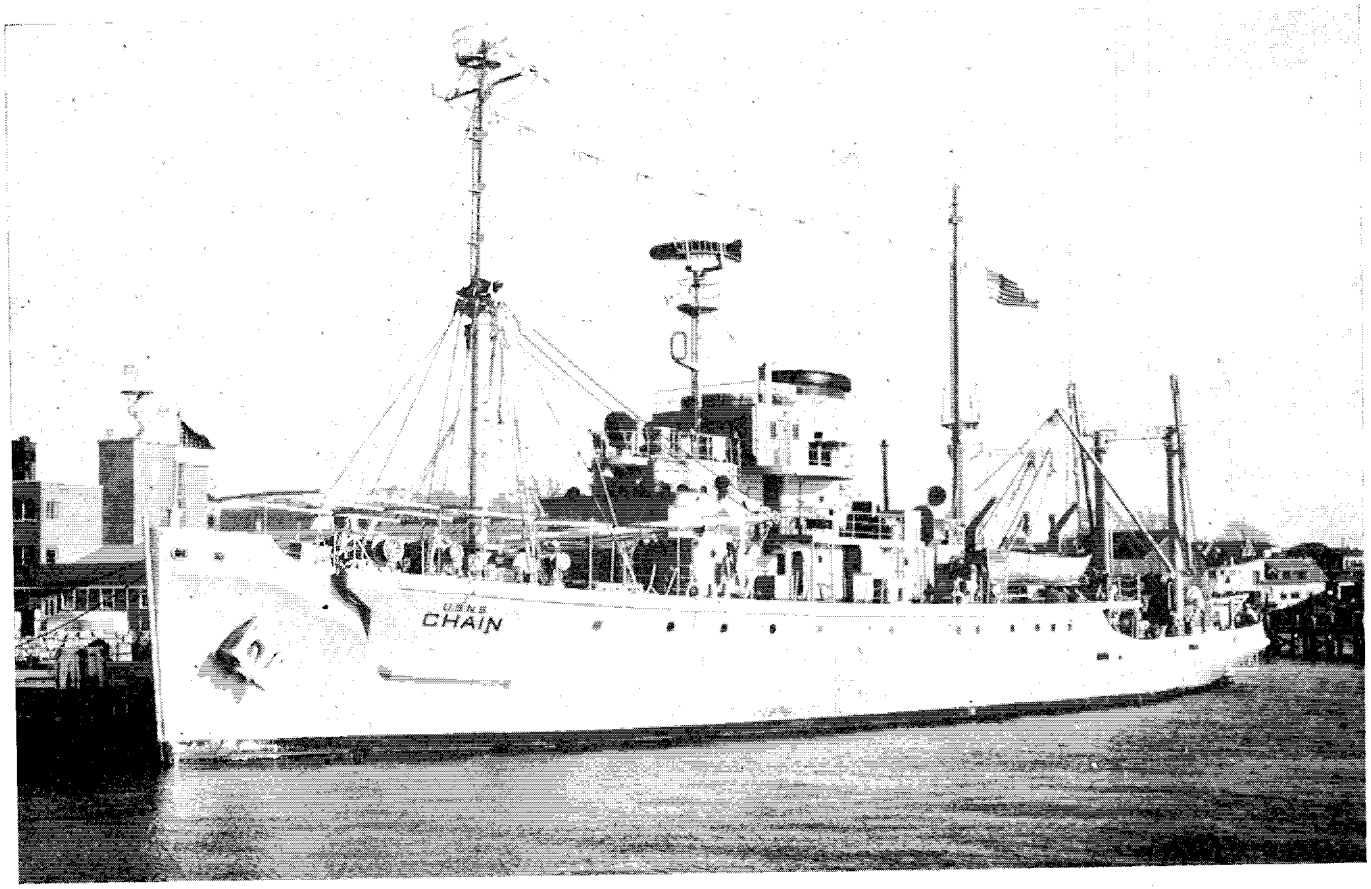
THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1958

1959



THE NEW RESEARCH VESSEL "CHAIN"

TABLE OF CONTENTS

I. TRUSTEES

(as of December 31, 1958)

Honorary Trustees

HENRY B. BIGELOW, Museum of Comparative Zoology, Cambridge 38, Mass.
L. O. COLBERT, 4408 29th Street, N.W., Washington, D. C.
MARION EPPLEY, 510 Park Avenue, New York, N. Y.
ALEXANDER FORBES, 610 Harland Street, Milton, Mass.
HORACE S. FORD, 77 Massachusetts Avenue, Cambridge 39, Mass.
ARNAUD C. MARTS, 521 Fifth Avenue, New York, N. Y.
LAWRASON RIGGS, Riggs, Ferris and Geer, Room 1201, 74 Trinity Place, New York 6, N. Y.
HENRY L. SHATTUCK, 10 Milk Street, Boston, Mass.
SELMAN A. WAKSMAN, Institute of Microbiology, Rutgers University, New Brunswick, N. J.

