform silicon into a complex cell wall consisting of a silica "shell" surrounded by an organic casing. Electron microscopic studies on two species of this single-celled plant (*N. pelliculosa* and *N. alba*) have established that, prior to cell division, the wall initially appears as a sequentially formed, compartmentalized vesicle within which silicon is deposited. Parallel chemical studies showed that the organic casing is unusually complex, consisting of ten previously unidentified polysaccharides and various proteinaceous components from which a number of unknown ninhydrin-reactive organic compounds have been isolated and are now being characterized. In addition it has been found that silicon is essential, not only for shell formation, but for photosynthesis, respiration, and other metabolic processes in the diatom, and thus represents an unusual biochemical system.

Studies of the effects of deep-sea pressures on the growth, survival, and biochemical reaction rates of micro-organisms have been continued by Dr. Claude E. ZoBell and his colleagues. Most terrestrial and shallow-water forms are adversely affected by pressures at depths of 2,000 to 4,000 meters, thereby suggesting that 200 to 400 atm may be the greatest pressures tolerated by cells of terrestrial or shallow-water organisms. The pressure-tolerance of barophobic bacteria is considerably less in the presence of hyperbaric oxygen; *e.g.*, only 10 to 25 atm at oxygen tensions five to 15 times higher than normal.

When compressed to 400 to 1,000 atm, at temperatures ranging from 15° to 35°C, most barophobic bacteria perish within a few hours or days. However, in the range of 0° to 5°C, certain barophobic bacteria remain alive, apparently in a completely dormant state, for many months at 400 to 1,000 atm, in the absence of pressure- or thermal-shock. Thus deep-sea pressures seem to act synergistically with refrigeration to preserve cellular materials. These observations may help to account for the large populations of barophobic bacteria found on the deep-sea floor where the temperature is near 3°C, and also suggest that appropriate application of deep-sea pressures may improve the preservation of animal tissues or organs being held for transplantation.

Dr. C. L. Hubbs has conducted extensive joint revisionary studies, mostly as senior author, on the hydrographic history and ichthyology of isolated basins in Nevada; an interglacial fauna on Guadalupe Island; the hagfishes of the Eastern Pacific; the scomberosocid fishes of the world; the achirid soles; the Pacific species of *Eucinostomus*; and the species of *Aulopus* of the world. Various other studies are continuing, including a long-deferred list, for formal publication, of the fishes of California (with W. I. Follett), and the researches on paleotemperatures and paleoecology in coastal and arid-interior areas.

The discovery of a new intertidal barnacle genus, (*Tetrachthamalus oblitteratus* gen. et. sp. nov.) found only at the upper ends of the Red Sea and the offshore islands of the Mauritius-Seychelles Ridge, has been made by Dr. William A. Newman. The distribution pattern is remarkable and suggests that the form is not successfully competitive with related species presently occupying intervening shores. Preliminary work on its reproductive biology indicates that, unlike shore barnacles that are generally cross-fertilizing hermaphrodites, *Tetrachthamalus* is predominantly male at one period of the year and female at another. A few apparently hermaphroditic individuals appear during the transition between these periods and this suggests sex reversal is taking place. However, whether this is simply a case of protandric hermaphroditism has not been resolved.

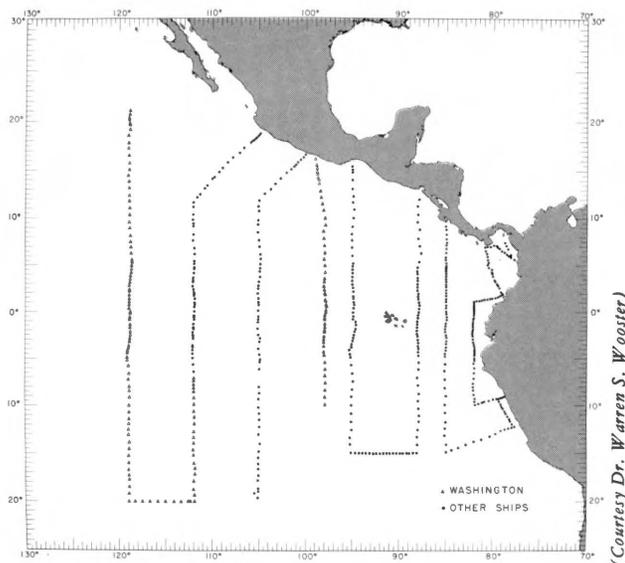
An intensive exploration of guyots along the Mid-Pacific Mountain this summer (1968), will be carried out by Drs. Richard H. Rosenblatt and Newman, with a group of graduate students and visiting biologists and geologists. This important oceanic chain extends some 1,500 nautical miles from Hawaii toward Japan and the fauna of seamounts and guyots in general is virtually unknown. Many of the guyots, now between 1,300 to 1,700 meters deep, were at the sea surface during the Cretaceous Period 100 million years ago. At the time, they provided habitats and migration routes for shallow-water organisms, as they must today for many organisms at midwater depths. The investigation

will center around the composition and distribution of recent and fossil forms in relation to the past and present biological importance of this drowned island chain.

OCEAN RESEARCH DIVISION

The work of the Ocean Research Division includes studies dealing with ocean water: its composition, including the organisms that inhabit the ocean; its movement, including waves and currents and the effect of this movement upon the organisms, bottom and the coastlines; and the exchange of quantities such as heat and water with the atmosphere and the solid earth. The investigators thus cover a wide range of research problems and techniques, involving both laboratory studies and long expeditions at sea; some impression of this range is given by the subject matter presented here.

From February, 1967, through April, 1968, ships of Mexico, Ecuador, Peru and Chile, and various U. S. laboratories conducted between the coast and 120°W a bimonthly program of observations, called Eastropac. The work was coordinated by Dr. W. S. Wooster. The purpose was to study the various processes leading from the atmosphere through the physical and chemical character and circulation of the upper part of the ocean, through the biosphere ultimately to commercial species of fish, principally tuna. Scripps participation included cruises of *Argo* in February-March, 1967, and *Thomas Washington* in August-September, 1967, and February-April, 1968. The observational program was built around modern instruments, such as the *in situ* salinometer, autoanalyzer and a complex of biological sampling devices. Tropical waters were sampled intensively, particularly in the zone of the equatorial current system, where special studies of velocity were made in the Equatorial Undercurrent. With the end of the fifteen-months' work at sea, routines were being developed for machine processing of the resulting large volume of data, including programs for transforming digital data recorded on magnetic tape into machine-drawn sections showing distribution of appropriate properties.



Tracks indicate Pacific Ocean covered by participating vessels in last cruise of Eastropac Expedition, February-April, 1968.

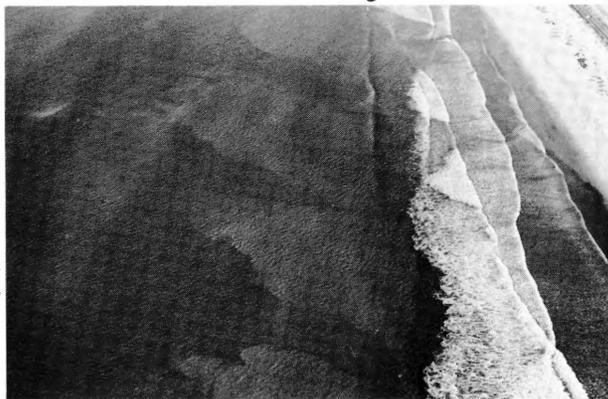
(Courtesy Dr. Warren S. Wooster)

J. L. Reid is extending his earlier studies of the circulation of surface and intermediate-depth waters to include the deep and bottom waters of the world ocean. Two expeditions to the South Pacific (Scorpio and Styx) have been carried out. Scorpio found evidence of a strong northward flow concentrated along the eastern side of the Tonga-Kermadec Ridge; the characteristics show that much of the deep water has come from the North Atlantic and has been carried by the Antarctic Circumpolar Current from the South Atlantic and through the Indian Ocean to the South Pacific. Beneath this water, at the very bottom, lies colder, less saline water originating from the Weddell Sea. Farther north the flow of this water toward the North Pacific is confined to a deep narrow passage near the Samoan Islands, and the Styx Expedition measured the characteristics and velocity of the water as it flows northward through the deep passage. Speeds averaged as much as 15 cm/sec at depths of 5,200 meters, and the total northward transport of the deepest 1,000 m has been roughly calculated to be more than 4 million tons per second. More refined calculations will include shallower waters also and may show a substantially greater total transport.

During 1967-68, Dr. M. C. Hendershott continued his work on the numerical solution of Laplace's Tidal Equations for the world's oceans. The immediate results of this calculation will be a set of global tidal charts giving the amplitude and phase of the most significant tidal components at intervals of several degrees everywhere in the oceans as well as a precise energy and momentum budget for the barotropic ocean tide. When the tidal flow field has been obtained, it will be possible to compute the electromagnetic fields generated as the water of the ocean moves through the earth's magnetic field in response to tide-generating forces. Knowledge of the global field of tidal elevation, combined with sea-floor measurements of the solid-earth tide, will yield information about the elasticity of the solid earth.

The research program of Dr. D. L. Inman's group studying shore processes and coastal oceanography includes field measurements of waves, currents, and sediment transport, and also an experimental program utilizing the wave and current facilities in the Scripps Hydraulics Laboratory. Their research accomplishments during the past year include: (1) development of a model for circulation and mixing in nearshore waters,

(Photo courtesy of Dr. D. L. Inman)



(2) initiation of a field and laboratory study of the spectra of wave run-up on beaches, (3) significant progress in the study of the relation between the longshore transport rate of sand and the magnitude and direction of energy flux of the breaking waves, (4) measurements of currents in the heads of Scripps Submarine Canyon and the identification of their generation mechanism, and (5) completion of the computations for a theoretical study of channelized turbidity currents by Paul Komar. Identification of the incident wave-edge wave mechanism governing the generation and spacing of rip currents along the beach led to a model for circulation and mixing in nearshore waters. The model assumes, as verified by field measurements, that the rate of mixing in nearshore waters is determined primarily by the spacing between rip currents and by the budget of water in the nearshore circulation cells.

Dr. Charles S. Cox has developed a series of instruments to examine the structure of temperature on a fine scale. These instruments are all of the "free fall" type which record data while sinking slowly through the sea. After completion of recording, they drop ballast so that they can float back to the surface. Because the instruments are free of any connection to a ship, they fall smoothly and uniformly. As a consequence, the variations of temperature with time can be interpreted accurately in terms of variation with depth. The vertical variation of temperature has often been found to consist of a series of sharp steps in which a thin layer (or several layers), where the temperature gradient is intense, separate nearly isothermal regions. The almost isothermal regions are usually a few meters thick in mid-depths. The thin interfaces with intense gradients are found to be one to several centimeters thick. The almost isothermal layers are slightly irregular in temperature, with temperature gradients of either sign equally likely. The amplitude of the slight irregularities varies widely from layer to layer. When a series of the free-fall instruments is released at intervals from a moving ship, it is possible to trace the horizontal extent of temperature structures. Individual layers are recognizable over a distance of a few hundred meters. Beyond this distance the arrangement of layers is so much transformed that it is impossible to recognize continuity of individual layers. Dr. Cox has also measured the electric and magnetic field fluctuations associated with ionospheric disturbances on and offshore in Peru (1967) and South India (1968) in order to investigate the electrical conductivity of rocks in the upper mantles. The method involves study of fluctuations having periods of order of a few hours which penetrate through the ocean and are effectively reflected by high conducting rocks in the mantle. The reflection coefficient (hence the structure of mantle conductivity) can be measured by oceanic and land measurements.

Position of regularly spaced rip currents on a real beach is indicated by concentrations of tracer just outside breaking waves. Tracer is being removed from surf zone by rip currents, demonstrating applicability of the circulation and mixing model to natural environment.

Drs. A. E. Bainbridge and C. D. Keeling are continuing their studies of the increase of carbon dioxide in the atmosphere and oceans in order to predict the amounts of excess CO₂ which will accumulate in the atmosphere, oceans, and biosphere owing to combustion of coal and petroleum and the effects which these excesses will have on man's environment. Dr. Keeling has prepared a map of the partial pressure of CO₂ in surface water of the world oceans which summarizes nearly three years of continuous measurements. The map will be used to study the oceanic cycle of carbon dioxide. C. S. Wong, a graduate student in his group, has nearly completed a thesis on the abundance of total inorganic carbon in the East Pacific Ocean. The distribution of inorganic carbon is being compared to that of oxygen and the nutrient chemicals to gain a fuller understanding of the role of biological processes in the chemistry of these fertile waters.

Dr. Robert S. Arthur has made a preliminary investigation of a dynamic model for the mean baroclinic flow in the California Current. Wind compilations on a grid scale finer than those available on a 5° scale are needed and plans to obtain such compilations have been initiated. Salinity-temperature-depth records available from the winter cruise in the Pacific Subarctic of the Boreas Expedition have been studied. Features of particular interest are the interaction between surface layer and atmosphere and the structure of the layer below the halocline.

A program led by Dr. T. R. Folsom has surveyed fallout radiocesium, Cs¹³⁷, in upper layers of the Pacific using 14 different ships. A recent summary report suggests a distortion of the fallout input caused by the major surface motions. Higher concentrations appear nearer California than Japan, corresponding to higher concentrations observed in tuna caught in 1965 near California. The new procedure for sampling below the surface has produced information of interest to physical oceanographers studying the movements of intermediate water masses. Simple devices are attached to an ordinary hydrographic wire in groups of 18 or more. These collect radioactive and natural cesium nuclides from the seawater by absorbing them on granular ferrocyanides. This procedure is convenient for use on a large class of ships.

Dr. T. J. Chow's research has included the following: (1) *The analyses of chemical composition of seawater.* Solid source mass spectrometry is one of the recent additions to the techniques available for marine chemical research. Owing to the extreme sensitivity of this method, only microgram quantities of samples are needed for accurate analysis. Last year, procedures were developed for measuring sub-microgram amounts of titanium, potassium and calcium in natural waters. (2) *The global distribution of lead.* During the Nova

and Circe Expeditions, marine air and water samples were collected and analyzed for their lead content. The lead distribution pattern will tell us how the terrestrial materials are transported as aerosols on a global basis. (3) *The addition of terrestrial materials in the ocean.* The chemical components permanently preserved in the snow fields of the Arctic and Antarctic regions have been studied. By determining chemical elements in the annual snow layers, the accumulation of materials from various sources in the snows can be chronologically recorded. (4) *Lead isotopes in Red Sea sediments.* A study of the isotopic composition of lead in the sediments throughout the Red Sea region was undertaken. Even though the lead content of the hot brine pool sediments is higher than its adjacent samples, its isotopic composition does not show any difference from other Red Sea sediment leads. Other investigators (USGS) reported a less radiogenic lead in the hot brine. It is not clear why a difference in isotopic composition should exist between the leads in the brine and their underlying sediments.

Dr. Ferren MacIntyre's interest centered upon surface processes: bubbles, jet drops, near-surface turbulence, ripples, and surfactants. The behavior of breaking bubbles (which act as surface microtomes and eject a thin layer of sea surface into the atmosphere) and their relation to anomalous ion-ratios in the marine atmosphere are under investigation, as is the thickness of the cut of the "bubble-microtome." A numerical hydrodynamics computer program incorporating realistic free-surface boundary conditions will model capillary processes for comparison with experimental results. Laser Doppler velocimetry is used to examine the "structure function" of turbulence within 1 cm of the surface, looking for anisotropy and for interaction between the molecular diffusion layer and capillary ripples, to explain the enhancement of gas transfer by such ripples. The electrical properties of the liquid surface are also of interest.

Dr. E. W. Fager and students have continued studies of the ecology of single species populations and communities. Recent work has included studies of the territorial behavior and population dynamics of the garibaldi (*Hypsypops rubicunda*), the species structure and distribution patterns of diatom communities in the North Pacific, feeding, food requirements and population dynamics of a high-beach isopod, ecological natural history of two species of gorgonian, the dynamics of populations of two species of predatory marine snails and the development of communities on artificial "rocks" placed in the midst of sandy environments. The work has involved a combination of field observation, field experiments and computer simulation studies. The latter have been used in an attempt to understand the dynamics of simple communities and predict the effects

of various types of perturbation applied to them.

Studies by Dr. J. A. McGowan's students were done on zooplankton patch dimensions and species structure. The patch dimension data were used in a computer model which tested the precision and accuracy of various sampling schemes in estimating abundance. A drogue which performed diurnal vertical migrations was constructed. Samples of zooplankton taken while following this drogue were studied in an attempt to measure the temporal longevity of the species structure of zooplankton patches. Multiple linear correlation analyses of the biological, physical and chemical data collected on two transects from Kodiak to near Hawaii have been completed. Among other things these analyses showed that the variability in zooplankton abundance was uncorrelated with dissolved organic carbon concentration in either winter or summer but correlated primarily with chlorophyll in the summer. None of the other 12 variables "accounted" for much of the zooplankton variability.

Dr. W. G. Van Dorn undertook a preliminary hydrodynamic study of the circulation around two isolated atolls in the Cook group. Relatively strong, quasi-periodic oscillations of nontidal frequency were found in the lee wake of both islands, suggesting that Karman-type eddies were being shed, but the maximum observed amplitude of thermocline oscillations never exceeded about 10 percent of the mean depth (500 m). The circular trajectories of drift buoys released upstream of these islands indicate that the main wind drift may extend considerably deeper than thermocline depth.

Dr. Van Dorn also completed a hydrodynamic analysis of the formation of the five concentric mountain rings surrounding the lunar Mare Orientale, on the hypothesis that they are actually a system of frozen gravity waves generated in the moon's basalt crust by the impact of a large meteorite. His results indicate that the moon has a crustal layer 50 km deep composed of impact rubble that was induced to fluidlike motions under the impact shock. Partial flooding of the Orientale rings with material strongly resembling lava, together with remnant mountain rings in all of the larger Maria, suggests that deeply penetrating impacts perforated the moon's plastic or molten interior, resulting in subsequent surface flooding.

Dr. J. T. Enright's research activities have centered around the study of biological rhythmicity. (1) He began computer analyses for periodicity in the abundance of nearshore phytoplankton, based on Allen's data obtained from 1919 to 1922. (2) Studies of the long-term persistence of tidal rhythms of activity were continued. Preliminary data seem to indicate an endogenous 15-day amplitude modulation of the daily tidal activity pattern, apparently phased with spring tides on the beach. (3) Computer studies of a stochastic

model for endogenous daily rhythms were also continued. The model involves mutual entrainment of an array of relaxation oscillators resembling spontaneous neurons. The objective is to develop a model which can account for a precise high-inertia rhythmicity, given low-inertia components which are extremely "sloppy."

Dr. N. W. Rakestraw has been involved in a research project concerning the occurrence and significance of C-14 in the ocean. During the last year the emphasis has been on the determination of surface values and of the concentration gradients in the vertical profile in the ocean. The former are important in relation to the "bomb carbon" in the atmosphere and the rate at which it is taken up by the sea surface; the latter are of interest in the study of the mixing processes in the upper ocean and complement the information obtained from such fallout products as strontium-90 and Cs¹³⁷.

The Radiocarbon Laboratory, under Drs. H. E. Suess and G. S. Bien, worked on the calibration of the radiocarbon time scale using accurately dated tree rings of the Bristlecone pine, 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.

A machine—designed and developed at Scripps Institution of Oceanography by Phillip R. Mack, under the supervision of Jeffery D. Frautschy and Dr. Marston C. Sargent—to digitize analog bathythermograph (BT) temperature-depth traces automatically, was delivered to Margaret Robinson's BT Analysis and Processing Group in December, 1967. The BT temperature curve is traced by a mechanical pantograph whose motion, measured by voltmeter, is electronically recorded on magnetic tape. Computer programs have been written to reformat the digital output into standard National Oceanographic Data Center form. The first six months of operation indicate the possibility of digitizing 400 BT observations per day. This is a decided improvement in speed and costs over previous hand-digitizing methods.

MARINE PHYSICAL LABORATORY

The Laboratory's activities continue to be directed toward understanding problems related to the generation, propagation, and detection of energy in the ocean and surrounding media. This involves interaction of diverse facets of marine physics and ocean technology. It is possible (with some oversimplification) to divide the work for descriptive purposes into four major areas of study: oceanic acoustic environment, sea-floor properties, signal processing, and ocean technology.

In addition to research in these four areas, a considerable effort is expended in assuring (largely through participation in advisory committees and study groups) that new ideas and understanding are passed along to

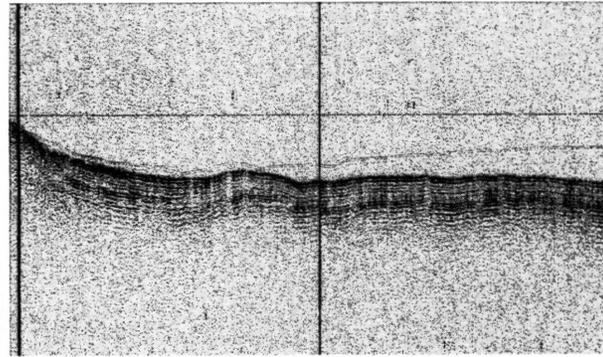
others who may be able to utilize them. For example, the senior members of the staff spent approximately one and a half man-years in short duration committee meetings and symposia for the benefit of federal agencies and scientific societies, including the National Academy of Sciences, National Academy of Engineers, U. S. Navy, National Council on Marine Resources and Engineering Development, Acoustical Society of America, and the American Geophysical Union. In addition, Dr. Fred N. Spiess directed a six-week summer study under the National Academy of Sciences' sponsorship, with Dr. Victor C. Anderson serving as a group leader in the same study.

Work in the field of oceanic acoustic properties has ranged from the laboratory and shop out into the deep ocean. Dr. Fred H. Fisher's laboratory program investigating the basic nature of seawater (using ultrasonic absorption and other experimental techniques) has concentrated on development of equipment to make precision measurements and on development of a valid equation of state for this complex liquid. At sea, Dr. Anderson continued his studies of acoustic volume reverberation. The frequency range covered in earlier work was from 8 to 25 kHz and in the more recent measurements this was extended down to 4 kHz. While much data remain to be analyzed, it appears that the technique is yielding a greater insight into the composition and spatial distribution of scatterers in the sea.

Long-range underwater sound propagation is being investigated by the group under Drs. William Whitney and Spiess. Their principal activity for the year has been the development of a vertical hydrophone array and related signal processing equipment, to be operated from FLIP as the receiving portion of a multi-institutional, Office of Naval Research-sponsored experiment to be conducted in the fall of 1968. An important aspect of this has been the design and construction of hydrophone mounts to minimize noise due to flow around the deep array as FLIP drifts with the surface current.

Investigations of the acoustic and magnetic properties of the sea floor and the earth's crust beneath it are being carried out by several groups. Drs. Russell W. Raitt and George G. Shor have confirmed the fact that, at several places in the Pacific Basin, the speed of sound in the crust below the Mohorovicic discontinuity varies, depending on the direction of transmission in the horizontal plane. Off the California coast, sound going east-west travels about 5 percent faster than that which goes north-south. Work by the same group using seismic reflection techniques (arcer and air gun) in the Western Pacific (between Midway and Samoa) has emphasized consideration of the shallower sediment layers, and indicates widespread occurrence

(Photo courtesy of Marine Physical Laboratory)



Record of seismic reflection (air gun) studies indicates a region between Midway Island and Pago Pago of almost acoustically transparent sediment. Depth of water was 2,800 fathoms.

of acoustically transparent sediment. The uppermost layer, a few hundred meters thick, has very poor surface reflectivity and very few internal reflectors as viewed in the 20 to 100 Hz band, although it is clearly defined by the conventional echo sounder operating at 12 kHz. In an attempt to bridge, between knowledge of the sea floor as seen with conventional echo sounders (at 12 kHz) and as seen with seismic reflection equipment (below 100 Hz), Dr. Shor has installed a 3½ kHz echo sounder on *Argo* for use in its current 'round-the-world Circe Expedition.

Fine-scale exploration of the sea floor, using deep-towed instruments, has also continued under Drs. Spiess, John D. Mudie, and Carl D. Lowenstein, with expeditions to document a portion of a deep-sea fan (San Lucas, off the south tip of Baja California) and a section of the crest of the East Pacific Rise (about at latitude 20°N). The fan was generally quite smooth, along the 3,000-meter contour, except for one region several miles in extent which showed a complicated set of small channels and depressions (20 to 50 m deep and 150 to 1,000 m wide). The rise crest showed rough topography with very little sediment cover and large amplitude (1,000 gamma) magnetic anomalies, uncorrelated with topography, and with characteristic wave length of about 500 meters. On the technological side it should be noted that one of the deep-tow vehicles was lost in 3,000 m of water south of Baja California in November, 1967, when the tow wire parted. After quick development of some special equipment, however, it was recovered in good condition the following May.

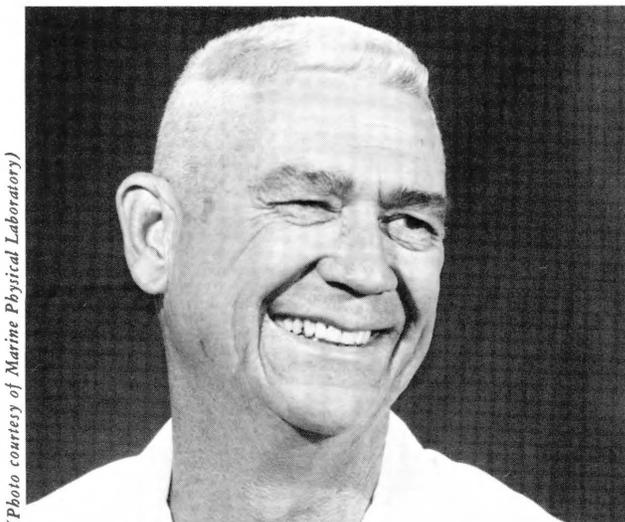
In the field of signal processing, the chief achievement was the first seagoing trial—a successful one—of Dr. Anderson's steerable null processor. The hydrophone array used for this work was mounted at the bottom of FLIP, and all processing was done on board in real time. Further operations with this unit, whose purpose is to provide near-optimum target detection in a noise field having a single strong source of interfer-

ence, is planned for late 1968. A second major development, under Dr. Lowenstein, is of a new high-resolution, side-looking sonar. This is an extension of a technique now in use from our deep-tow work (and vehicles of other groups) to give a much sharper resolution for the same transducer dimensions. A preliminary model has shown resolution of better than one foot at a range of 150 feet, a factor of about four better than that of an equivalent, unprocessed system output.

The summer of 1967 saw an application of conventional side-looking sonar technology by Maurice S. McGehee, Dwight E. Boegeman, and Bruce Luyendyk, who made complete underwater shadowgraph maps of two areas off the Turkish coast in conjunction with University of Pennsylvania archaeological studies being conducted there. The data led to discovery of one ancient shipwreck later that summer, and a second one in the summer of 1968.

Specialized seagoing facilities have been substantially upgraded. FLIP has been given added laboratory space and much improved habitability through addition of a deckhouse. A much larger step has been made in the construction of ORB—a manned barge (45' x 45') with a large center well (15' x 20') through which the remote-controlled, bottom-working tractor, RUM, will be operated. This craft was launched December 1 and has begun fitting out. A major feature is the special constant-tension winch which will allow putting RUM safely on the bottom and maintaining it there in spite of motion of the barge in the seaway.

Finally, it seems appropriate here to pay tribute to Finn W. Outler, who retired this year after nearly 25 years of dedicated service to the University. He has been the technical superintendent and business manager of Marine Physical Laboratory since its founding in 1946, and took on all of the roughest administrative and personnel problems. He will be sorely missed.



(Photo courtesy of Marine Physical Laboratory)

Finn W. Outler retires after 22 years as technical superintendent and business manager of MPL.

Dr. Per F. Scholander has continued studies with the mechanism of osmosis, based on the demonstration of negative hydrostatic pressure in plants. This has led to a new concept of osmotic mechanism which unifies osmosis with imbibition. With graduate student Alan Hargens, further studies are being made on the osmotic behavior of macro molecules. A wick technique has been developed which measures the negative interstitial fluid pressure in animals. Application of this to excised tissues demonstrated a sharp break in the pressure-volume relations we have seen also in plants, and which undoubtedly signifies packing of the cell constituents. This technique is being applied to solutions of macro molecules.

Dr. Sigmund Stromme has extended the wick technique to his studies of the effect of dehydration of frogs on the negative interstitial pressure.

Dr. H. T. Hammel has continued his studies of temperature regulation in vertebrates, using heating and cooling of the hypothalamus.

Dr. Walter Garey has studied the hypothesis that the maintenance of the pH of arterial blood at a constant value above the ionization point of water may be a unifying parameter in the regulation of respiration in general. Laboratory observations of cold-blooded vertebrates at 10°C and 20°C and in the warm waters of the Amazon, support this pH-temperature relationship.

Dr. Robert Elsner and his colleagues have continued studies describing circulatory adjustments of asphyxia of the mammalian fetus. Maternal and fetal circulation of sheep has been studied, using Doppler ultrasonic flow transducers placed on various arteries of both the ewe and fetus. Similar experiments with Weddell seals are in progress at McMurdo Sound, Antarctica, where the asphyxial episode is much more prolonged. Unrestrained diving experiments have shown that Weddell seals in late pregnancy are capable of dives up to 40-50 minutes. Also, in recent months a pressure chamber has been installed at PRL, and studies of pressure effects on diving birds and mammals have been initiated.

Dr. Aristides Yayanos has set up a high-pressure system in his laboratory where he is studying the pressure effect on enzymatic reactions. The aim of this work is to determine compressibilities and partial specific volumes as a function of pressure for a number of solutions of biological molecules and to observe what facets of molecular structure affect these quantities.

Dr. Edvard Hemmingsen carried out studies on supersaturation of gases and cavitation in liquids. He is also continuing studies of snow blindness in animals and of metabolism in antarctic fishes at Palmer Station.

Dr. Susumu Hagiwara and his colleagues of the Neurobiology Unit investigated ionic mechanisms in

giant muscle fibers of a barnacle and their dependence on pH of the internal and external media. The permeability of the membrane to anion and cation movement changes with pH in accordance with the idea of an amphotelic nature of the membrane.

By employing voltage clamp techniques, Drs. Donald Geduldig and Rafael Gruener have studied the competition between calcium and sodium in the initiation of action potentials in ganglion cells of the sea hare, *Aplysia*.

The transducer mechanism in the photoreceptors of the lateral eye of a barnacle was investigated by Drs. H. M. Brown, Robert Meech, and Hideo Sakata. Illumination of the receptors results in a conductance increase of the membrane which is mainly due to sodium ions.

Studies by Dr. H. O. Schwassmann concerning the neurophysiology of vision in teleost fish resulted in the demonstration of precise topographic relations between the retina and the midbrain roof, the principal visual center. The projection of the fovea in the eye of several marine basses (*Serranidae*) was found to occupy a disproportionally large area of the midbrain center.

VISIBILITY LABORATORY

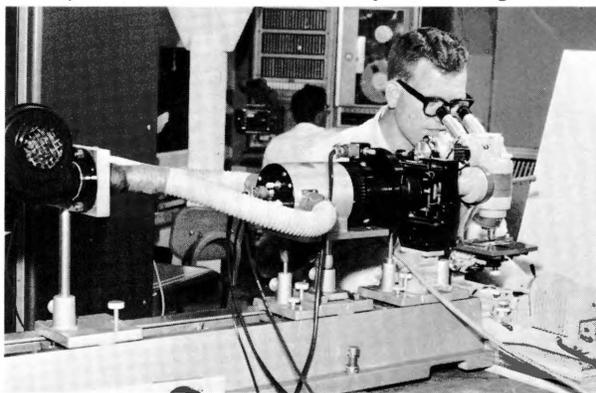
Studies of the penetration of daylight into the ocean and its utilization there for vision by marine animals and by man or for photosynthesis by plants are prominent among the continuing programs of research in the Visibility Laboratory. Corresponding studies of the distribution and utilization of light in the atmosphere have long been a continuing research interest of Dr. S. Q. Duntley, Almerian R. Boileau, and their associates in the Laboratory. A newly-instrumented aircraft and a new mobile ground station were recently completed for use in this research. Simultaneous detailed meteorological data are taken in the hope of evolving methods for forecasting the optical properties of the atmosphere. Data collections with the new equipment began in dry desert regions near San Diego and are expected to continue in tropical environments during the coming year.

Surveys of the optical properties of ocean water were made in many parts of the Pacific Ocean under the direction of R. W. Austin, using new types of instrumentation devised by him for this purpose. Support from the National Science Foundation enabled studies of the utilization of underwater daylight by photosynthetic organisms in the oceans to be made by J. E. Tyler and Dr. R. C. Smith, both in laboratory tanks and at sea. During May, 1968, scientists from six nations interested in optical studies of photosynthesis in the sea participated in a three-week cruise in the Gulf of California in Baja California aboard a Scripps ship. Each scientist used his own equipment in order that inter-comparisons of techniques and resulting data could be made. This

unique expedition was an activity of Working Group 15 of the Scientific Committee on Oceanic Research (SCOR); it was organized and directed by the Group's chairman, J. E. Tyler of the Visibility Laboratory. Advanced theoretical analyses of the underwater light field by Dr. R. W. Preisendorfer contributed prominently to all of the above researches.

Site surveys in both the Atlantic and the Pacific Oceans were made under the direction of Professor Duntley for experimental studies of the propagation of beams of light produced by underwater lasers. Scattering by even the clearest water spreads such needle-like beams to a much greater extent than is observed in a clear atmosphere. These spreading effects are under study because the image-forming light, by means of which man and marine animals see, may be considered as a super-position of many fine beams. Thus, the detailed nature of underwater imagery can be usefully explored in a more detailed way, through studies of the propagation of light from underwater lasers. James L. Harris, Sr., and his associates have found that images degraded by random refractive processes contain more information than can be seen by ordinary visual inspection. Methods for the extraction of such hidden information from poor quality imagery are resulting from Harris' continuing research program within the Visibility Laboratory. Sharp pictures have been produced from unsharp ones by transforming the degraded image into a frequency-space representation where it is possible to correct the amplitudes and phases of the separate spatial frequency components. After transformation back to its ordinary form, a vast improvement in image quality is often achieved. Even the highest quality defraction-limited imagery, such as that produced by the best optical microscopes, can be improved in its resolution by an extension of the same procedure.

Remote sensing techniques for measuring the distribution of the wind field at the surface of the sea by means of airborne photographic or electro-optical radiometry continued to be studied by C. R. Edgerton.



(Photo courtesy of Visibility Laboratory)

Photoelectric image-dissecting microscope was developed by Visibility Laboratory to aid research in image structure.

MARINE LIFE RESEARCH GROUP

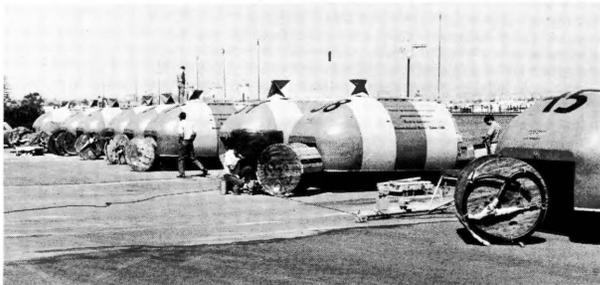
The Marine Life Research Group (MLRG) carries out the portion of the California Cooperative Fisheries Investigations that has been assigned to the University of California. The program is broadly involved in investigations of the ecology of the California Current System, and the North Pacific in general, with its currents, temperatures, chemistry, climate, and populations of organisms, and with the fluctuations of these parameters.

Originally concerned with the California Current System, MLRG has, over the years, considerably augmented and expanded its scope, both in depth and width, into the conditions and processes of the eastern and central North Pacific.

The basic report of the Marine Life Research program is contained in the publications of its investigators. This resumé briefly points out some of the scientific developments.

The North Pacific Study, a program to study the large-scale oceanographic and meteorological conditions in the North Pacific, is beginning.

An array of unmanned instrument platforms is scheduled to be anchored in the central North Pacific. Data will be collected by eight such stations. Near-surface meteorological data and water temperatures from the near surface to 300 m will be collected. Data from a large buoy designed by the Convair division of General Dynamics, will be telemetered daily to Scripps for use in this study and for immediate use by the U. S. Weather Bureau, the U. S. Navy, and the U. S. Bureau of Commercial Fisheries. Such information, in conjunction with an extensive historical study in progress, should provide a greater understanding of the ocean conditions and weather off the California coast. The North Pacific Study is financed by the Office of Naval Research.



Scripps-developed Bumblebee buoys line wharf at Nimitz Marine Facility in preparation for North Pacific Buoy Project.

Zooplankton, an extremely important component of the living populations of the sea, continues to be studied intensively. Plankton collections at sea have always been a major part of the CalCOFI surveys. There is now, in the archives at Scripps, the greatest and most complete plankton collection for the California Current Region of any region in the world. Only a miniscule

fraction of the value of such a collection can be realized unless careful scholarly analysis is continuously conducted. Analysis of this collection and publication of results have thus always been a major portion of MLRG work.

All of the major groups of zooplankton are under continuous study. Results of these studies have shed more and more light on the processes in the California Current. For example, a study of the community structure and distribution of zooplankton, sampled during a spring cruise that covered a large part of the California Current, has shown: (1) very little pattern of community distribution and (2) no relationship to physical stability. This lends support to an earlier conclusion based on purely biogeographic data, namely that the primary factor influencing the numerical species relationships in most of the California Current is advection, not trophic relationships. That is, the principal factor that determines the composition of the important zooplankton populations in the California Current is the current system, rather than the level of phytoplankton, the chemistry, or other conditions. This is a most important confirmation of earlier indications.