To serve until 1962

CHARLES FRANCIS ADAMS, Raytheon Manufacturing Company, 138 River Street, Waltham 54, Mass.
COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.
AUGUSTUS P. LORING, Loring, Walcott Office, Inc., 35 Congress Street, Boston, Mass.
ALBERT E. PARR, American Museum of Natural History, Central Park West at 79th Street, New York, N. Y.
ATHELSTAN F. SPILHAUS, Institute of Technology, University of Minnesota, Minneapolis 14, Minn.
ALFRED M. WILSON, Minneapolis-Honeywell Regulator Co., 2747 4th Avenue, South, Minneapolis 8, Minn.

To serve until 1961

HARVEY BROOKS, Division of Applied Science, Harvard University, Cambridge 38, Mass.
FRANK A. HOWARD, 30 Rockefeller Plaza, New York, N. Y.
ROBERT R. SHROCK, Department of Geology and Geophysics, Massachusetts Institute of Technology, Cambridge 39, Mass.
EDWARD H. SMITH, Woods Hole, Mass.
RAYMOND STEVENS, c/o Arthur D. Little, Inc., 30 Memorial Drive, Cambridge 42, Mass.
E. BRIGHT WILSON, JR., Department of Chemistry, Harvard University, Cambridge 38, Mass.

To serve until 1960

DETLEV W. BRONK, The Rockefeller Institute of Medical Research, 66th Street and York Avenue, New York 21, N. Y.
NOEL B. MCLEAN, Edo Corporation, College Point 56, N. Y.
DANIEL MERRIMAN, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.
EMANUEL R. PIORE, International Business Machines Corp., 590 Madison Avenue, New York 22, N. Y.
ALFRED C. REDFIELD, Woods Hole Oceanographic Institution, Woods Hole, Mass.
GERARD SWOPE, JR., c/o International General Electric Co., 570 Lexington Avenue, New York, N. Y.

To serve until 1959

J. S. COLES, Bowdoin College, Brunswick, Maine
CARL H. ECKART, Scripps Institution of Oceanography, La Jolla, Calif.
ROSS G. HARRISON, Osborn Zoological Laboratory, Yale University, New Haven, Conn.
MILFORD R. LAWRENCE, Siders Pond Road, Falmouth, Mass.
HARLOW SHAPLEY, Sharon Cross Road, Peterborough, N. H.
FRANCIS C. WELCH, 73 Tremont Street, Boston, Mass.

Ex Officio

EDWIN D. BROOKS, JR., P.O. Box 1135, Boston 3, Mass.
MARY SEARS, Woods Hole Oceanographic Institution, Woods Hole, Mass.
PAUL M. FYE, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Officers

RAYMOND STEVENS, President of the Corporation, c/o Arthur D. Little, Inc., 30 Memorial Drive, Cambridge 42, Mass.
HENRY B. BIGELOW, Chairman of the Board of Trustees, Museum of Comparative Zoology, Cambridge 38, Mass.
EDWIN D. BROOKS, JR., Treasurer, P.O. Box 1135, Boston 3, Mass.
MARY SEARS, Clerk of the Corporation, Woods Hole Oceanographic Institution, Woods Hole, Mass.

II. MEMBERS OF THE CORPORATION

CHARLES FRANCIS ADAMS, Raytheon Manufacturing Company, 138 River Street, Waltham 54, Mass.

OLIVER AMES, III, "Edgewater", Beverly Farms, Mass.

PHILIP ARMSTRONG, Medical Center of Syracuse, State University of New York, Syracuse, N. Y.

ERIC G. BALL, Harvard Medical School, Shattuck Street, Boston, Mass.

HENRY B. BIGELOW, Museum of Comparative Zoology, Cambridge 38, Mass.

LINDSAY BRADFORD, 215 East 72nd Street, New York, N. Y.

DETLEV W. BRONK, The Rockefeller Institute of Medical Research, 66th Street and York Avenue, New York 21, N. Y.

EDWIN D. BROOKS, Jr., P.O. Box 1135, Boston 3, Mass.

HARVEY BROOKS, Division of Applied Science, Harvard University, Cambridge 38, Mass.

C. LLOYD CLAFF, Single Cell Research Foundation, Inc., 5 Van Beal Road, Randolph, Mass.

E. L. COCHRANE, Office of Vice President for Industrial and Governmental Relations, Massachusetts Institute of Technology, Cambridge 39, Mass.

L. O. COLBERT, 4408 29th Street, N.W., Washington, D. C.

KENNETH S. COLE, National Institutes of Health, Bethesda 14, Md.

J. S. COLES, Bowdoin College, Brunswick, Maine

HENRY B. DUPONT, Wilmington, Del.

FERDINAND EBERSTADT, 39 Broadway, New York 6, N. Y.

CARL H. ECKART, Scripps Institution of Oceanography, La Jolla, Calif.

HARRISON P. EDDY, c/o Metcalf & Eddy, 1300 Statler Building, Boston, Mass.

MARION EPPLEY, 510 Park Avenue, New York, N. Y.

ALEXANDER FORBES, 610 Harland Street, Milton, Mass.

HORACE S. FORD, 77 Massachusetts Avenue, Cambridge, Mass.

PAUL M. FYE, Woods Hole Oceanographic Institution, Woods Hole, Mass.

JOHN A. GIFFORD, 14 Wall Street, New York 5, N. Y.

PAUL HAMMOND, 230 Park Avenue, New York 17, N. Y.

ROSS G. HARRISON, Osborn Zoological Laboratory, Yale University, New Haven, Conn.

HUDSON HOAGLAND, Worcester Foundation for Experimental Biology, 222 Maple Avenue, Shrewsbury, Mass.

FRANK A. HOWARD, 30 Rockefeller Plaza, New York, N. Y.

COLUMBUS O'D. ISELIN, Woods Hole Oceanographic Institution, Woods Hole, Mass.

AUGUSTUS B. KINZEL, Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

MILFORD R. LAWRENCE, Siders Pond Road, Falmouth, Mass.

ALFRED L. LOOMIS, Room 2420, 14 Wall Street, New York, N. Y.

AUGUSTUS P. LORING, Loring, Walcott Office, Inc., 35 Congress Street, Boston, Mass.

ARNAUD C. MARTS, 521 Fifth Avenue, New York, N. Y.

ROBERT E. MCCONNELL, First National Bank, Hobe Sound, Fla.

NOEL B. MCLEAN, Edo Corporation, College Point 56, N. Y.

DANIEL MERRIMAN, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.

HENRY S. MORGAN, 2 Wall Street, New York, N. Y.

FRANK A. PACE, General Dynamics Corporation, 445 Park Avenue, New York 22, N. Y.

ALBERT E. PARR, American Museum of Natural History, Central Park West at 79th Street, New York, N. Y.

SUMNER T. PIKE, Lubec, Maine

EMANUEL R. PIORE, International Business Machines Corp., 590 Madison Avenue, New York 22, N. Y.

ALFRED C. REDFIELD, Woods Hole, Mass.
GEORGE H. RICHARDS, 68 William Street, New York, N. Y.
LAWRASON RIGGS, Riggs, Ferris and Geer, Room 1201, 74 Trinity Place, New York 6, N. Y.
FRANCIS C. RYDER, 37 Larchwood Drive, Cambridge 39, Mass.
MARY SEARS, Woods Hole Oceanographic Institution, Woods Hole, Mass.
HARLOW SHAPLEY, Sharon Cross Road, Peterborough, N. H.
HENRY L. SHATTUCK, 10 Milk Street, Boston, Mass.
ROBERT R. SHROCK, Department of Geology and Geophysics, Massachusetts Institute of Technology, Cambridge 39, Mass.
EDWARD H. SMITH, Woods Hole, Mass.
ATHELSTAN F. SPILHAUS, Institute of Technology, University of Minnesota, Minneapolis 14, Minn.
LYMAN SPITZER, JR., Princeton University Observatory, 14 Prospect Ave., Princeton, N. J.
RAYMOND STEVENS, c/o Arthur D. Little, Inc., 30 Memorial Drive, Cambridge 42, Mass.
JULIUS A. STRATTON, Office of the Vice President and Provost, Massachusetts Institute of Technology, Cambridge 39, Mass.
GERALD SWOPE, JR., c/o International General Electric Co., 570 Lexington Avenue, New York, N. Y.
J. H. VAN VLECK, Lyman 332, Harvard University, Cambridge 38, Mass.
SELMAN A. WAKSMAN, Institute of Microbiology, New Brunswick, N. J.
THOMAS J. WATSON, JR., International Business Machines Corporation, 590 Madison Avenue, New York 22, N. Y.
FRANCIS C. WELCH, 73 Tremont Street, Boston, Mass.
ALFRED M. WILSON, Minneapolis-Honeywell Regulator, 2747 4th Avenue, South, Minneapolis 8, Minn.
E. BRIGHT WILSON, JR., Department of Chemistry, Harvard University, Cambridge 38, Mass.