The discoveries of the scientists working with the zooplankton strongly suggest that the coming surveys in 1969 should include a considerable number of stratified net tows. For example, some of the important species of zooplankton seemingly disappear from the California Current in certain regions. Actually these species descend in those regions out of the range of the conventional plankton nets. Because of this and other sorts of changes in vertical distribution, vertically stratified sampling is to be an important part of the 1969 cruises.

Considerable advances have been made in artificially rearing some of the larvae of the planktonic organisms. This, of course, finally allows these larval organisms to be identified positively. This and other research throw important light on the rate of growth and reproduction of the zooplankton. The growth rates of plankton appear to be much more rapid than they were previously thought to be. That unexpectedly rapid growth may be the rule, rather than the exception, is also indicated by studies of the rate of production of the sediments, which is discussed later.

Although the exact species identification of the creatures in the plankton is essential for a complete understanding of the planktonic populations, such identification of all species, in all samples, is an extremely lengthy task. Insofar as concerns the plankton as food for higher organisms, such as fish, the exact species spectrum of plankton present is undoubtedly not as important as are the abundances of important types of plankton. For example, the proportion of crustacea, worms, and jellies in the plankton is more important

to a fish than is the exact species composition.

Thus, several years ago, techniques for biomass analysis were developed in the Marine Life Research program. This work of the Biomass Analysis Laboratory has developed very satisfactorily. The plankton are separated into about 20 functional groups and their total biomass is measured.

The first major results of this work are now in advanced stages of publication. They show that profound changes in the functional groups of zooplankton have occurred in critical years.

Continued analysis of the varved (layered) sediments from the Santa Barbara Basin, and elsewhere, shows increasing details of the history of oceanic conditions and of fish populations along the eastern North Pacific. About eight periods of abundance of sardine scales have now been identified during the last 2,000 years. These periods occurred, on the average, about every 250 years, and their average duration was of the order of 70 to 120 years. The populations of hake and anchovies apparently remained relatively large throughout the entire period, although they also fluctuated.

Attempts to separate and study the relative populations of Pacific and jack mackerel were unsuccessful, because of the rarity of Pacific mackerel scales.

The indicated minimum total populations of anchovies and hake are close to, but somewhat below, the present estimates from larval and other data.

In the sediments are found pteropods, foraminifera, and diatom material. The use of these materials will allow insight into the climatological and paleo-oceanographic changes.

The study of sedimentation is a new entree into the productivity of the California Current, and involves the collection of debris from the surface waters that is falling to the bottom. Development of an autonomous collector to carry out this difficult task has been successful. Results indicate that the maximum generation time of the planktonic organisms studied was much briefer than supposed. This supports the findings reported above of studies of zooplankton populations.

Autonomous current recorders developed by MLRG now permit the long-term measurement of the bottom water flow over large areas. Since the major part of the productivity of the North Pacific is the ultimate result of this deep flow, the measurement of the total flow into the North Pacific is of substantial importance. Exploratory attempts at measuring the flow have been encouraging, and the first major effort has recently been completed for the region where the deep Antarctic water, flowing northward in the South Pacific, enters the North Pacific (north of the Samoa Islands about 300 miles). Northward flows, through a 60 km-wide pass, were measured up to 20 cm/sec near the bottom in more than 5,000 m depth.

Photographs of large populations of fish and crabs, at depths to more than 5,000 m, indicate that the populations are much larger than previously thought. These fish may be dependent upon windfalls of large particles of food, such as the carcasses of whales, large sharks, or large fish, and possibly upon quantities of smaller fish debris resulting from predator attacks on large near-surface schools of prey. They may have a greater density along shipping routes where garbage could be a factor in their population size. Most of the fish at these great depths are a half to a meter long. Large predators (sharks estimated to be 5-8 m long) have been photographed on a number of occasions to 2,000 m depth.

In consonance with the CalCOFI program, in general, the Marine Life Research program is continuing its task of fundamental elucidation of the potential of the eastern North Pacific for man's use.

Although the major constraints to this use by the State of California appear now to be institutional rather than strictly scientific, technical, or economic, the continued expansion of knowledge of these important resources cannot fail to be of ultimate benefit in a future enlightened period.

NEUROBIOLOGY UNIT

Dr. Theodore H. Bullock and his colleagues, including Dr. Nobuo Suga, recorded the electrical activity of nerve cells in auditory parts of the brain of porpoises in response to tones, clicks, and FM sounds. They found a high degree of specialization for analysis of brief, ultrasonic, complex sounds at the level of the midbrain. This is the first study based on recording from the brains of cetaceans. Drs. Bullock and Suga are extending it at present to sea lions and other pinnipeds. The results indicate that in spite of their making ample sounds, including clicks, and facing the same environmental problems and opportunities, sea lions have no such specialization as porpoises.

The behavior of electric fish, particularly that released by electric signals, simulating other fish of their own kind has been under study by Dr. Bullock. A wide range of different kinds of responses has been found among various species. In these and other materials he is working on the general problem of coding in the nervous system or the means of representing information in channels of nerve cells and fibers.

Dr. R. B. Livingston with Dr. Hideo Shimamura turned up some unexpected discrepancies in the supposed evolution of long spinal pathways connecting brain and spinal cord in a series of lower vertebrates including teleosts and elasmobranchs.

Dr. Robert Galambos and his associates are investigating the reduction in auditory responses of the brain

during eye movements as well as problems involving the immunological responses to antigens from brain tissue.

Dr. John Thorson has recently pursued two projects of special Scripps relevance. In one, using digital computer simulation, he has devised and tested a new hypothesis for the actin-myosin interactions underlying muscle tension. In the other, together with Dr. M. Biederman-Thorson and Dr. David Lange, a psychophysical phenomenon has been discovered and examined in man. A motion illusion which really represents an extrapolation of the apparent motion due to the sequential flashing of two tiny spots of light so close together as to be unresolved, permits quantitative analyses of the system properties in motion perception.

Dr. Lange continues his study of neural interactions in the *Limulus* eye and of a digital computer model of these mechanisms.

Drs. Suga, Biederman-Thorson, and students, Robert Piddington and Peter Hartline, are investigating various aspects of the brain mechanisms in hearing in a range of lower vertebrates. Using electrophysiological techniques, often in conjunction with an on-line computer, they are able to analyze nerve cells singly and in groups with specified stimulus conditions. Novel routes for the mechanical stimulus to reach the ear, cells which recognize frequency modulated tones, others specialized for white noise or pure tones or combinations, and brain control of the ear's sensitivity are among the types of findings.

Dr. Susumu Hagiwara and his colleagues of the Neurobiology Unit investigated ionic mechanisms in giant muscle fibers of a barnacle and their dependence on pH of the internal and external media. The permeability of the membrane to anion and cation movement changes with pH in accordance with the idea of an amphotelic nature of the membrane.

By employing voltage clamp techniques, Drs. Donald Geduldig and Rafael Gruener have studied the competition between calcium and sodium in the initiation of action potentials in ganglion cells of the sea hare, *Aplysia*.

The transducer mechanism in the photoreceptors of the lateral eye of a barnacle was investigated by Drs. H. M. Brown, Robert Meech, and Hideo Sakata. Illumination of the receptors results in a conductance increase of the membrane which is mainly due to sodium ions.

Studies by Dr. H. O. Schwassmann concerning the neurophysiology of vision in teleost fish resulted in the demonstration of precise topographic relations between the retina and the midbrain roof, the principal visual center. The projection of the fovea in the eye of several marine basses (*Serranidae*) was found to occupy a disproportionately large area of the midbrain center.

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.

Dr. H. W. Menard is studying the topography and structure of the seafloor and is interested, in particular, with the apparent spreading of the ocean floor by mantle convection. Recent studies have shown the crest of the North Pacific moves as a block. The direction of movement has changed many times. This is shown by the simultaneous changes in trends of magnetic anomalies and fracture zones in the region. Symmetrical magnetic anomalies show that the Gulf of California has been opened by sea-floor spreading from the crest of the East Pacific Rise. Most of the opening occurred during only the last four million years.

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. The field part of these cruises ended in April and the emphasis for the next year will be on description and analysis of these results.



R. L. Linn, left, and Dr. J. D. H. Strickland use net to filter zooplankton in studies of food chain conducted by IMR.

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. A sophisticated field program ended this winter on recording the near-shore productivity of the sea adjacent to La Jolla. Analysis of these results continues.

Dr. M. B. Schaefer, Director of the Institute, is on leave of absence to serve as the Science Advisor to the Secretary of the Interior. Dr. Menard is Acting Director.

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, 1968.

**INSTITUTE OF GEOPHYSICS AND
PLANETARY PHYSICS**

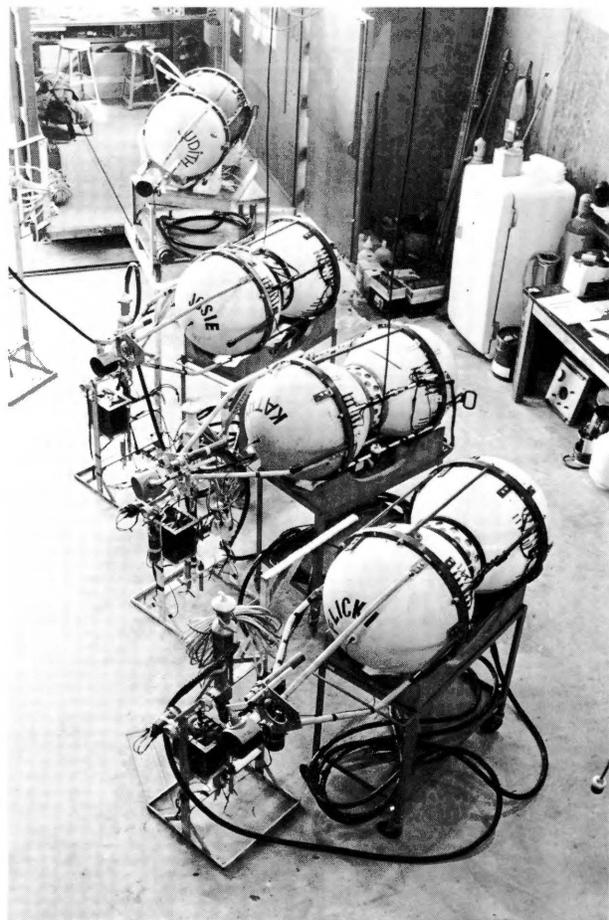
The Institute of Geophysics and Planetary Physics (IGPP) is a Universitywide Institute with branches at La Jolla, Los Angeles and Riverside. The Institute at La Jolla is intimately related to Scripps Institution, not only because of geographical proximity, but more importantly, because of common scientific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

Dr. Munk and Frank E. Snodgrass have, over the past three 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. As a result of these measurements, the properties of the boundary layer of the bottom of the deep sea are becoming understood. Another effort has to do with the behavior of the propagating tides over California's continental shelf and borderland. Tidal measurements in the Antarctic Ocean are being planned. This work has been sponsored by the Office of Naval Research (ONR), the Environmental Science Services Administration (ESSA) and the National Science Foundation.

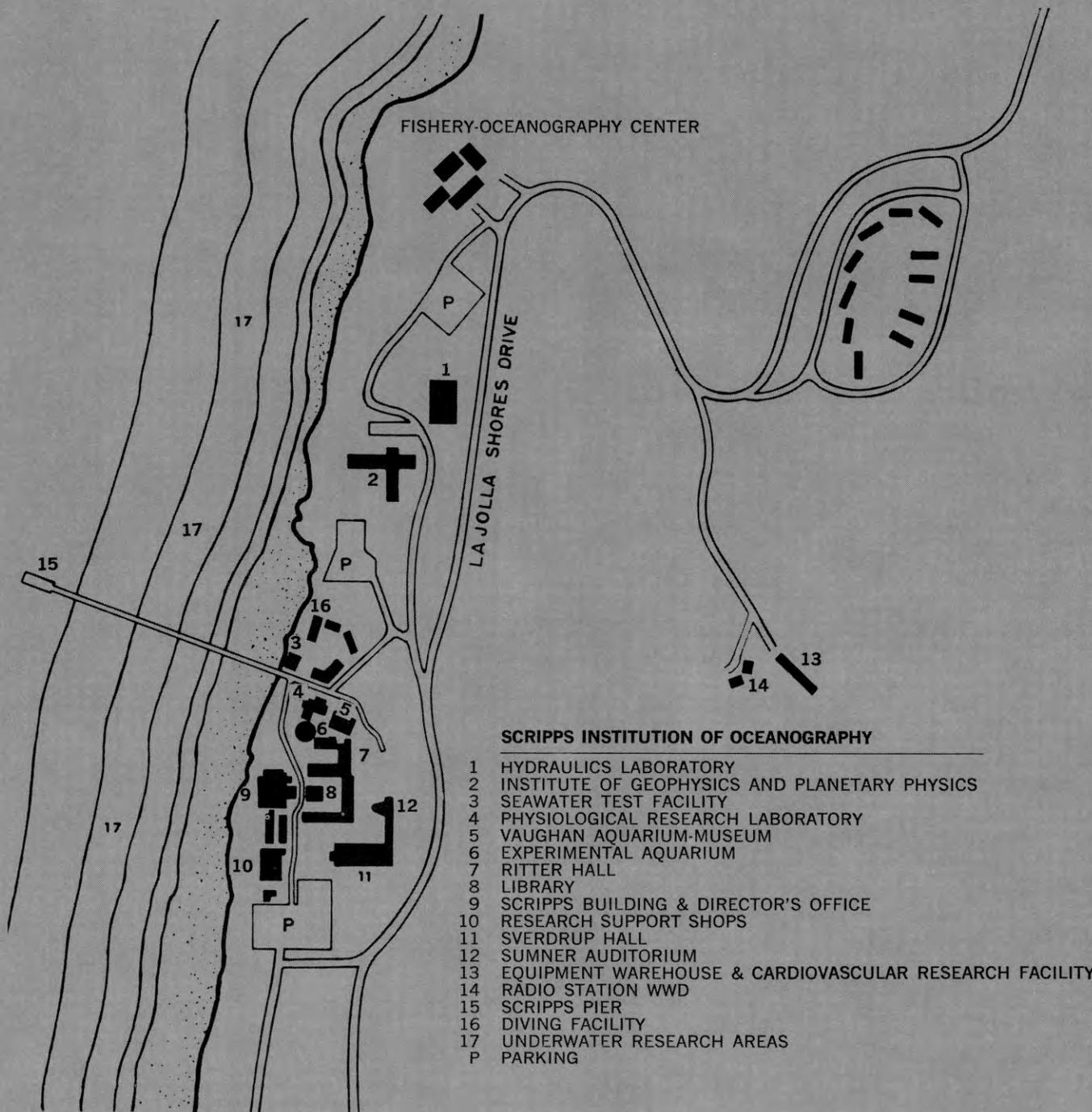
Wind-generated waves, an ever-present feature of the

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. The generation of internal waves resulting from a flow of stratified fluid over obstacles (submarine ridges) is being studied.

Professor Haubrich is studying microseisms arising from distant storms at sea. Professors Backus and Gilbert are computing the internal properties of the Earth from observed "normal mode" oscillations following major earthquakes. Various instruments are being developed for measuring earth strain, tilt and gravity fluctuation of very low frequencies. Support for this work has been provided by the Air Force Office of Scientific Research (AFOSR), the United States Geological Survey (USGS), and the National Science Foundation.



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



SHORE FACILITIES AND COLLECTIONS

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 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 marine plants and 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.

Research Support Shops (10). These shops were involved in the design, development, and fabrication of research equipment and instrumentation in support of the Scripps fleet, various laboratories at Scripps, UCSD, University Hospital, and various 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 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 Library (8). The library houses a vast amount of oceanographic information with outstanding collections in oceanography, marine biology, and under-sea technology. In addition to a basic collection of monographs and serials in mathematics, physics, chemistry, geology and zoology, the main collection includes extensive expedition literature. As of June 30, 1968, the Scripps Library held 71,878 bound volumes, 32,709 maps, 20,611 reprints, 11,612 documents and reports, and 1,179 pieces of microfilm.



(Photo courtesy of Tom F. Walters)

Scripps Library maintains vast collection of oceanographic information in books, reports, reprints, maps, and microfilm.

Photographer sits on boom above Hydraulics Laboratory wave basin to photograph wave-scattering caused by cylindrical island.



(Photo courtesy of Dr. D. L. Inman)

Hydraulics Laboratory (1). This laboratory is equipped with a 50 x 60-foot wave basin provided with a wave maker and an adjustable simulated beach; a 131-foot-long, glass-walled, wave and current channel equipped with an electronically modulated wave generator for wave and sediment transport studies; and an insulated, refrigerated cylindrical tank, 34 feet deep and ten feet in diameter, with sampling and viewing ports at several levels. The latter is used for a variety of physical and biological studies.

Scripps Pier (15). A familiar landmark is the 1,000-foot Scripps Pier, built in 1915 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 deliver the seawater used in laboratories and aquaria of Scripps and the Fishery-Oceanography Center of the U. S. Bureau of Commercial Fisheries.

Seawater System (15). The system provides seawater 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. Normal delivery capacity is 750 to 800 gallons per minute.

Electron Microprobe Laboratory (11). This laboratory permits the chemical analysis of volumes as small as one cubic micron at concentration levels above a few hundred parts per million. This is achieved by accurate spectrographic measurements of the X-radiation from the area 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, together with freeze-etching (Balzers) and accessory equipment, provide high resolution in the study of ultrafine structure.

Diving Facility (16). The diving facility, which has easy access to the ocean, provides air for tanks, loan equipment, and locker and storage space.

Scripps' SCUBA diving training program, among the oldest diver training and scientific diving programs in the country, conducts a number of SCUBA training classes annually. These are generally limited to University personnel who have the need to work or study underwater, but federal, state, and local government employees may be admitted by special permission. Some 100 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 marine research area set aside by the State of California. The taking of marine invertebrates and plants in this area is permitted only for scientific purposes. An adjoining ocean area is reserved by the Navy for Navy and Scripps 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 circulation and pressure in the heart.

Physiological Research Laboratory Pool Facility (4). This Physiological Research Laboratory facility consists

of a holding pool for large marine mammals and fish; a ring pool of 32-foot radius equipped with a variable speed trolley carrying instruments for various hydrodynamic and 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.

Carbon-14 and Tritium Laboratories (7). The carbon-14 laboratory provides equipment for the radiocarbon dating of specimens up to 40,000 years. This laboratory 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.

Seawater Test Facility (3). The University's seawater conversion study utilized a 90-foot tower in a "multiple effect flash" evaporation system that produced 3,000 gallons of fresh water from seawater daily. The study, which has since been moved to Bodega Bay, is financed by the State of California through the University's Water Resources Center at UCLA.

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.

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 24 x 50-foot enclosed platform moored in 140 feet of water offering 4,500 feet of unobstructed range.

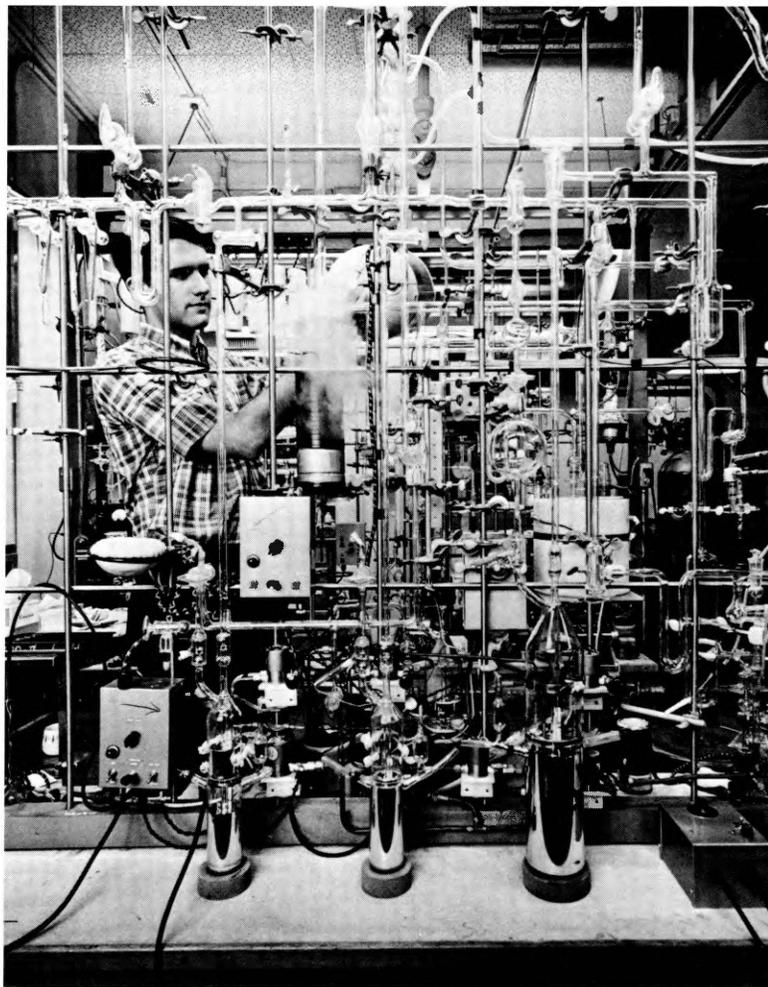
SPECIAL COLLECTIONS

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). This consists of some 750,000 specimens of 2,500 catalogued species of marine fishes. Added in 1967 were 300 collections of fish taken during work at sea.

Marine Invertebrates (Basements of Ritter Hall and Vaughan Aquarium-Museum and at Matthews Campus). In this collection are nearly 60,000 fully documented plankton samples; of these, some 5,000 are from special expeditions and some 450 from deep-water (IKMT) trawls. Samples are supplemented by full meteorological, hydrographic, physical, and chemical data.

Carbon-14 Laboratory provides equipment for the radiocarbon dating of specimens up to 40,000 years old.

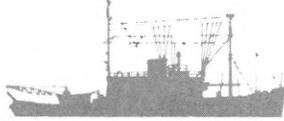


(Photo courtesy of Harry Crosby)

Geological Samples (Storage locker adjoins Seawater Test Facility). This collection contains some 4,000 geological samples, including 3,000 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 modules, taken mainly from the Pacific and Indian Oceans, and drill-cores obtained near Guadalupe Island during the experimental Mohole operation.

Oceanographic Data Archive (11). This collection includes more than 500,000 bathythermographic observations, tide gauge records taken since 1925 at Scripps Pier, and daily temperature and salinity records from southern California shore stations taken since 1916. Summaries of the shore station data, issued annually, are available upon request.

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



PUBLICATIONS

The publications of the faculty and staff of Scripps Institution of Oceanography are representative of the diverse research carried out during the past year. The SIO publications range from short internal reports to the long detailed studies published in the *Bulletin*.

The seven main series of the Institution are listed on the next few pages with notes about the series and directions on where individual issues may be obtained.

BULLETIN

The *Scripps Institution of Oceanography Bulletin* publishes lengthy research papers by the Scripps faculty and staff.

For a list of the numbers still available in the *Bulletin* Series, please write The University of California Press, 2223 Fulton Street, Berkeley, California 94720.

The volumes issued this year are listed below:

Volume 9. TAFT, Bruce A. and John A. KNAUSS. The 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, *Euprotomicros bispinatus*.

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

Volume 12. FROST, B. and A. FLEMINGER. A revision of the Genus *Clausocalanus* (Copepoda: Calanoida) with remarks on distributional patterns in diagnostic characters.

THE CALCOFI¹ ATLAS SERIES

This is a series of atlases containing data on the hydrography and plankton from the region of the California Current. The field work was carried out by the California Cooperative Oceanic Fisheries Investigations (CalCOFI), 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: California Academy of Sciences; California Department of Fish and Game; Stanford University, Hopkins Marine Station; U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries; University of California, San Diego, Scripps Institution of Oceanography.

CalCOFI atlases are issued as individual units as they become available. They provide processed physical, chemical, and biological measurements of the California Current region. Each number may contain one or more contributions.

¹Usually abbreviated CalCOFI, sometimes CALCOFI or CCOFI.

The atlases are prepared by the Data Collection and Processing Group of the Marine Life Research Program, Scripps Institution of Oceanography. The atlases published since 1966 are listed below:

CalCOFI Atlas No. 5: BRINTON, E. Distributional atlas of Euphausiacea (Crustacea) in the California Current region. Part 1.

CalCOFI Atlas No. 6: McGOWAN, J. A. Distributional atlas of pelagic molluscs in the California Current region.

CalCOFI Atlas No. 7: FLEMINGER, A. Distributional atlas of calanoid copepods in the California Current region. Part 2.

CalCOFI Atlas No. 8: BERNER, L. Distributional atlas of Thaliacea in the California Current region.

CalCOFI Atlas No. 9: KRAMER, D., and E. H. AHLSTROM. Distributional atlas of fish larvae in the California Current region: Northern Anchovy, *Engraulis mordax* Girard, 1951 through 1965.

CONTRIBUTIONS

The faculty and staff of the Scripps Institution of Oceanography publish numerous scientific papers each year, which appear in books and journals both here and abroad.

Each year these papers are collected and published as the Scripps Institution of Oceanography *Contributions*. The *Contributions* are exchanged with over 950 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, California 92037.

Papers from Volume 37, 1967, are listed below in alphabetical order by first author.

Information concerning reprints may be obtained by writing directly to the authors in care of Scripps Institution of Oceanography; or by contacting Technical Publications, Director's Office, Scripps Institution of Oceanography.

ALLISON, Edwin C., J. Wyatt DURHAM and Leigh W. MINTZ. New southeast Pacific echinoids. *California Academy of Sciences. Occasional Papers*, no. 62, 1967. pp. 1-23.

ALVARIÑO, Angeles. Bathymetric distribution of Chaetognatha, Siphonophorae, Medusae and Ctenophorae off San Diego, California. *Pacific Science*, v. 21, no. 4, October 1967. pp. 474-485.

ALVARIÑO, Angeles. A new Siphonophora, *Vogtia kuruae* n. sp. *Pacific Science*, v. 21, No. 2, April 1967. pp. 236-240.

ALVARIÑO, Angeles. Zoogeografía de California: Quetognatos. *Sociedad Mexicana de Historia Natural. Revista*, v. 27, December 1966. pp. 199-243.

- ANDERSON, Victor C. Command and control of deep submergence vehicles. *IEEE Transactions on Aerospace and Electronic Systems*, v. AES-3, no. 1, 1967. pp. 99-106.
- ANDERSON, Victor C. Frequency dependence of reverberation in the ocean. *Acoustical Society of America. Journal*, v. 41, no. 6, June 1967. pp. 1467-1474.
- ANDERSON, Victor C. and William WHITNEY. Observations of transients in background noise from FLIP. *U. S. Navy Journal of Underwater Acoustics*, v. 17, no. 3, July 1967. pp. 423-428.
- ANDERSON, Victor C. Spatial and spectral dependence of acoustic reverberation. *Acoustical Society of America. Journal*, v. 42, no. 5, November 1967. pp. 1080-1088.
- ARMSTRONG, F. A. J., C. R. STEARNS and J. D. H. STRICKLAND. The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 381-389.
- ARMSTRONG, F. A. J., P. M. WILLIAMS and J. D. H. STRICKLAND. Photo-oxidation of organic matter in sea water by ultra-violet radiation, analytical and other applications. *Nature*, v. 211, no. 5048, July 30, 1966. pp. 481-483.
- BACKUS, George E. Converting vector and tensor equations to scalar equations in spherical coordinates. *Geophysical Journal*, v. 13, 1967. pp. 71-101.
- BACKUS, George E. and J. Freeman GILBERT. Numerical applications of a formalism for geophysical inverse problems. *Geophysical Journal*, v. 13, 1967. pp. 247-276.
- BEERS, John R. and Gene L. STEWART. Microzooplankton in the euphotic zone at five locations across the California Current. *Canada. Fisheries Research Board. Journal*, v. 24, no. 10, 1967. pp. 2053-2068.
- BEERS, John R., Gene L. STEWART and J. D. H. STRICKLAND. A pumping system for sampling small plankton. *Canada. Fisheries Research Board. Journal*, v. 24, no. 8, 1967. pp. 1811-1818.
- BERGER, Wolfgang H. Distinguishing juvenile foraminifera in plankton samples by using biological dyes. *Journal of Paleontology*, v. 40, no. 4, July 1966. pp. 975-976.
- BERGER, Wolfgang H. Foraminiferal ooze: solution at depths. *Science*, v. 156, no. 3773, April 21, 1967. pp. 383-385.
- BERGER, Wolfgang H. and Andrew SOUTAR. Planktonic Foraminifera: field experiment on production rate. *Science*, v. 156, no. 3781, June 16, 1967. pp. 1495-1497.
- BIEN, George S. and Hans E. SUESS. Transfer and exchange of ^{14}C between the atmosphere and the surface water of the Pacific Ocean. *Radioactive Dating and Methods of Low-Level Counting*. Vienna, International Atomic Energy Agency, 1967. pp. 105-115.
- BIERI, Rudolf H., Minoru KOIDE and Edward D. GOLDBERG. Geophysical implications of the excess helium found in Pacific waters. *Journal of Geophysical Research*, v. 72, no. 10, May 15, 1967. pp. 2497-2511.
- BIERI, Rudolf H., Minoru KOIDE and Jack D. DYMOND. A high temperature ultra high vacuum furnace for gas extraction from geologic samples. *Earth and Planetary Science Letters*, v. 1, 1966. pp. 395-396.
- BIERI, Rudolf H. and Minoru KOIDE. Valve for precise pipetting of small amounts of gases. *Review of Scientific Instruments*, v. 38, no. 8, August 1967. pp. 1159-1160.
- BLACKBURN, Maurice. Biological oceanography of the eastern tropical Pacific: summary of existing information. *U. S. Fish and Wildlife Service. Special Scientific Report-Fisheries*, no. 540, November 1966. pp. 1-18.
- BODEN, Brian P. and Elizabeth M. KAMPA. The influence of natural light on the vertical migrations of an animal community in the sea. *Zoological Society of London. Symposia*, no. 19, 1967. pp. 15-26.
- BRINTON, Edward. Remarks on euphausiacean phylogeny. *Marine Biological Association of India. Symposium Series 2, 1965*. pp. 255-259.
- BRINTON, Edward. Vertical migration and avoidance capability of euphausiids in the California Current. *Limnology and Oceanography*, v. 12, no. 3, July 1967. pp. 451-483.
- BROMLEY, LeRoy A., Valeria A. DE SAUSSURE, James C. CLIPP and James S. WRIGHT. Heat capacities of sea water solutions at salinities of 1 to 12‰ and temperatures of 2° to 80° C. *Journal of Chemical and Engineering Data*, v. 12, no. 2, April 1967. pp. 202-206.
- BROMS, R. S. D. and James R. MORIARTY. The antiquity and inferred use of stone spheroids in Southwestern archaeology, *The Masterkey*, v. 41, no. 3, July-September 1967. pp. 98-112.
- BROWN, W. D., Roland FINCH, T. W. KWON, H. S. OLCOTT and Milner B. SCHAEFER. Relation of quality of canned yellowfin tuna (*Thunnus albacares*) to length of fish, time of holding on deck, frozen storage aboard vessel, and biochemical variables. *Fishery Industrial Research*, v. 4, no. 1, December 1967. pp. 1-21.
- CLARKE, Thomas A., Arthur O. FLECHSIG and Richard W. GRIGG. Ecological studies during Project SEALAB II. *Science*, v. 157, no. 3795, September 22, 1967. pp. 1381-1389.
- CLUTTER, Robert. Zonation of nearshore mysids. *Ecology*, v. 48, no. 2, 1967. pp. 200-208.
- COOMBS, J., P. J. HALICKI, O. HOLM-HANSEN and Benjamin E. VOLCANI. Studies on the biochemistry and fine structure of silica shell formation in

- diatoms. Changes in concentration of nucleoside triphosphates during synchronized division of *Cylindrotheca fusiformis* Reimann and Lewin. *Experimental Cell Research*, v. 47, 1967. pp. 302-314.
- COOMBS, J., P. J. HALICKI, O. HOLM-HANSEN and Benjamin E. VOLCANI. Studies on the biochemistry and fine structure of silica shell formation in diatoms. II. Changes in concentration of nucleoside triphosphates in silicon-starvation synchrony of *Navicula pelliculosa* (Bréb.) Hilse. *Experimental Cell Research*, v. 47, 1967. pp. 315-328.
- COOMBS, J., W. M. DARLEY, O. HOLM-HANSEN and Benjamin E. VOLCANI. Studies on the biochemistry and fine structure of silica shell formation in diatoms. Chemical composition of *Navicula pelliculosa* during silicon-starvation synchrony. *Plant Physiology*, v. 42, no. 11, November 1967. pp. 1601-1606.
- COOMBS, J., C. SPANIS and Benjamin E. VOLCANI. Studies on the biochemistry and fine structure of silica shell formation in diatoms. Photosynthesis and respiration in silicon-starvation synchrony of *Navicula pelliculosa*. *Plant Physiology*, v. 42, no. 11, November 1967. pp. 1607-1611.
- COX, Charles S. Internal waves. *American Geophysical Union. Transactions*, v. 48, no. 2, June 1967. pp. 588-591.
- CRAIG, Harmon, Ray F. WEISS and W. B. CLARKE. Dissolved gases in the equatorial and South Pacific Ocean. *Journal of Geophysical Research*, v. 72, no. 24, December 15, 1967. pp. 6165-6181.
- CROZIER, George F. Carotenoids of seven species of *Sebastodes*. *Comparative Biochemistry and Physiology*, v. 23, 1967. pp. 179-184.
- CURRAY, Joseph R. and Robert D. NASON. San Andreas fault north of Point Arena, California. *Geological Society of America. Bulletin*, v. 78, March 1967. pp. 413-418.
- DAWSON, E. Yale. New records of marine algae from the Gulf of California. *Arizona Academy of Sciences. Journal*, v. 4, no. 2, October 1966. pp. 55-66.
- DELANY, A. C., Audrey Clair DELANY, D. W. PARKIN, John J. GRIFFIN, Edward D. GOLDBERG and Bernhard E. F. REIMANN. Airborne dust collected at Barbados. *Geochimica et Cosmochimica Acta*, v. 31, 1967. pp. 885-909.
- DOCKINS, K. O., A. E. BAINBRIDGE, Jan HOUTERMANS and Hans E. SUESS. Tritium in the mixed layer of the North Pacific Ocean. *Radioactive Dating and Methods of Low-Level Counting. Vienna, International Atomic Energy Agency*, 1967. pp. 129-141.
- DOUGLAS, Everett. Carbon monoxide solubilities in sea water. *Journal of Physical Chemistry*, v. 71, no. 6, May 1967. pp. 1931-1933.
- ELSNER, R. W. and Per F. SCHOLANDER. Circulatory adaptations to diving in animals and man. *Physiology of Breath-hold Diving and the Ama of Japan. National Academy of Sciences—National Research Council, Publication 1341*, 1965. pp. 281-294.
- ENNS, Theodore. Gas transport and the red cell. *Federation Proceedings*, v. 26, no. 6, November-December 1967. pp. 1802-1804.
- ENNS, Theodore, Everett DOUGLAS and Per F. SCHOLANDER. Role of the swimbladder rete of fish in secretion of inert gas and oxygen. *Advances in Biological and Medical Physics*, v. 11. New York, Academic Press, 1967. pp. 231-244.
- ENRIGHT, James T. Temperature compensation in short-duration time-measurement by an intertidal amphipod. *Science*, v. 156, no. 3781, June 16, 1967. pp. 1510-1512.
- ENRIGHT, James T. and W. M. HAMNER. Vertical diurnal migration and endogenous rhythmicity. *Science*, v. 157, no. 3791, August 25, 1967. pp. 937-941.
- FAUGHN, J. L. and Bruce A. TAFT. Current measurements at the mouth of the Gulf of Thailand, November 1964. *Journal of Geophysical Research*, v. 72, no. 6, March 15, 1967. pp. 1691-1695.
- FIADEIRO, M., L. SOLORZANO and J. D. H. STRICKLAND. Hydroxylamine in seawater. *Limnology and Oceanography*, v. 12, no. 3, July 1967. pp. 555-556.
- FILLOUX, Jean H. An ocean bottom, D component magnetometer. *Geophysics*, v. 32, no. 6, December 1967. pp. 978-987.
- FISHER, Frederick H. and Douglas F. DAVIS. Effect of pressure on the dissociation of the $(\text{LaSO}_4)_+$ complex ion. *Journal of Physical Chemistry*, v. 71, no. 4, March 1967. pp. 819-822.
- FISHER, Frederick H. Ion pairing of magnesium sulfate in seawater: determined by ultrasonic absorption. *Science*, v. 157, no. 3790, August 18, 1967. p. 823.
- FISHER, Robert L., G. Leonard JOHNSON and Bruce C. HEEZEN. Mascarene Plateau, Western Indian Ocean. *Geological Society of America. Bulletin*, v. 78, October 1967. pp. 1247-1266.
- FLEMINGER, Abraham. Taxonomy, distribution, and polymorphism in the *Labidocera jollae* group with remarks on evolution within the group (Copepoda: Calanoida). *U. S. National Museum. Proceedings*, v. 120, no. 3567, 1967. pp. 1-61.
- FOX, Denis L. and George F. CROZIER. Astaxanthin in the blue oceanic barnacle *Lepas fascicularis*. *Experientia*, v. 23, 1967. pp. 12-13.
- FOX, Denis L., George F. CROZIER and V. Elliott SMITH. Carotenoid fractionation in the plumose anemone *Metridium*. *Comparative Biochemistry and Physiology*, v. 22, no. 1, 1967. pp. 177-188.
- FOX, Denis L., V. Elliott SMITH and Arthur A. WOLFSON. Carotenoid selectivity in blood and feathers of lesser (African), Chilean and greater (Euro-