III. RESEARCH STAFF

(As of December 31, 1958)

ARNOLD B. ARONS, Associate in Physical Oceanography.
Professor of Physics, Amherst College.

WILLIAM D. ATHEARN, Research Associate in Geology.

JOHN C. AYERS, Associate in Marine Biology.
Associate Professor, Great Lakes Research Institute, and Associate Professor of Zoology, Department of Zoology, University of Michigan.

RICHARD H. BACKUS, Research Associate in Marine Biology.

JOHN P. BARLOW, Associate in Marine Biology.
Assistant Professor of Oceanography, Cornell University.

LINCOLN BAXTER II, Research Associate in Physics.

DAVID L. BELDING, Associate in Marine Biology.
Professor of Bacteriology and Experimental Pathology (Emeritus), Boston University; Consultant, U. S. Fish & Wildlife Service.

BRUCE BENSON, Associate in Physics.
Associate Professor of Physics, Amherst College.

HENRY B. BIGELOW, Associate in Oceanography.
Professor of Zoology (Emeritus), Harvard University; Research Oceanographer, Museum of Comparative Zoology.

DUNCAN C. BLANCHARD, Research Associate in Meteorology.

BERT BOLIN, Associate in Meteorology.
Director, Institute of Meteorology, University of Stockholm.

VAUGHAN T. BOWEN, Geochemist.
Lecturer in Zoology, Yale University.

ROBERT R. BROCKHURST, Research Associate in Physics.

JOHN G. BRUCE, JR., Research Associate in Oceanography.

DEAN F. BUMPUS, Oceanographer.

ELIZABETH T. BUNCE, Research Associate in Physics.

ANDREW F. BUNKER, Meteorologist.

CORNELIA L. CAREY, Associate in Marine Bacteriology.
Associate Professor of Botany (retired), Barnard College.

CHARLES E. CARVER, JR., Associate in Hydraulics.
Associate Professor of Civil Engineering, University of Massachusetts.

JOSEPH CHASE, Research Associate in Physical Oceanography.

GEORGE L. CLARKE, Marine Biologist.
Associate Professor of Zoology, Harvard University.

NATHANIEL CORWIN, Research Associate in Chemistry.

HERBERT CURL, JR., Research Associate in Marine Biology.

WILLARD DOW, Electronics Engineer.

RICHARD S. EDWARDS, Research Associate in Geophysics.

MAURICE EWING, Associate in Geophysics.
Professor of Geology, Columbia University; Director, Lamont Geological Observatory.

ALAN J. FALLER, Research Associate in Meteorology.

HARLOW G. FARMER, JR., Research Associate in Hydraulics.

CHARLES J. FISH, Associate in Marine Biology.
Professor of Marine Biology, University of Rhode Island; Director, Narragansett Marine Laboratory.

DAVID H. FRANTZ, JR., Research Associate in Engineering.

FREDERICK C. FUGLISTER, Physical Oceanographer.

PAUL M. FYE, Chemist.

MICHAEL GARSTANG, Research Associate in Meteorology.

ROBERT H. GIBBS, JR., Associate in Marine Biology.
Assistant Professor of Biology, Boston University.

JOHN W. GRAHAM, Research Associate in Geology.

DONALD R. GRIFFIN, Associate in Physiology.
Professor of Zoology, Harvard University.

ROBERT R. L. GUILLARD, Research Associate in Marine Biology.

BERNARD J. HAURWITZ, Associate in Meteorology.
Professor of Meteorology and Chairman of the Department of Meteorology and Oceanography, New York University.

EARL E. HAYS, Physicist.