- pean) flamingos. *Comparative Biochemistry and Physiology*, v. 23, no. 1, 1967. pp. 225-232.
- FOX, Denis L. Color adornment in birds. *Zoonoos*, v. 39, no. 8, 1966. pp. 14-19.
- FOX, Denis L. and Thomas S. HOPKINS. The comparative biochemistry of pigments. *Physiology of Echinodermata*, edited by Richard A. Boolootian. New York, Wiley, 1967. pp. 277-300.
- FOX, Denis L., V. Elliott SMITH and Arthur A. WOLFSON. Disposition of carotenoids in the blue goose barnacle *Lepas fascicularis*. *Experientia*, v. 23, 1967. pp. 965-966.
- FOX, Denis L. Some comparative features of metabolic fractionation of carotenoids among vertebrates. *Norwegian Journal of Chemistry, Mining and Metallurgy*, v. 26, no. 6-7, 1966. pp. 125-132.
- FRANCIS, T. J. G. and Russell W. RAITT. Seismic refraction measurements in the southern Indian Ocean. *Journal of Geophysical Research*, v. 72, no. 12, June 15, 1967. pp. 3015-3041.
- FRAZER, J. Z. and Gustaf O. S. ARRHENIUS. Geometry of divergent-beam diffraction. *Optique des Rayons X et Microanalyse*, edited by R. Castaing, P. Deschamps and J. Philibert. Paris, Editions Scientifiques Hermann, 1966. pp. 516-533.
- FRIEND, J. K. and William R. RIEDEL. Cenozoic orosphaerid radiolarians from tropical Pacific sediments. *Micropaleontology*, v. 13, no. 2, April 1967. pp. 217-232.
- FROST, Bruce W. A new species of the genus *Harpacticus* (Copepoda: Harpacticoida) from Kodiak Island, Alaska. *Crustaceana*, v. 12, pt. 2, 1967. pp. 133-140.
- GUNDERSEN, K., A. F. CARLUCCI and Kurt BOSTROM. Growth of some chemoautotrophic bacteria at different oxygen tensions. *Experientia*, v. 22, 1966. pp. 229-230.
- HAMILTON, R. D. and Kathryn E. AUSTIN. Assay of relative heterotrophic potential in the sea: the use of specifically labelled glucose. *Canadian Journal of Microbiology*, v. 13, 1967. pp. 1165-1173.
- HAMILTON, R. D. and Kathryn E. AUSTIN. Physiological and cultural characteristics of *Chromobacterium marinum*, sp. n. *Antonie van Leeuwenhoek*, v. 33, no. 3, 1967. pp. 257-264.
- HARRISON, C. G. A. Palaeomagnetism of deep-sea sediments. *International Dictionary of Geophysics*, edited by K. Runcorn and others. New York, Pergamon, 1967. pp. 1134-1141.
- HARRISON, C. G. A., J. C. BELSHE, A. S. DUNLAP, John D. MUDIE and Anthony I. REES. A photographic compass inclinometer for the orientation of deep sea sediment samples. *Journal of Ocean Technology*, v. 1, no. 2, 1967. pp. 37-39.
- HARRISON, C. G. A. and John D. MUDIE. Stereoscopic representation of bathymetric and magnetic profiles. *Underwater Photo-Optics Seminar, Santa Barbara, California, 1966. Proceedings*. pp. D-XXI-1 to D-XXI-5.
- HEALEY, F. P., J. COOMBS and Benjamin E. VOLCANI. Changes in pigment content of the diatom *Navicula pelliculosa* (Bréb.) Hilse in silicon-starvation synchrony. *Archiv für Mikrobiologie*, v. 59, 1967. pp. 131-142.
- HILDE, Thomas W. C. and Celeste G. ENGEL. Age, composition and tectonic setting of the Granite Island, Hon Trung Lon, off the coast of South Vietnam. *Geological Society of America. Bulletin*, v. 78, October 1967. pp. 1289-1294.
- HOLLAND, William R. On the wind-driven circulation in an ocean with bottom topography. *Tellus*, v. 19, no. 4, 1967. pp. 582-600.
- HOLM-HANSEN, O., J. D. H. STRICKLAND and P. M. WILLIAMS. A detailed analysis of biologically important substances in a profile off southern California. *Limnology and Oceanography*, v. 11, no. 4, October 1966. pp. 548-561.
- HOLM-HANSEN, O. Factors affecting the viability of lyophilized algae. *Cryobiology*, v. 4, no. 1, 1967. pp. 17-23.
- HOLM-HANSEN, O., J. COOMBS, Benjamin E. VOLCANI and P. M. WILLIAMS. Quantitative micro-determination of lipid carbon in microorganisms. *Analytical Biochemistry*, v. 19, no. 3, June 1967. pp. 561-568.
- HOLMES, Robert W. The dissolution of protoplasm in thecate dinoflagellates by ultra-violet induced oxidation. *Stain Technology*, v. 42, no. 1, 1967. pp. 34-35.
- HOLMES, Robert W., P. M. WILLIAMS and Richard W. EPPLEY. Red water in La Jolla Bay, 1964-1966. *Limnology and Oceanography*, v. 12, no. 3, July 1967. pp. 503-512.
- HOUTERMANS, Jan, Hans E. SUESS and Walter H. MUNK. Effect of industrial fuel combustion on the carbon-14 level of atmospheric CO₂. *Radioactive Dating and Methods of Low-Level Counting*. Vienna, International Atomic Energy Agency, 1967. pp. 57-68.
- HUBBS, Carl L. A discussion on the geochronology and archeology of the California Islands. *Symposium on the Biology of the California Islands, Santa Barbara, 1965. Proceedings*, 1967. pp. 337-341.
- 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*. *Scripps Institution of Oceanography Bulletin*, v. 10, 1967. vi, 64 p.
- HUBBS, Carl L. and Laura C. HUBBS. Gray whale census by airplane in Mexico. *California Fish and Game*, v. 53, no. 1, 1967. pp. 23-27.
- HUBBS, Carl L. and George S. BIEN. La Jolla natural radiocarbon measurements V. *Radiocarbon*, v. 9, 1967. pp. 261-294.

- HUBBS, Carl L. Occurrence of the Pacific lamprey, *Entosphenus tridentatus*, off Baja California and in streams of southern California; with remarks on its nomenclature. *San Diego Society of Natural History. Transactions*, v. 14, no. 21, 1967. pp. 301-312.
- HUBBS, Clark. Analysis of phylogenetic relationships using hybridization techniques. *National Institute of Sciences of India. Bulletin*, no. 34, 1967. pp. 48-59.
- ISAACS, John D. Food from the sea. *International Science and Technology*, no. 64, April 1967. pp. 61-68.
- ISAACS, John D. Remarks on some present and future buoy developments. *International Buoy Technology Symposium. Transactions, 2d, Washington, 1967*. pp. 503-529.
- JERDE, Charles W. A comparison of euphausiid shrimp collections made with a micronekton net and a one-meter plankton net. *Pacific Science*, v. 21, no. 2, April 1967. pp. 178-181.
- JOHNSON, Martin W. Some observations on the hatching of *Tortanus discaudatus* eggs subjected to low temperatures. *Limnology and Oceanography*, v. 12, no. 3, July 1967. pp. 405-410.
- JONES, Galen E. Growth of *Escherichia coli* in heat- and copper-treated synthetic seawater. *Limnology and Oceanography*, v. 12, no. 1, January 1967. pp. 167-172.
- JONES, Galen E. Precipitates from autoclaved seawater. *Limnology and Oceanography*, v. 12, no. 1, January 1967. pp. 165-167.
- KATAYAMA, Masayuki and A. A. BENSON. *a*-Linolenate and photosynthetic activity in *Chlorella protothecoides*. *Plant Physiology*, v. 42, no. 3, March 1967. pp. 308-313.
- KUCHNOW, Karl P. and Perry W. GILBERT. Preliminary *in vivo* studies on pupillary and tapetal pigment responses in the lemon shark, *Negaprion brevirostris*. *Sharks, Skates and Rays*, edited by Perry W. Gilbert, Robert F. Mathewson and David P. Rall. Baltimore, Johns Hopkins Press, 1967. pp. 465-477.
- LAURITIS, James A., Barbara Bruff HEMMINGSON and Benjamin E. VOLCANI. Propagation of *Hantzschia* sp. Grunow daughter cells by *Nitzschia alba* Lewin and Lewin. *Journal of Phycology*, v. 3, 1967. pp. 236-237.
- LIEBERMANN, Leonard N. Resonance absorption. *Physical Acoustics*, v. 4A. New York, Academic, 1966. pp. 183-193.
- LONGHURST, Alan R. Diversity and trophic structure of zooplankton communities in the California Current. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 393-408.
- LONGHURST, Alan R. The pelagic phase of *Pleuroncodes planipes* Stimpson (Crustacea, Galatheididae) in the California Current. *California Cooperative Oceanic Fisheries Investigations. Reports*, v. 11, July 1, 1963 to June 30, 1966. pp. 142-154.
- LONGHURST, Alan R. and D. L. R. SEIBERT. Skill in the use of Folsom's plankton sample splitter. *Limnology and Oceanography*, v. 12, no. 2, 1967. pp. 334-335.
- LONGHURST, Alan R. Vertical distribution of zooplankton in relation to the eastern Pacific oxygen minimum. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 51-63.
- LONGINELLI, A. and Harmon CRAIG. Oxygen-18 variations in sulfate ions in sea water and saline lakes. *Science*, v. 156, no. 3771, April 7, 1967. pp. 56-59.
- LONGUET-HIGGINS, Michael S. On the wave-induced difference in mean sea level between the two sides of a submerged breakwater. *Journal of Marine Research*, v. 25, no. 2, 1967. pp. 148-153.
- LORENZEN, Carl J. Vertical distribution of chlorophyll and phaeo-pigments: Baja California. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 735-745.
- LOWENSTEIN, Carl D. and John D. MUDIE. On the optimization of transponder spacing for range-range navigation. *Journal of Ocean Technology*, v. 1, no. 2, 1967. pp. 29-31.
- LUYENDYK, Bruce P. and William G. MELSON. Magnetic properties and petrology of rocks near the crest of the Mid-Atlantic Ridge. *Nature*, v. 215, no. 5097, July 8, 1967. pp. 147-149.
- McGLAMERY, Benjamin L. Restoration of turbulence-degraded images. *Optical Society of America. Journal*, v. 57, no. 3, March 1967. pp. 293-297.
- MATSUI, Tetsuo. Review of the mackerel genera *Scomber* and *Rastrelliger* with description of a new species of *Rastrelliger*. *Copeia*, no. 1, 1967. pp. 71-83.
- MENARD, Henry W. and Jacqueline MAMMERIX. Abyssal hills, magnetic anomalies and the East Pacific Rise. *Earth and Planetary Science Letters*, v. 2, 1967. pp. 465-472.
- MENARD, Henry W. Sea floor spreading, topography, and the second layer. *Science*, v. 157, no. 3791, August 25, 1967. pp. 923-924.
- MENARD, Henry W. Transitional types of crust under small ocean basins. *Journal of Geophysical Research*, v. 72, no. 12, June 15, 1967. pp. 3061-3073.
- MILES, John W. Decay of spherical blast waves. *Physics of Fluids*, v. 10, no. 12, December 1967. pp. 2707-2708.
- MILES, John W. Electrostatics of slender bodies. *Journal of Applied Physics*, v. 38, no. 1, January 1967. pp. 192-196.
- MILES, John W. Internal waves in a continuously stratified atmosphere or ocean. *Journal of Fluid Mechanics*, v. 28, pt. 2, 1967. pp. 305-310.
- MILES, John W. On the generation of surface waves by shear flows. Part 5. *Journal of Fluid Mechanics*, v. 30, pt. 1, 1967. pp. 163-175.

- MILES, John W. Surface-wave damping in closed basins. *Royal Society of London. Proceedings. Series A.*, v. 297, 1967. pp. 459-475.
- MILES, John W. Surface-wave scattering matrix for a shelf. *Journal of Fluid Mechanics*, v. 28, pt. 4, 1967. pp. 755-767.
- MILES, John W. and John K. DIENES. Taylor instability in a viscous liquid. *Physics of Fluids*, v. 9, no. 12, December 1966. pp. 2518-2519.
- MIYACHI, Shigetoh, Shizuko MIYACHI and A. A. BENSON. Sulfolipid in *Ochromonas danica*. *Journal of Protozoology*, v. 13, no. 1, 1966. pp. 76-78.
- MOORE, Theodore C., Jr. and G. Ross HEATH. Abyssal hills in the central equatorial Pacific: detailed structure of the sea floor and subbottom reflectors. *Marine Geology*, v. 5, 1967. pp. 161-179.
- MORIARTY, James R. and Norma C. MORIARTY. In the wake of the SAN PEDRO. *Southern California Quarterly*, v. 48, no. 2, June 1966. pp. 115-136.
- MORIARTY, James R. and Mary S. KEISTMAN. Philip II orders the journey of the first Manila galleon. *Journal of San Diego History*, v. 12, no. 2, April 1966. pp. 1-16.
- MORIARTY, James R. Transitional pre-desert phase in San Diego County, California. *Science*, v. 155, no. 3762, February 3, 1967. pp. 553-556.
- MULLIN, Michael M. and Elaine R. BROOKS. Laboratory culture, growth rate and feeding behavior of a planktonic marine copepod. *Limnology and Oceanography*, v. 12, no. 4, October 1967. pp. 657-666.
- MUNK, Walter H. and B. ZETLER. Deep-sea tides: a program. *Science*, v. 158, no. 3803, November 17, 1967. pp. 884-886.
- NEWMAN, William A. A new genus of *Chthamalidae* (Cirripedia, Balanomorpha) from the Red Sea and Indian Ocean. *Journal of Zoology*, v. 153, 1967. pp. 423-435.
- NEWMAN, William A. Prospectus on larval cirriped setation formulae. *Crustaceana*, v. 9, pt. 1, 1965. pp. 51-56.
- NEWMAN, William A. Shallow-water versus deep-sea *Octolasmis* (Cirripedia Thoracica). *Crustaceana*, v. 12, pt. 1, 1967. pp. 13-32.
- NIERENBERG, W. A. Atomic beam magnetic resonance. In *Physica 33. Zeeman Centennial Conference, Amsterdam, 1965*. pp. 18-28.
- NIERENBERG, W. A. Oceanography tomorrow. *Tutorial Lecture Series. Annual Technical Meeting, 13th, Washington, D.C. 1967. Proceedings. Institute of Environmental Sciences*. pp. 63-68.
- NIGRINI, Catherine. Radiolaria in pelagic sediments from the Indian and Atlantic Oceans. *Scripps Institution of Oceanography. Bulletin*, v. 11, 1967. v, 106p.
- PARKER, Frances L. Late Tertiary biostratigraphy (planktonic foraminifera) of tropical Indo-Pacific deep-sea cores. *Bulletin of American Paleontology*, v. 52, no. 235, 1967. pp. 115-208.
- PATTON, S., P. T. CHANDLER, E. B. KALAN, A. R. LOEBLICH III, G. FULLER and A. A. BENSON. Food value of red tide (*Gonyaulax polyedra*). *Science*, v. 158, no. 3802, November 10, 1967. pp. 789-790.
- PATTON, S. and A. A. BENSON. Phytol metabolism in the bovine. *Biochimica et Biophysica Acta*, v. 125, 1966. pp. 22-32.
- PAULLING, J. R., Jr. and Maxwell SILVERMAN. Model studies for an oceanographic ship derived from an offshore supply vessel. *Marine Technology*, v. 4, no. 4, 1967. pp. 403-415.
- PUSHKAR, Paul and M. N. A. PETERSON. Strontium isotopic analyses of three marine phillipsites from the Pacific Ocean. *Earth and Planetary Science Letters*, v. 2, 1967. pp. 349-350.
- RADOK, Rainer, Walter H. MUNK and John D. ISAACS. A note on mid-ocean internal tides. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 121-124.
- RASMUSSEN, Robert A. Ultrasonic absorption in bromoform. *Journal of Chemical Physics*, v. 47, no. 5, September 1, 1967. pp. 1871-1873.
- REID, Joseph L. Intermediate and deep circulation. *American Geophysical Union*, v. 48, no. 2, June 1967. pp. 572-575.
- REID, Joseph L. Oceanic environments of the genus *Engraulis* around the world. *California Cooperative Oceanic Fisheries Investigations. Reports*, v. 11, July 1, 1963 to June 30, 1966. pp. 29-33.
- REID, Joseph L. Upwelling. *International Dictionary of Geophysics*, edited by K. Runcorn and others. New York, Pergamon Press, 1967. pp. 1638-1640.
- RICHARDS, Michael L., Victor VACQUIER and Gerald D. VAN VOORHIS. Calculation of the magnetization of uplifts from combining topographic and magnetic surveys. *Geophysics*, v. 32, no. 4, August 1967. pp. 678-707.
- ROBINSON, Margaret K. Comparison of M. Koizumi and M. K. Robinson computations of seasonal variation of mean sea surface temperatures in the East China Sea. *Oceanographical Society of Japan. Journal*, v. 23, no. 1, February 1967. pp. 29-38.
- RODEN, Gunnar I. A modern statistical analysis and documentation of historical temperature records in California, Oregon and Washington, 1821-1964. *Journal of Applied Meteorology*, v. 5, no. 1, February 1966. pp. 3-24.
- ROSENBLATT, Richard H. and George S. LOSEY, Jr. Alarm reaction of the top smelt *Atherinops affinis*: re-examination. *Science*, v. 258, no. 3801, November 3, 1967. pp. 671-672.
- ROSENBLATT, Richard H. and Bernard J. ZAHURANEC. The eastern Pacific groupers of the genus *My-*

- cteroperca*, including a new species. *California Fish and Game*, v. 53, no. 4, 1967. pp. 228-245.
- ROSENBLATT, Richard H. and Terence D. PARR. The identity of the blenny *Paraclinus altivelis* (Lockington) and the status of *P. sinus* Hubbs. *Copeia*, no. 3, September 1, 1967. pp. 675-677.
- ROSENBLATT, Richard H. The osteology of the congrid eel *Gorgasia punctata* and the relationships of the Heterocongrinae. *Pacific Science*, v. 21, no. 1, January 1967. pp. 91-97.
- ROSENBLATT, Richard H. The zoogeographic relationships of the marine shore fishes of tropical America. *Studies in Tropical Oceanography*, no. 5, 1967. pp. 579-592.
- ROSEFELDER, Andre Marcel. Hydrostatic actuation of deep-sea instruments. *Journal of Ocean Technology*, v. 1, no. 1, 1966. pp. 53-63.
- ROSEFELDER, Andre Marcel and Neil F. MARSHALL. Obtaining large, undisturbed, and orientated samples in deep water. *Marine Geotechnique*, edited by Adrian F. Richards. Urbana, University of Illinois Press, 1967. pp. 243-263.
- ROSS, Arnold and William A. NEWMAN. Eocene Balanidae of Florida, including a new genus and species with a unique plan of "turtle-barnacle" organization. *American Museum Novitates*, no. 2288, April 13, 1967. pp. 1-21.
- ROSS, David A. and William R. RIEDEL. Comparison of upper parts of some piston cores with simultaneously collected open-barrel cores. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 285-294.
- RUDNICK, Philip and E. D. SQUIER. Fluctuations and directionality in ambient sea noise. *Acoustical Society of America. Journal*, v. 41, no. 5, May 1967. pp. 1347-1351.
- RUDNICK, Philip. Motion of a large spar buoy in sea waves. *Journal of Ship Research*, v. 11, no. 4, 1967. pp. 257-267.
- SCHAEFER, Milner B. Dynamics of the fishery for the anchoveta, *Engraulis ringens*, off Peru. *Instituto del Mar del Peru. Boletin*, v. 1, no. 5, 1967. pp. 191-303.
- SCHAEFER, Milner B. Fishery dynamics and present status of the yellowfin tuna population of the eastern Pacific Ocean. *Inter-American Tropical Tuna Commission. Bulletin*, v. 12, no. 3, 1967. pp. 87-136.
- SCHAEFER, Milner B. Oceanography and the marine fisheries. *Canadian Fisheries Reports*, no. 5, June 1965. pp. 29-35.
- SCHICK, George B. and Philip M. MARSHALL. Jacketed deep-sea mooring line. *Geo-Marine Technology*, v. 2, no. 7, July/August 1966. pp. 16-19.
- SCHICK, George B. Mooring line cutter. *Geo-Marine Technology*, v. 2, no. 7, July/August, 1966. pp. 23-25.
- SCLATER, John G. and Charles E. CORRY. Heat flow, Hawaiian area. *Journal of Geophysical Research*, v. 72, no. 14, July 15, 1967. pp. 3711-3715.
- SCLATER, John G. and Henry W. MENARD. Topography and heat flow of the Fiji Plateau. *Nature*, v. 216, no. 5119, December 9, 1967. pp. 991-993.
- SEKI, Humitake and Claude E. ZOBELL. Microbial assimilation of carbon dioxide in the Japan Trench. *Oceanographical Society of Japan. Journal*, v. 23, no. 4, August 1967. pp. 182-188.
- SHEPARD, Francis P. and Joseph R. CURRAY. Carbon-14 determination of sea level changes in stable areas. *Progress in Oceanography*, v. 4. New York, Pergamon Press, 1967. pp. 283-291.
- SHEPARD, Francis P. Delta-front diapirs off Magdalena River, Colombia compared with hills off other large deltas. *Gulf Coast Association of Geological Societies. Transactions*, v. 17, 1967. pp. 316-325.
- SHEPARD, Francis P., Joseph R. CURRAY, William A. NEWMAN, A. L. BLOOM, N. D. NEWELL, J. I. TRACEY, Jr. and H. H. VEEH. Holocene changes in sea level: evidence in Micronesia. *Science*, v. 157, no. 3788, August 4, 1967. pp. 542-544.
- SHEPARD, Francis P. Submarine canyon origin: based on deep-diving vehicle and surface ship operations. *Revue de Géographie Physique et de Géologie Dynamique, Series 2*, v. 9, no. 5, 1967. pp. 347-356.
- SHIBUYA, Isao, Bunji MARUO and A. A. BENSON. Sulfolipid localization in lamellar lipoprotein. *Plant Physiology*, v. 40, no. 6, November 1965. pp. 1251-1256.
- SHOR, George G. Explosion seismology at sea. *American Geophysical Union. Transactions*, v. 48, no. 2, June 1967. pp. 415-420.
- SHOR, George G. Non-explosive profilers; methods (arcers, sparkers, boomers, gas-guns, air-guns, and similar devices). *International Dictionary of Geophysics*, edited by K. Runcorn and others. New York, Pergamon Press, 1967. pp. 1018-1021.
- SHOR, George G. Seismic refraction profile in Coral Sea Basin. *Science*, v. 158, no. 3803, November 17, 1967. pp. 911-913.
- SMITH, Raymond C. and John E. TYLER. Optical properties of clear natural water. *Optical Society of America. Journal*, v. 57, no. 5, May 1967. pp. 589-595.
- SNODGRASS, James M. and Perry W. GILBERT. A shark bite meter. *Sharks, Skates and Rays*, edited by Perry W. Gilbert, Robert F. Mathewson and David P. Rall. Baltimore, Johns Hopkins Press, 1967. pp. 331-337.
- SPIESS, Fred N., John D. MUDIE and Carl D. LOWENSTEIN. Environmental limitations to deep sea research. *U. S. Navy Symposium on Military Oceanography. Proceedings. 4th, Hawaii, 1967*, v. 1, pp. 69-80.
- SPIESS, Fred N. Instrumenting the environment-marine physics. *Tutorial Lecture Series. Annual Technical Meeting, 13, Washington, D.C., 1967. Proceedings. Institute of Environmental Sciences*. pp. 27-32.



- SPIESS, Fred N. Underwater acoustic positioning; applications. *Marine Geodesy Symposium, 1st, Columbus, Ohio, 1966. Proceedings*, pp. 93-101.
- STRIDE, A. H., R. H. BELDERSON, Joseph R. CURRAY and David G. MOORE. Geophysical evidence on the origin of the Faeroe Bank Channel. I. Continuous reflection profiles. *Deep-Sea Research and Oceanographic Abstracts*, v. 14, 1967. pp. 1-6.
- SUESS, Hans E. Bristlecone pine calibration of the radiocarbon time scale from 4100 B.C. to 1500 B.C. *Radioactive Dating and Methods of Low-Level Counting. Vienna, International Atomic Energy Agency. 1967.* pp. 143-151.
- TAFT, Bruce A. Equatorial currents. *American Geophysical Union. Transactions*, v. 48, no. 2, June 1967. pp. 569-572.
- TAFT, Bruce A. and John A. KNAUSS. The equatorial undercurrent of the Indian Ocean as observed by the Lusiad Expedition. *Scripps Institution of Oceanography. Bulletin*, v. 9, 1967. vi, 163p.
- TAFT, Bruce A. Equatorial undercurrent of the Indian Ocean, 1963. *Studies in Tropical Oceanography*, no. 5, 1967. pp. 3-14.
- TYLER, John E. The blue sea. *Physics Teacher*, v. 5, no. 8, November 1967. pp. 382-384.
- TYLER, John E. and Raymond C. SMITH. Spectroradiometric characteristics of natural light under water. *Optical Society of America. Journal*, v. 57, no. 5, May 1967. pp. 595-601.
- UYEDA, Seiya, Victor VACQUIER, Masashi YASUI, John G. SCLATER, T. SATO, Jan LAWSON, Teruhiko WATANABE, Fred S. DIXON, Eli A. SILVER, Y. FUKAO, K. SUDO, M. NISHIKAWA and T. TANAKA. Results of geomagnetic survey during the cruise of *R/V Argo* in Western Pacific 1966 and the compilation of magnetic charts of the same area. *Tokyo University. Earthquake Research Institute, Bulletin*, v. 45, 1967. pp. 799-814.
- VACQUIER, Victor, and Seiya UYEDA. Palaeomagnetism of nine seamounts in the Western Pacific and of three volcanoes in Japan. *Tokyo University. Earthquake Research Institute. Bulletin*, v. 45, 1967. pp. 815-848.
- VACQUIER, Victor, Seiya UYEDA, Masashi YASUI, John G. SCLATER, Charles E. CORRY and Teruhiko WATANABE. Studies of the thermal state of the earth. The 19th paper: heat-flow measurements in the northwestern Pacific. *Tokyo University. Earthquake Research Institute. Bulletin*, v. 44, 1966. pp. 1519-1535.
- VACQUIER, Victor, John G. SCLATER and Charles E. CORRY. Studies of the thermal state of the earth. The 21st paper: heat-flow, eastern Pacific. *Tokyo University. Earthquake Research Institute. Bulletin*, v. 45, 1967. pp. 375-393.
- van ANDEL, Tjeerd H., John B. CORLISS and Vaughan T. BOWEN. The intersection between the Mid-Atlantic Ridge and the Vema Fracture zone in the North Atlantic. *Journal of Marine Research*, v. 25, no. 3, 1967. pp. 343-351.
- van ANDEL, Tjeerd H., G. Ross HEATH, Theodore C. MOORE, Jr., and David F. R. McGEARY. Late Quaternary history, climate, and oceanography of the Timor Sea, northwestern Australia. *American Journal of Science*, v. 265, November 1967. pp. 737-758.
- van ANDEL, Tjeerd H. The Orinoco delta. *Journal of Sedimentary Petrology*, v. 37, no. 2, June 1967. pp. 297-310.
- VEEVERS, J. J. and Tjeerd H. van ANDEL. Morphology and basement of the Sahul Shelf. *Marine Geology*, v. 5, 1967. pp. 293-298.
- VON HERZEN, Richard P. and Victor VACQUIER. Terrestrial heat flow in Lake Malawi, Africa. *Journal of Geophysical Research*, v. 72, no. 16, August 15, 1967. pp. 4221-4226.
- von HUENE, R., George G. SHOR and Erk REIMNITZ. Geological interpretation of seismic profiles in Prince William Sound, Alaska. *Geological Society of America. Bulletin*, v. 78, February 1967. pp. 259-268.
- von HUENE, R., Richard J. MALLOY, George G. SHOR and Pierre ST. AMAND. Geologic structures in the aftershock region of the 1964 Alaskan earthquake. *Journal of Geophysical Research*, v. 72, no. 14, July 15, 1967. pp. 3649-3660.
- WEIER, T. Elliot and A. A. BENSON. The molecular nature of chloroplast membranes. *NATO Advanced Study Institute, Aberswyth, August 1965. Proceedings. Biochemistry of Chloroplasts*, v. 1, ed. by T. W. Goodwin. New York, Academic, 1966. pp. 91-113.
- WEIER, T. Elliot and A. A. BENSON. The molecular organization of chloroplast membranes. *American Journal of Botany*, v. 54, no. 4, April 1967. pp. 389-402.
- WINDOM, H. L., John J. GRIFFIN and Edward D. GOLDBERG. Talc in atmospheric dusts. *Environmental Science and Technology*, v. 1, no. 11, November 1967. pp. 923-926.
- WOOSTER, Warren S. Further observations on the secondary nitrite maximum in the northern equatorial Pacific. *Journal of Marine Research*, v. 25, no. 2, 1967. pp. 154-161.
- YANG, S. F., Sofia FREER and A. A. BENSON. Transphosphatidylolation by phospholipase D. *Journal of Biological Chemistry*, v. 242, no. 3, February 10, 1967. pp. 477-484.
- YOUNG, D. R. and Theodore R. FOLSOM. Loss of Zn^{65} from the California sea-mussel *Mytilus californianus*. *Biological Bulletin*, v. 133, no. 2, October 1967. pp. 438-447.
- ZOBELL, Claude E. Bacteriology of the sea. *Fundamental Principles of Bacteriology*, by A. J. Salle. New York, McGraw-Hill, 1967. pp. 514-527.

ZOBELL, Claude E. Formal discussion of [Effect of marine plankton in destruction of enteric bacteria, by Maurice Aubert, Henri Lebout and Jacqueline Aubert.] *Advances in Water Pollution Research*, v. 3, 1965. pp. 311-314.

ZOBELL, Claude E. and Leslie L. HITTLE. Some effects of hyperbaric oxygenation on bacteria at increased hydrostatic pressures. *Canadian Journal of Microbiology*, v. 13, 1967. pp. 1311-1319.

ZULLO, Victor A. and William A. NEWMAN. Thoracic Cirripedia from a southeast Pacific guyot. *Pacific Science*, v. 18, no. 4, October 1964. pp. 355-372.

OTHER PUBLISHED WORKS

ENRIGHT, J. T. Responses to Light. A review of Insect Photoperiodism, by S. D. Beck. *Science*, 1968. pp. 1327-1328.

FAGER, E. W. Review. The Ecology of Wytham Hill. *The Pattern of Animal Communities*, by C. S. Elton. *Quarterly Review of Biology*, no. 42, 1967. pp. 514-516.

KOONTZ, W. A. and D. L. INMAN. A multi-purpose data acquisition system for field and laboratory instrumentation of the nearshore environment. U.S. Army, Corps of Engineers. *Coastal Engineering Research Center, Technical Memo 21*, 1967. 38 p.

PHLEGER, Fred B and Marjorie PHLEGER. *Off to the Races*. Random House, New York, 1968.

RAFF, Arthur. Magnetometers. In *French Encyclopedia*, Grolier, Paris, 1968.

SHEPARD, Francis P. *The Earth Beneath the Sea*, Revised Edition. Johns Hopkins Press, Baltimore, Maryland, 1967. 242 p.

SHOR, George G. Review. Gadgets at sea. *Riches of the Sea, The New Science of Oceanology*. Norman Carlisle, Sterling Publishing Co., Inc., New York, 1967. October 1968.

SHOR, George G. and Elizabeth Noble SHOR. Biography of Gutenberg, Beno (Seismology). For *Dictionary of Scientific Biography*, Charles Scribner's Sons, May 1968.

SINKANKAS, John. *Catalog of Gemstones*. D. Van Nostrand Co., Inc., Princeton, New Jersey, 1967. 250 p.

SINKANKAS, John. *D. Van Nostrand's Standard Catalog of Gems*. D. Van Nostrand Co., Inc., Princeton, New Jersey, 1968. 300 p.

MARINE PHYSICAL LABORATORY TECHNICAL MEMORANDA

The Marine Physical Laboratory technical memoranda are informal reports written mainly for "in house" use. Information concerning their availability may be obtained by writing to Reports and Drafting, Marine Physical Laboratory, Scripps Institution of Oceanography, P. O. Box 109, La Jolla, California 92037.

The memoranda written this year are listed below:
No. 183 SQUIER, E. D. A variable frequency thermometer. April 1967.
No. 184 Not yet published.
No. 185 SPIESS, F. N. Notes on side-looking sonar. June 1967.
No. 186 BENSON, A. A. Deep-towed proton magnetometer. August 1967.
No. 187 LOUGHRIDGE, M. S. and F. N. SPIESS. Sound velocity corrections to baseline lengths of acoustic transponder nets. January 1968.
No. 188 BENSON, A. A. MPL digital counter output converter. February 1968.
No. 189 PEPPER, C. S. Vehicle system developed for a sea floor recording magnetometer. March 1968.

NAGA REPORTS

Scripps Institution of Oceanography cooperated with the governments of South Vietnam and Thailand and the U. S. International Cooperation Administration from 1959 to 1961 in conducting an oceanographic study of the South China Sea and the Gulf of Thailand. In 1964 the NAGA report series was started to provide a medium for publishing the larger papers resulting from the study. The papers published this year are listed below. For information concerning the availability of these reports contact Technical Publications, Director's Office, Scripps Institution of Oceanography, P. O. Box 109, La Jolla, California 92037.
Volume 4, part 1. STEPHENSON, W. The portunid crabs (Crustacea: portunidae) collected by the NAGA Expedition and IMBACH, M. C. Gammaridean Amphipoda from the South China Sea.
Volume 4, part 2. ALVARIÑO, Angeles. The Chaetognatha of the NAGA Expedition (1959-1961) in the South China Sea and the Gulf of Thailand.
Volume 4, part 3. GALLARDO, V. A. Polychaeta from the soft sublittoral bottoms of the Bay of Nha-trang, South Vietnam, and FAUCHALD, K. Nephytyidae (Polychaeta) from the Bay of Nha-trang, South Vietnam.

SCRIPPS INSTITUTION OF OCEANOGRAPHY REFERENCE SERIES

This series consists mainly of research reports which are too preliminary or too detailed for inclusion in scientific journals.

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.