JOHN B. HERSEY, Geophysicist.
Associate Professor of Oceanography, Massachusetts Institute of Technology.

EDWARD M. HULBURT, Research Associate in Marine Biology.

COLUMBUS O'D. ISELIN, Henry Bryant Bigelow Oceanographer.
Associate Professor of Physical Oceanography, Harvard University; Research Oceanographer, Museum of Comparative Zoology.

HENRY R. JOHNSON, Research Associate in Underwater Acoustics.

JOHN W. KANWISHER, Research Associate in Biophysics.

BOSTWICK H. KETCHUM, Senior Oceanographer.

DAVID D. KETCHUM, Research Associate in Electronics.

SYDNEY T. KNOTT, JR., Research Associate in Engineering.

BERNHARD KUMMEL, Associate in Submarine Geology.
Associate Professor of Geology, Harvard University.

RICHARD G. LEAHY, Research Associate in Geology.

BENJAMIN B. LEAVITT, Associate in Marine Biology.
Associate Professor of Biological Sciences, University of Florida.

JOYCE C. LEWIN, Research Associate in Marine Biology.

ROBERT A. LUFBURROW, Associate in Physics.
Assistant Professor of Physics, St. Lawrence University.

JOANNE S. MALKUS, Meteorologist.

WILLEM V. R. MALKUS, Physical Oceanographer.

FRANK J. MATHER III, Research Associate in Oceanography.

JAMES W. MAVOR, JR., Associate in Applied Physics.
Associate Professor of Mechanical Engineering, Northeastern University.

WILLIAM G. METCALF, Physical Oceanographer.

ARTHUR R. MILLER, Physical Oceanographer.

ROBERT L. MILLER, Associate in Submarine Geology.
Associate Professor in Qualitative Sedimentology, The University of Chicago.

RAYMOND B. MONTGOMERY, Associate in Physical Oceanography.
Associate Professor of Oceanography, Chesapeake Bay Institute, The Johns Hopkins University.

HILARY B. MOORE, Associate in Marine Biology.
Professor in Marine Biology and Assistant Director, Marine Laboratory, University of Miami.

JAMES M. MOULTON, Associate in Marine Biology.
Assistant Professor of Biology, Bowdoin College.

JEROME NAMIAS, Associate in Meteorology.
Chief, Extended Forecast Section, U. S. Weather Bureau.

A. CONRAD NEUMANN, Research Associate in Sedimentary Geology.

GEOFFREY D. NICHOLLS, Associate in Geochemistry.
Lecturer, Department of Geology, University of Manchester, Manchester, England.

DANIEL R. NORTON, Associate in Chemical Oceanography.
Research Chemist, Sprague Electric Co., North Adams, Massachusetts.

CHARLES B. OFFICER, JR., Geophysicist.
Associate Professor of Geology, Rice Institute.

DAVID M. OWEN, Research Associate in Underwater Photography.

MARY ALYS PLUNKETT, Associate in Chemistry.
Associate Professor of Chemistry, Vassar College.

ALFRED C. REDFIELD, Senior Oceanographer (Emeritus).
Professor of Physiology (Emeritus), Harvard University.

CHARLES E. RENN, Associate in Engineering.
Professor of Sanitary Engineering, School of Engineering, The Johns Hopkins University.

FRANCIS A. RICHARDS, Chemical Oceanographer.

WILLIAM S. RICHARDSON, Physical Chemist.

GORDON A. RILEY, Associate in Marine Physiology.
Associate Director, Bingham Oceanographic Laboratory, Yale University.

NATHAN W. RISER, Associate in Marine Biology.
Professor of Zoology, Northeastern University.

HELEN M. ROBERTS, Associate in Mathematics.
Assistant Professor of Mathematics, University of Connecticut.

F. CLAUDE RONNE, Research Associate in Photography.

JOHN H. RYTHER, Marine Biologist.

HOWARD L. SANDERS, Research Associate in Marine Biology.

HAROLD E. SAWYER, Research Engineer.

IRVING I. SCHELL, Associate in Meteorology.
Research Associate, Department of Geology, Tufts University.

WILLIAM E. SCHEVILL, Associate in Oceanography.
Research Associate in Zoology, Museum of Comparative Zoology, Harvard University.

KARL E. SCHLEICHER, Research Associate in Physics.

WILLIAM C. SCHROEDER, Ichthyologist.
Associate Curator of Fishes, Museum of Comparative Zoology, Harvard University.