The reports in the 1967 reference series are listed below:

67-1 ENSMINGER, Richard L. and Robert F. HOW-

- ARTH. Photocathode protection circuit. Visibility Laboratory. January 1967. 3 p.
- 67-2 BOILEAU, Almerian R. and Floyd D. MILLER. Changes in spectral sensitivity of multiplier phototubes resulting from changes in temperature. Visibility Laboratory. January 1967. 11 p.
- 67-3 TAYLOR, John H. Visual performance on the moon. Visibility Laboratory. January 1967. 8 p.
- 67-4 GIBSON, D. K. and R. P. LEWIS. Transducer calibration facility at San Vicente Lake. Marine Physical Laboratory. January 1967. 53 p.
- 67-5 Physical, chemical and biological data; Ursa Major Expedition; 4 August—4 October 1965. 1967. 71 p.
- 67-6 FOLSOM, T. R., W. E. WEITZ, and J. M. MOORE. Automatically converting a standard numerical strip printer so as to combine two-dimensional pulse analyzer information into a convenient page. January 1967. 34 p.
- 67-7 FOLSOM, T. R. Studies of background radioactivity levels in the marine environment near Southern California. (Also issued as IMR Reference Number 67-3.) Institute of Marine Resources. February 1967. 42 p.
- 67-8 RAITT, R. W., G. G. SHOR, T. J. G. FRANCIS and G. B. MORRIS. Anisotropy of the Pacific Upper Mantle. Marine Physical Laboratory. November 1967. 44 p.
- 67-9 Surface water temperatures at shore stations; United States West Coast; 1966; including surface salinities from several stations and five-meter temperatures and salinities at Scripps Pier. April 1967. 21 p.
- 67-10 Cancelled.
- 67-11 TYLER, John E. Investigation of errors in the measurement of radiant energy for correlation with primary productivity. Visibility Laboratory. May 1967. 12 p.
- 67-12 ANDERSON, Victor C. and W. R. CHERRY. Precision hydrophones for the null steering array. Marine Physical Laboratory. May 1967. 31 p.
- 67-13 Physical, chemical and biological data; Cruise Tempo (TO-62-1) August 1962. (Also issued as IMR Reference Number 67-15.) Institute of Marine Resources. 1967. 91 p.
- 67-14 ARRHENIUS, G. Deep sea sedimentation; a critical review of U. S. work; 1963-1967. 1967. 26 p.
- 67-15 BLACKBURN, Maurice. Scripps Tuna Oceanography Research (STOR) Program report for the half-year July 1, 1966-December 31, 1966. (Also issued as IMR Reference Number 67-16.) Institute of Marine Resources. June 1967. 25 p.
- 67-16 Physical and chemical data; CCOFI Cruise 6504; 31 March-24 April 1965, and CCOFI Cruise 6505 (El Golfo II) 14 May-17 June 1965. 1967. 52 p.
- 67-17 Physical and chemical data; CCOFI Cruise 6507; 15 June-11 August 1965 and CCOFI Cruise 6509; 31 August-25 September 1965. 1967. 152 p.
- 67-18 FILLOUX, Jean H. Oceanic electric currents, geomagnetic variations and the deep electrical conductivity structure of the ocean-continent transition of Central California. June 1967. 166 p.
- 67-19 FOLSOM, T. R., J. N. JOHNSON and D. R. YOUNG. Zeolites in sea water; a brief summary of findings at SIO concerning use of zeolites in sea water for concentrating fallout traces. April 1963. 7 p.
- 67-20 FOLSOM, T. R., C. SREEKUMARAN, W. E. WEITZ, Jr. and D. A. TENNANT. A flame photometer for small amounts of cesium. May 1967. 35 p.
- 67-21 FOLSOM, T. R. and C. SREEKUMARAN. Survey of downward penetration of fallout in the ocean by *in situ* absorption. 1967. 12 p.
- 67-22 FOLSOM, T. R. and C. SREEKUMARAN. The Urechis program: rapid survey of fallout cesium in the ocean. 1967. 17 p.
- 67-23 BARKDOLL, Ivan Harry. Computerized visibility calculations; maximum sighting range program. Visibility Laboratory. July 1967. 122 p.
- 67-24 Physical, chemical, and biological data; Cruise TO-60-1, May 1960. (Also issued as IMR Reference Number 68-1.) Institute of Marine Resources. July 1967. 41 p.
- 67-25 CLASSIFIED.
- 67-26 BOILEAU, Almerian R. Atmospheric optical measurements in central Colorado in connection with long range oblique photography. August 1967. 20 p.
- 67-27 EDGERTON, Catharine Fean. Relationship between meteorological conditions and optical properties of the atmosphere. August 1967. 25 p.
- 67-28 COX, Charles. The relation of backscattered radiation to wind-stress at the sea surface. October 1967. 30 p.
- 67-29 FRAZER, Jane Z. A computer fit to mass absorption coefficient data. Institute for the Study of Matter. 1967. 37 p.
- 67-30 HANOR, Jeffrey S. Frequency distribution of compositions in the Barite-Celestite series. 1967. 6 p.
- 67-31 Cancelled.
- 67-32 Progress report (July 1966 to July 1967). Research sponsored by Office of Naval Research. November 1967. 139 p.
- 67-33 Cancelled.
- 67-34 VAN DORN, William G., Peter W. HACKER and Ronald K. LAM. Circulation around oceanic islands; summary report for period January 2, 1967, to September 30, 1967. 1967. 26 p.
- 67-35 LEWIN, Ralph A. Nordic Council for Marine Biology Summer Course: Shore Microbiology, Tvärminne Zoological Station, Finland. August 1967. 30 p.

**INSTITUTE OF MARINE RESOURCES
REFERENCE SERIES**

- 67-16 BLACKBURN, Maurice. Scripps Tuna Oceanography Research (STOR) Program.
- 67-17 SCHAEFER, M. B. Institute of Marine Resources Annual Report for the year ending 30 June 1967.
- 68-1 GRIFFITHS, Raymond C., *et al.* Physical, chemical and biological data; Cruise TO-60-1; May 1960.
- 68-2 BROWN, W. D. Investigations into Tuna Quality.
- 68-3 BROWN, W. D. Investigations into Tuna Quality.
- 68-4 THOMAS, William H. Effects of Nutrients on Growth of phytoplankton.
- 68-5 BLACKBURN, M. Scripps Tuna Oceanography Research (STOR) Program progress report.
- 68-6 BROWN, W. D. Investigations into Tuna Quality, quarterly report, October 1, 1967, through December 31, 1967.
- 68-7 BROWN, W. D. Investigations into Tuna Quality, quarterly report, January 1 through March 31, 1968.
- 68-8 STRICKLAND, J. D. H. Marine Food-Chain Group. Progress report for the period January 1967-June 1968. Part 1—Introduction and Account of Work in Progress. Part 2—Manuscript Reports of Work Concluded, Vols. 1 and 2. Part 3—Data Record. Coastal Plankton Survey, 1967 — Section 1 — Chemistry and Productivity.

PATENTS

- Copies of the patents listed below, issued to members of the Scripps staff, can be obtained for a small fee from the U. S. Patent Office, Washington, D.C. 20231.
- Victor C. Anderson Real-Time Running Mean Generator
3,316,544 (April 1967)
- Rudolf H. Bieri Hermetically Sealing Water Sampler
3,367,190 (March 1968)
- Frederick H. Fisher and C. S. Mundy Terminal End Clamp for an Armored Electrical Cable
3,249,684 (May 1966)
- Frederick H. Fisher and Victor C. Anderson Pressure Actuated Anchor
3,311,080 (March 1967)
- M. N. A. Peterson Ultrasonic Sieving
3,305,481 (February 1967)
- Andre M. Rosfelder Trimming System for Underwater Vehicles
3,362,367 (January 1968)
- Andre M. Rosfelder Core Sampler
3,393,131 (May 1968)
- James M. Snodgrass Low-Torque Electric Generator
3,319,094 (May 1967)

**CURRENT EXPENDITURES BY MAJOR FUNCTION
FISCAL YEAR 1967-68**

	CURRENT FUNDS			DISTRIBUTION		
	Total	General	Restricted	Salaries and Wages	Other Expenditures	Less: Transfers
By Major Function						
Administration	\$ 153,400	\$ 130,799	\$ 22,601	\$ 114,222	\$ 39,178	\$ —
Instruction & Research	477,235	385,404	91,831	421,592	55,643	—
Research Divisions	2,875,068	585,623	2,289,445	1,842,550	1,032,518	—
Research Groups	6,553,607	664,497	5,889,110	3,362,073	3,191,534	—
Research Support	4,696,021	620,277	4,075,744	2,064,301	6,724,434	4,092,714
Sub-Totals	14,755,331	2,386,600	12,368,731	7,804,738	11,043,307	4,092,714
Associated Research	1,665,695	249,363	1,416,332	1,006,681	659,012	—
Sub-Totals	16,421,026	2,635,963	13,785,063	8,811,419	11,702,319	4,092,714
Other SIO Support	682,403	664,102	18,300	462,885	601,662	382,144
Totals	17,103,429	3,300,065	13,803,363	9,274,304	12,303,981	4,474,858
Less: Transfers					4,474,858	
Total Expenditures	\$17,103,429	\$3,300,065	\$13,803,363	\$9,274,304	\$ 7,829,123	\$ —

NOTE: Totals may not compare because of rounding



STAFF

NAME	RESEARCH GROUP	FIELD
#Elbert H. Ahlstrom	Department SIO	Biological Oceanography
Angeles Alvarino de Leira	Marine Life Research Group	Marine Biology
Victor C. Anderson	Marine Physical Laboratory	Marine Physics
Gustaf Arrhenius	Geological Research Division	Marine Geology
Robert S. Arthur	Ocean Research Division	Physical Oceanography
Roswell W. Austin	Visibility Laboratory	Optical Physics
George E. Backus	Institute of Geophysics and Planetary Physics	Geophysics
Arnold E. Bainbridge	Ocean Research Division	Marine Chemistry
Manuel N. Bass	Geological Research Division	Geology
John R. Beers	Institute of Marine Resources	Marine Zoology
Andrew A. Benson	Marine Biology Research Division	Marine Biology
George S. Bien	Ocean Research Division	Chemistry
Rudolf Bieri	Geological Research Division	Physics
Maurice Blackburn	Institute of Marine Resources	Biological Oceanography
Brian P. Boden	Marine Biology Research Division	Marine Biology
Elizabeth Kampa Boden	Marine Biology Research Division	Marine Biology
Almerian R. Boileau	Visibility Laboratory	Atmospheric Optics
*Milton N. Bramlette	Ocean Research Division	Geology
Edward Brinton	Marine Life Research Group	Marine Biology
#Edward C. Bullard	Scientific Support Division	Geophysics
Theodore H. Bullock	Neurosciences	Neurophysiology
Angelo F. Carlucci	Marine Life Research Group	Marine Biology
Thomas E. Chase	Geological Research Division	Marine Geology
Tsaihwa J. Chow	Ocean Research Division	Chemistry
Charles S. Cox	Ocean Research Division	Physical Oceanography
Harmon B. Craig	Geological Research Division	Geochemistry
Joseph R. Curray	Geological Research Division	Marine Geology
Seibert Q. Duntley	Visibility Laboratory	Physics
Carl Eckart	Scientific Support Division	Marine Geophysics
Norman Terence Edgar	Deep Sea Drilling Project	Geology
Robert W. Elsner	Physiological Research Laboratory	Marine Physiology
A. E. J. Engel	Geological Research Division	Geology
Theodore Enns	Marine Biology Research Division	Physiology
James T. Enright	Ocean Research Division	Biological Oceanography
Richard W. Eppley	Institute of Marine Resources	Biological Oceanography
Martha W. Evans	Marine Life Research Group	Physical Oceanography
E. W. Fager	Ocean Research Division	Biological Oceanography
Frederick H. Fisher	Marine Physical Laboratory	Physics
Robert L. Fisher	Geological Research Division	Marine Geology
Arthur Flechsig	Ocean Research Division	Biological Oceanography
Abraham Fleminger	Marine Life Research Group	Marine Biology
Theodore Folsom	Ocean Research Division	Physical Oceanography
Denis L. Fox	Marine Biology Research Division	Marine Biology
Dean L. Franklin	Physiological Research Laboratory/ School of Medicine	Physiology
Jeffery D. Frautschy	Scientific Support Division	Marine Technology
Walter F. Garey	Physiological Research Laboratory	Physiology
Elizabeth L. Gealy	Deep Sea Drilling Project	Geology
Donald Geduldig	Physiological Research Laboratory	Physiology
Joris M. T. M. Gieskes	Ocean Research Division	Marine Chemistry
J. Freeman Gilbert	Institute of Geophysics and Planetary Physics	Geophysics

NAME	RESEARCH GROUP	FIELD
Edward D. Goldberg	Geological Research Division	Marine Chemistry
John J. Griffin	Geological Research Division	Marine Chemistry
Nicholas Grijalva	Ocean Research Division	Physical Oceanography
Roger Grismore	Ocean Research Division	Physical Oceanography
Raphael P. Gruener	Physiological Research Laboratory	Physiology
Susumu Hagiwara	Physiological Research Laboratory	Neurophysiology
Robert D. Hamilton	Institute of Marine Resources	Marine Biology
Harold T. Hammel	Physiological Research Laboratory	Physiology
Jeffrey S. Hanor	Geological Research Division	Marine Geology
James L. Harris	Visibility Laboratory	Optical Physics
Richard A. Haubrich	Institute of Geophysics and Planetary Physics	Geophysics
James W. Hawkins	Geological Research Division	Geology
Francis T. Haxo	Marine Biology Research Division	Marine Botany
Hideo Hayashi	Physiological Research Laboratory	Neurophysiology
Edvard Hemmingsen	Physiological Research Laboratory	Physiology
Myrl C. Hendershott	Ocean Research Division	Physical Oceanography
Nicholas D. Holland	Marine Biology Research Division	Marine Biology
Osmund Holm-Hansen	Institute of Marine Resources	Marine Biology
*Carl Hubbs	Marine Biology Research Division	Marine Biology
Douglas L. Inman	Ocean Research Division	Physical Oceanography
John D. Isaacs	Marine Life Research Group	Oceanography
*Martin W. Johnson	Marine Life Research Group	Marine Biology
Charles D. Keeling	Ocean Research Division	Marine Chemistry
Helen K. Kirk	Marine Physical Laboratory	Marine Geophysics
Hans T. Klein	Marine Life Research Group	Physical Oceanography
Margaret Knight	Marine Life Research Group	Biological Oceanography
Minoru Koide	Geological Research Division	Marine Chemistry
Devendra Lal	Geological Research Division	Nuclear Geophysics
#Reuben Lasker	Marine Biology Research Division	Marine Biology
Ralph Lewin	Marine Biology Research Division	Marine Biology
Leonard N. Liebermann	Marine Physical Laboratory/ Physics Department	Physics
Carl D. Lowenstein	Marine Physical Laboratory	Physics
Ferren MacIntyre	Ocean Research Division	Marine Chemistry
Edward D. McAlister	Applied Oceanography Group	Physics
*George F. McEwen	Ocean Research Division	Marine Chemistry
John A. McGowan	Marine Life Research Group	Biological Oceanography
William McLeish	Applied Oceanography Group	Physics
Gillian Maggert	Marine Life Research Group	Biological Oceanography
Tetsuo Matsui	Marine Life Research Group	Biological Oceanography
Henry W. Menard	Geological Research Division/ Institute of Marine Resources	Marine Geology
Julian Miller	Marine Life Research Group	Biological Oceanography
John D. Mudie	Marine Physical Laboratory	Geophysics
Michael M. Mullin	Institute of Marine Resources	Biological Oceanography
Walter H. Munk	Institute of Geophysics and Planetary Physics	Geophysics
†Yutaka Nagata	Ocean Research Division	Physical Oceanography
Tadashi Nakajima	Marine Biology Research Division	Biochemistry
William A. Newman	Scientific Support Division	Biological Oceanography
William A. Nierenberg	Director	Physics
Benton B. Owen	Marine Physical Laboratory	Chemistry
Francis L. Parker	Geological Research Division	Paleontology
Robert L. Parker	Institute of Geophysics and Planetary Physics/ Ocean Research Division	Geophysics
Melvin N. A. Peterson	Geological Research Division	Marine Geology

NAME	RESEARCH GROUP	FIELD
Fred B Phleger	Geological Research Division	Marine Geology
Rudolph W. Preisendorfer	Visibility Laboratory	Mathematics
Arthur D. Raff	Geological Research Division	Marine Geophysics
Russell W. Raitt	Geological Research Division	Marine Geophysics
N. Solomon Raju	Marine Life Research Group	Marine Zoology
*Norris W. Rakestraw	Ocean Research Division	Marine Chemistry
Robert A. Rasmussen	Marine Physical Laboratory	Marine Physics
Archibald M. Reid	Geological Research Division	Mineralogy
Joseph L. Reid	Marine Life Research Group	Physical Oceanography
*Roger R. Revelle	Scientific Support Division	Marine Geology
Sumner Richman	Institute of Marine Resources	Marine Biology
William R. Riedel	Scientific Support Division	Marine Geology
Margaret K. Robinson	Ocean Research Division	Physical Oceanography
Richard H. Rosenblatt	Scientific Support Division	Marine Zoology
André M. Rosfelder	Geological Research Division	Geology
Philip Rudnick	Marine Physical Laboratory	Physics
Milner B. Schaefer	Institute of Marine Resources	Biological Oceanography
Walter R. Schmitt	Marine Life Research Group	Geophysics
Per F. Scholander	Physiological Research Laboratory	Marine Physiology
Richard A. Schwartzlose	Marine Life Research Group	Physical Oceanography
John G. Sclater	Marine Physical Laboratory	Geophysics
*Francis P. Shepard	Ocean Research Division	Submarine Geology
George G. Shor	Geological Research Division/ Marine Physical Laboratory	Marine Geophysics
Maxwell Silverman	Scientific Support Division	Marine Engineering
John Sinkankas	Geological Research Division	Mineralogy
Raymond C. Smith	Visibility Laboratory	Physics
Stuart M. Smith	Geological Research Division	Marine Geology
Frank E. Snodgrass	Institute of Geophysics and Planetary Physics	Geophysics
James M. Snodgrass	Special Developments	Instrumentation
Lucia Solorzano	Institute of Marine Resources	Biochemistry
Fred Noel Spiess	Marine Physical Laboratory	Marine Physics
John D. H. 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	Marine Physical Laboratory	Geophysics
Tj. H. van Andel	Ocean Research Division	Marine Geology
William G. Van Dorn	Ocean Research Division	Physical Oceanography
Benjamin E. Volcani	Marine Biology Research Division	Marine Microbiology
Theodore J. Walker	Ocean Research Division	Marine Biology
*Charles D. Wheelock	Scientific Support Division	Naval Architecture
Donald W. Wilkie	Aquarium — Museum	Marine Biology
Francis Williams	Institute of Marine Resources	Marine Biology
Peter M. Williams	Institute of Marine Resources	Biological Oceanography
Edward L. Winterer	Geological Research Division	Marine Geology
Jacqueline Winterer	Geological Research Division	Marine Geology
Robert L. Wisner	Marine Biology Research Division	Marine Biology
Warren S. Wooster	Ocean Research Division	Physical Oceanography
Bernt F. K. Zeitzschel	Institute of Marine Resources	Marine Biology
Claude E. ZoBell	Marine Biology Research Division	Marine Microbiology

*Emeritus

†Visiting

#Professor-in-Residence



APPENDIX A

DIRECTOR—DEAN

W. A. Nierenberg

ASSOCIATE DIRECTORS

A. A. Benson
G. G. Shor
F. N. Spiess

ASSISTANT DIRECTOR

J. D. Frautschy

INSTRUCTION

GRADUATE DEPARTMENT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

E. L. Winterer, Chairman
R. H. Rosenblatt, Vice Chairman

APPLIED OCEAN SCIENCES

S. Q. Duntley

BIOLOGICAL OCEANOGRAPHY

J. A. McGowan

GEOPHYSICS

J. F. Gilbert

MARINE BIOLOGY

A. A. Benson

MARINE CHEMISTRY

E. D. Goldberg

MARINE GEOLOGY

H. W. Menard

PHYSICAL OCEANOGRAPHY

C. S. Cox

RESEARCH SUPPORT

AQUARIUM—MUSEUM

D. L. Wilkie

MARINE FACILITIES

P. G. Trapani

SCIENTIFIC SUPPORT DIVISION

J. D. Frautschy

RESEARCH DIVISIONS

GEOLOGICAL RESEARCH

G. G. Shor

MARINE BIOLOGY

D. L. Fox

OCEAN RESEARCH

J. L. Reid

RESEARCH GROUPS

DEEP SEA DRILLING

K. E. Brunot

MARINE LIFE RESEARCH

J. D. Isaacs

MARINE PHYSICAL LABORATORY

F. N. Spiess

NEUROBIOLOGY UNIT

T. H. Bullock

PHYSIOLOGICAL RESEARCH LABORATORY

P. F. Scholander

VISIBILITY LABORATORY

S. Q. Duntley

ASSOCIATED RESEARCH

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

OTHER SUPPORT

LIBRARY

W. J. Goff

PHOTOGRAPHIC LABORATORY

J. E. Rupert

PUBLIC INFORMATION

R. N. Fuller

APPENDIX B

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. Department of the Interior
(U. S. Bureau of Commercial Fisheries and
U. S. Geological Survey)
California State Water Resources Control Board

OTHER

Achievement Rewards for College Scientists
American Chemical Society
American Heart Association
American Optical Company
American Petroleum Institute
A. P. Sloan Foundation
Beckman Instruments, Inc.
Bendix Corporation
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.
Jersey Production Research Co.
John B. McKee Fund
Kennecott Copper Corporation
Lockheed Missiles and Space Company
M. C. Fleischmann Foundation
National Geographic Society
Ocean Science and Engineering, Inc.
Pan American Petroleum Foundation, Inc.
Rockefeller Foundation
San Diego County Heart Association
Searles Fund
Francis P. Shepard Foundation
Socony Mobil Oil Company, Inc.
Sun Oil Company
The Superior Oil Company
U. S. Steel Foundation
Westinghouse Electric Corporation

APPENDIX C

MAJOR AWARDS AND HONORS

Among the major awards and honors bestowed upon faculty and staff members of the Institution since July 1, 1967, have been these:

- Dr. Theodore H. Bullock Recipient, Karl Spencer Lashley Prize of the Council of the American Philosophical Society.
- Dr. Henry W. Menard Elected Member, National Academy of Sciences.
- Dr. Walter H. Munk Recipient, 1968 Gold Medal of the Royal Astronomical Society of London.
- Dr. Francis P. Shepard Awarded honorary Doctor of Science degree by Beloit College, Beloit, Wisconsin.
- James M. Snodgrass Elected Fellow, Instrument Society of America; Recipient, U.S. Navy Distinguished Public Service Award.
- Dr. Warren S. Wooster Elected President, Scientific Committee on Oceanic Research (SCOR) of the International Commission of Scientific Unions; Elected Fellow, American Geophysical Union.



APPENDIX D

RESEARCH VESSELS OF SCRIPPS INSTITUTION OF OCEANOGRAPHY

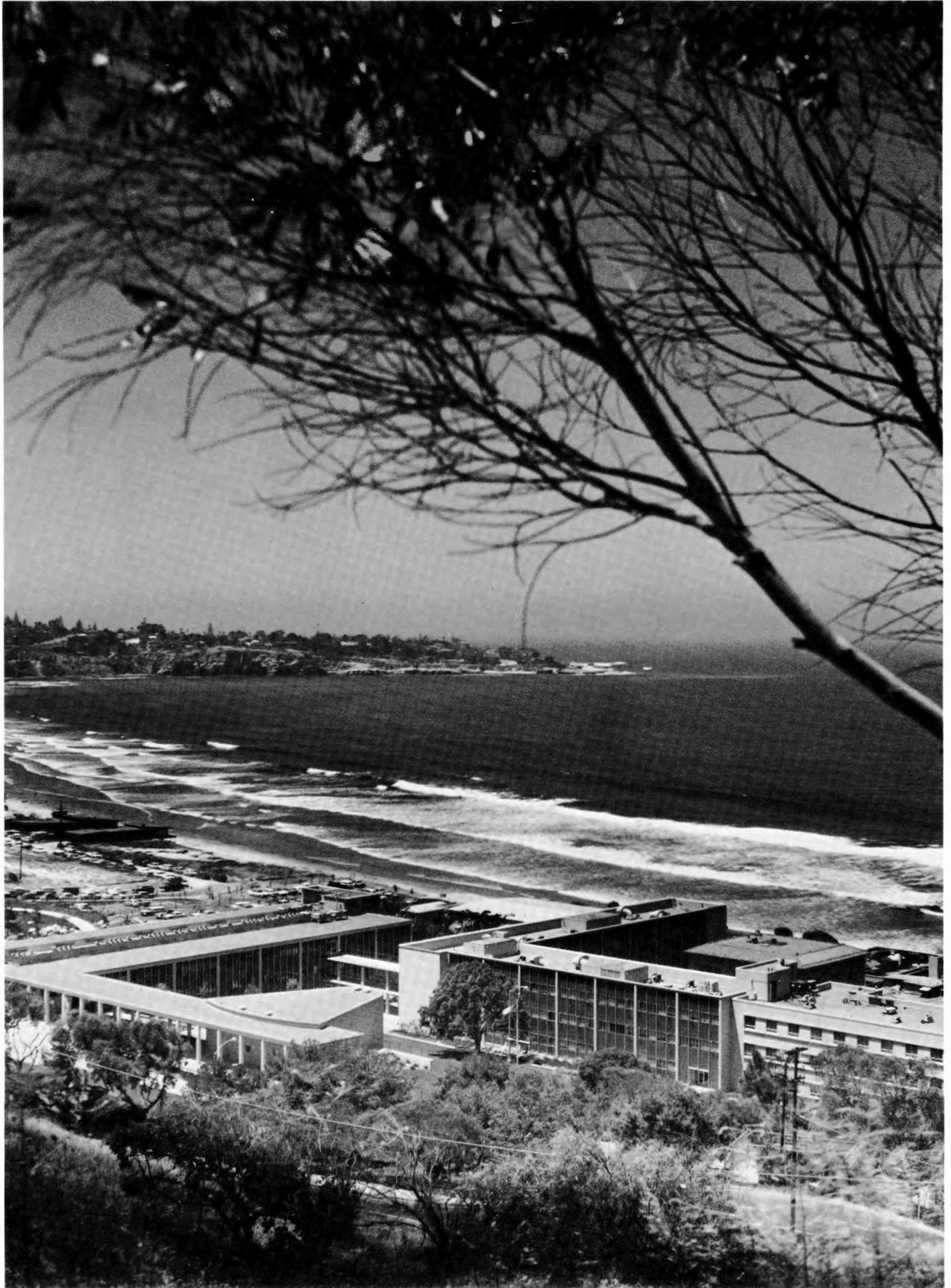
	Alexander Agassiz	Argo	Alpha Helix	Horizon	Oconostota	Ellen B. Scripps	Thomas Washington	T-441	ST-908	FLIP
Type:	light freight	rescue and salvage	oceanographic research (biological)	tug	tug	off-shore supply	oceanographic research	cargo and passenger	harbor tug	floating instrument platform
Hull:	steel	steel	steel	steel	steel	steel	steel	steel	steel	steel
Year Built:	1944	1944	1965-1966	1944	1944	1964-1965	1965	1953	1945	1962
Year acquired by SIO:	1961	1959	1966	1948	1962	1965	1965	1955	1961	1962
From whom acquired:	State Educational Agency for Surplus Property	U. S. Navy	National Science Foundation	U. S. Navy	U. S. Navy	Dantzier Boat and Barge Co.	U. S. Navy	U. S. Navy	U. S. Army	Gunderson Bros. Shipbuilding Co.
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	University of California	U. S. Navy
Length:	180'	213'	133'	143'	102'	95'	209'	65'	45'	355'
Beam:	32'	40'	31'	33'	25'	24'	40'	18'	12'5¾"	20/12'
Draft:	10'	15'1"	10'5½"	13'6"	10'	6'	14'	6'	5'1"	10'/300'
Displacement tons (full):	825	2,079	512	900	206	115	1,362	99	28	2,100 (vertical)
Cruising speed:	11	13	11	11½	12	11	11	10½	7	varies ⁻¹
Maximum speed:	12	14	12	12½	12	12	12	11	8	varies ⁻¹
Minimum speed:	3	½	3	½	½	3	½	3	2	varies ⁻¹
Range (miles):	7,700	8,000	6,200	6,800	6,000	4,700	8,000	1,830	655	varies ⁻¹
Endurance (days):	27	60	24	48	25	17	48	5	1	varies ⁻¹
Crew:	17	32	12	19	8	5	25	—	1	6
Scientific party:	14	24	10	16	6	8	16	9 ⁻²	4	8

⁻¹ Depends on towing vessel

⁻² Including crew

1967-1968 TOTAL DAYS AT SEA: 1,474

1967-1968 NAUTICAL MILES STEAMED: 169,472



APPENDIX E

DOCTOR OF PHILOSOPHY DEGREES
AWARDED IN 1967-68,
WITH TITLES OF DISSERTATIONS

EARTH SCIENCES

Norman G. Banks, "Geology and Geochemistry of the Leadville Limestone (Mississippian, Colorado) and Its Diagenetic, Supergene, Hydrothermal and Metamorphic Derivatives."

John R. Booker, "Geomagnetic Secular Variation and the Kinematics of the Earth's Core."

Yan Bottinga, "Isotopic Fractionation in the System: Calcite-Graphite-Carbon Dioxide-Methane-Hydrogen-Water."

Herbert Windom, "Atmospheric Dust Records in Glacial Snow Fields: Implications to Marine Sedimentation."

MARINE BIOLOGY

Brian G. D'Aoust, "'Anaerobic' Glycolysis Under Hyperbaric Oxygen in the Gas Gland of the Vermillion Rockfish, *Sebastes miniatus*."

Everett L. Douglas, "Studies on Gas Secretion in the Swim Bladder of Fishes."

Frank J. Hester, "Visual Contrast Thresholds of the Goldfish, *Carassius auratus*."

Karl P. Kuchnow, "Tapetal-Pigment Response of Elasmobranchs."

David L. Leighton, "A Comparative Study of Food Selection and Nutrition in the Abalone *Haliotis rufescens* Swainson, and the Sea Urchin *Strongylocentrotus purpuratus* (Stimpson)."

Rabindra Prasad, "Studies on Enzymatic Hydrolysis of Glycerophosphoryl Esters."

Vann Elliott Smith, "Comparative Cytology and Biochemistry of Two Marine Sponges."

OCEANOGRAPHY

Thomas A. Clarke, "Territorial Behavior and Population Dynamics of the Garibaldi, *Hypsypops rubicunda* (Girard), Pisces: Pomacentridae."

Robert L. Zalkan, "Observation of High Frequency Internal Waves in the Pacific Ocean."

MASTER OF SCIENCE DEGREES
AWARDED IN 1967-68

EARTH SCIENCES

Christian E. Abranson

MARINE BIOLOGY

Jean A. Brenchley

Hillil Gordin

Charles F. Phleger

Janet E. Preslan

Martin G. Sattler

Barbara A. Symroski

OCEANOGRAPHY

Philip A. Rasmussen

APPENDIX F

AMAZON EXPEDITION PARTICIPANTS

David J. Aidley	Oxford University, Oxford, England
David W. Allen	Duke University, Durham, North Carolina
Paulo de T. Alvim	Centro de Pésquisas do Cacau, Itábuna, Bahia, Brazil
A. A. Auerbach	College of Physicians and Surgeons, Columbia University, New York
Metry Bacilla	University of São Paulo, Brazil
D. E. Barcus	University of California, Los Angeles
Robert S. Bandurski	Michigan State University, East Lansing, Michigan
Djalma Batista	Instituto Nacional de Pésquisas de Amazonia, Manaus, Brazil
Denis Bellamy	The University, Sheffield, England
M. V. L. Bennett	College of Physicians and Surgeons, Columbia University, New York
Andrew A. Benson	Scripps Institution of Oceanography
Allan Berlind	Harvard University, Cambridge, Massachusetts
Jacob B. Biale	University of California, Los Angeles
Theodore H. Bullock	University of California, San Diego
M. Cavalcanti	University of Rio de Janeiro, Brazil
Paulo Cavaleanti	Museu Goeldi, Manaus, Brazil
Luiz Coelho	Instituto Nacional de Pésquisas de Amazonia, Manaus, Brazil
Leopoldo Magno Coutinho	University of São Paulo, Brazil
A. C. da Silva	São Paulo Medical School, Brazil
D. Días	University of Rio de Janeiro, Brazil
Per S. Enger	University of Oslo, Norway
Walter Garey	Scripps Institution of Oceanography
Malcolm S. Gordon	University of California, Los Angeles
H. T. Hammel	Yale University, New Haven, Connecticut
Alan R. Hargens	Scripps Institution of Oceanography
Peter H. Hartline	University of California, San Diego

Peter W. Hochachka	University of British Columbia, Vancouver	Hebe L. Martelli	University of Brazil, Rio de Janeiro
Bo Holmstedt	Karolinska Institute, Stockholm, Sweden	A. W. Matheis	Los Angeles County General Hospital
Mañuel L. Ibanéz	Louisiana State University, Baton Rouge	Stanley L. Miller	University of California, San Diego
Kjell Johansen	Friday Harbor Laboratory, Oslo, Norway	Vicente Moraes	Instituto de Pésquisas Experi- mentáso Agropecuárias do Norte, Belem, Brazil
L. C. Junqueira	University of São Paulo, Brazil	Kenneth S. Norris	University of California, Los Angeles
Fotis C. Kafatos	Harvard University, Cambridge, Massachusetts	F. C. Novaes	Museu Goeldi, Manaus, Brazil
John Kanwisher	Woods Hole Oceanographic Institution, Massachusetts	Vicente Nuñez	Instituto de Pésquisas Experi- mentáso Agropecuárias do Norte, Belem, Brazil
Alexei P. Kusnetzov	Institute of Oceanology, Academy of Sciences of the USSR, Moscow	Yoshika Oniki	Instituto de Pésquisas Experi- mentáso Agropecuárias do Norte, Belem, Brazil
Antonio Lamberti	University of São Paulo, Brazil	M. de Oliveira Pérez	Instituto de Pésquisas de Marinha, Rio de Janiero
Claude Lenfant	Firland Sanatorium, Seattle, Washington	Jorge Petersen	University of São Paulo, Brazil
Donald B. Lindsley	University of California, Los Angeles	P. J. Peterson	Plant Chemistry Division, D.S.I.R., Palmerston North, New Zealand
Robert B. Livingston	University of California, San Diego	Robert W. Piddington	Scripps Institution of Oceanography
R. S. Loomis	University of California, Davis	Murca Pires	Instituto de Pésquisas Experi- mentáso Agropecuárias do Norte, Belem, Brazil
Thom McManus	Duke University, Durham, North Carolina		
Brian K. McNab	University of São Paulo, Brazil		
John Machin	University of Toronto, Canada		
Hubert Markl	Zoologisches Institut Universität Frankfurt a. M., Germany		



Shore camp for the Amazon Expedition provided supplemental living space and laboratory facilities.

David Prescott	University of Colorado, Boulder, Colorado	John M. Teal	Woods Hole Oceanographic Institution, Massachusetts
Hermann Rahn	State University of New York, Buffalo, New York	William H. Telfer	University of Pennsylvania, Philadelphia, Pennsylvania
William A. Rodrigues	Instituto Nacional de Pésquisas de Amazonia, Manaus, Brazil	Terrence Thomas	Institute of Geophysics and Planetary Physics, University of California, Los Angeles
Richard H. Rosenblatt	Scripps Institution of Oceanography	R. M. Tinoco	Instituto de Pésquisas de Marinha, Brazil
Louis M. Roth	U. S. Army Natick Laboratories, Natick, Massachusetts	Eberhard G. Trams	National Institutes of Health, Bethesda, Maryland
Robert F. Sahara	University of California, Los Angeles	S. N. Turitzin	University of Pennsylvania, Philadelphia, Pennsylvania
Paulo Sawaya	University of São Paulo, Brazil	Harold Ungemach	Instituto Nacional de Pésquisas de Amazonia, Manaus, Brazil
Knut Schmidt-Nielsen	Duke University, Durham, North Carolina	Manuel M. Ventura	Instituto de Química, University of Cear, Fortáleza, Brazil
Per F. Scholander	Scripps Institution of Oceanography	G. Villéla	Instituto Oswaldo Cruz, Rio de Janeiro, Brazil
Richard E. Schultes	Harvard University, Cambridge, Massachusetts	Stuart Warren	Hastings Infectious Disease Laboratory, Los Angeles, California
Edward Shallenberger	University of California, Los Angeles	Frits W. Went	Desert Research Institute, University of Nevada, Reno
Nellie Stark	Desert Research Institute, University of Nevada, Reno	Carroll M. Williams	Harvard University, Cambridge, Massachusetts
Johan B. Steen	University of Oslo, Norway	W. A. Williams	University of California, Davis
A. B. Steinbach	The Rockefeller Institute, New York	Fred N. White	University of California, Los Angeles
Nobuo Suga	University of California, San Diego		
Thomas Szabo	Centre National de Recherche, Scientifique, Paris, France		



(Photo courtesy of Physiological Research Laboratory)

R/V Alpha Helix docked at Manaus, Brazil, during Amazon Expedition.

APPENDIX G

REGENTS EX OFFICIO

Ronald Reagan
Governor of California and President of The Regents
Edward Reinecke
Lieutenant Governor of California
Robert T. Monagan
Speaker of the Assembly
Max Rafferty
State Superintendent of Public Instruction
Allan Grant
President of the State Board of Agriculture
Joseph A. Moore, Jr.
President of the Mechanics' Institute
Roger C. Pettitt
President of the Alumni Association of the University of California
Charles J. Hitch
President of the University

APPOINTED REGENTS

Edwin W. Pauley
Edward W. Carter
Mrs. Randolph A. Hearst
John E. Canaday
Philip L. Boyd
Norton Simon
William E. Forbes
William M. Roth
Mrs. Edward H. Heller
Frederick G. Dutton
William K. Coblentz
DeWitt A. Higgs
W. Glenn Campbell
William French Smith
Robert O. Reynolds
Dean A. Watkins

PRINCIPAL OFFICERS OF THE REGENTS

Ronald Reagan
Governor of California, President
DeWitt A. Higgs
Chairman
Mrs. Edward H. Heller
Vice Chairman
Thomas J. Cunningham
General Counsel
Robert M. Underhill
Treasurer, Emeritus
Owsley B. Hammond
Treasurer
Miss Marjorie J. Woolman
Secretary

ADMINISTRATIVE OFFICERS—UNIVERSITY-WIDE

Charles J. Hitch
President of the University
John W. Oswald (Effective September 1, 1968)
Executive Vice President
Angus E. Taylor
Vice President—Academic Affairs
Earl C. Bolton
Vice President—Administration
James B. Kendrick, Jr.
Vice President—Agricultural Sciences
Graeme C. Bannerman
Vice President—Business and Finance
Frank L. Kidner
Vice President—Educational Relations
Elmo R. Morgan
Vice President—Physical Planning and Construction
Frederick E. Balderston
Vice President—Planning and Analysis
Travis Cross
Vice President—University Relations
Edward B. Roessler (Acting)
Dean of University Extension

UNIVERSITY-WIDE 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
Harry R. Wellman
Vice President of the University, Emeritus (Effective September 1, 1968)
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
Charles E. Young
Chancellor at Los Angeles
Ivan H. Hinderaker
Chancellor at Riverside
John S. Galbraith
William J. McGill (Effective August 1, 1968)
Chancellor at San Diego
Philip R. Lee
Chancellor at San Francisco
Vernon I. Cheadle
Chancellor at Santa Barbara
Dean E. McHenry
Chancellor at Santa Cruz



(Photo courtesy of Glasbeen Graphics)



**SCRIPPS INSTITUTION OF OCEANOGRAPHY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
P. O. BOX 109, LA JOLLA, CALIFORNIA 92037**