MARY SEARS, Planktonologist.

RAYMOND SIEVER, Associate in Geology.
Assistant Professor of Geology, Harvard University.

EDWARD H. SMITH, Associate in Oceanography.
Development Office, The Cooper Union for the Advancement of Science and Art.

PAUL FERRIS SMITH, Associate in Physical Oceanography.
Electronics Engineer, Rockefeller Institute for Medical Research.

FLOYD M. SOULE, Associate in Physical Oceanography.
Oceanographer, U. S. Coast Guard.

ALLARD T. SPENCER, Research Associate in Engineering.

ATHELSTAN F. SPILHAUS, Associate in Physical Oceanography.
Dean, Institute of Technology, University of Minnesota.

MELVIN E. STERN, Research Associate in Physics.

HENRY M. STOMMEL, Physical Oceanographer.

EDWARD D. STROUP, Research Associate in Physical Oceanography.

THOMAS T. SUGIHARA, Associate in Geochemistry.
Associate Professor of Chemistry, Clark University.

WILLIAM H. SUTCLIFFE, JR., Associate in Marine Biology.
Director, Bermuda Biological Station for Research, Inc.

PARKER D. TRASK, Associate in Submarine Geology.
Professor of Geological Engineering, University of California.

HARRY J. TURNER, JR., Marine Biologist.
Lecturer in Zoology, University of New Hampshire.

RALPH F. VACCARO, Research Associate in Microbiology.

GEORGE VERONIS, Research Associate in Mathematics.

ALLYN C. VINE, Physical Oceanographer.

GORDON H. VOLKMANN, Research Associate in Physical Oceanography.

WILLIAM S. VON ARX, Physical Oceanographer.
Associate Professor of Oceanography, Massachusetts Institute of Technology.

ARTHUR D. VOORHIS, Research Associate in Physics.

ROBERT G. WALDEN, Research Associate in Electronics.

EDMOND E. WATSON, Associate in Physical Oceanography.
Professor of Physics, Queen's University, Kingston, Ontario.

STANLEY W. WATSON, Research Associate in Bacteriology.

RAYMOND WEXLER, Associate in Meteorology.
Allied Research Associates, Inc., Boston, Massachusetts.

GEOFFREY G. WHITNEY, JR., Research Associate in Physical Oceanography.

ALFRED H. WOODCOCK, Oceanographer.

GEORGE P. WOOLLARD, Associate in Geophysics.
Professor of Engineering Geology and Geophysics, University of Wisconsin.
L. VALENTINE WORTHINGTON, Physical Oceanographer.
CHARLES S. YENTSCH, Research Associate in Marine Biology.
JOHN M. ZEIGLER, Research Associate in Marine Geology.

ADMINISTRATIVE STAFF

PAUL M. FYE	Director
RICHARD G. LEAHY	Assistant to the Director
RONALD A. VEEDER	Assistant to the Director
JOHN MCGILVRAY	Business Manager
JAN HAHN	Public Information
NORMAN T. ALLEN	Administrator
HARVEY MACKILLOP	Controller
JOHN F. PIKE	Port Captain

IV. DIRECTOR'S REPORT

Introduction

This has been an interesting and exciting year in science. The period following the first satellites has been alive with a resurging interest in science and cultural pursuits. The International Geophysical Year has proven to be a huge success and oceanography has shared in this resurgence and these successes.

The Institution's contribution to the I.G.Y. has been outstanding. In all, approximately 1,000 hydrographic stations have been taken during the total period and over 24,000 samples of water obtained for analysis. Staff members have participated in twelve complete sections of the North and South Atlantic Oceans and in four partial crossings east of the Mid-Atlantic Ridge. The I.G.Y. funds helped oceanography weather a difficult financial period and the returns have been rewarding. One of the most important results has been a new high in international cooperation among scientists the world over. Dr. Arnold B. Arons represented the Institution at the I.G.Y. meetings in Moscow in August and Dr. Columbus O'D. Iselin attended the second meeting of the Special Committee for Oceanic Research (SCOR) of the International Council for Scientific Unions in Paris in September. It is sincerely hoped that these evidences of scientific goodwill throughout the world will increase and that this Institution will play an important role in continued international cooperation.

The National Academy of Sciences' Committee on Oceanography headed by Professor Harrison Brown has been holding frequent and energetic meetings throughout the year. Dr. Iselin has represented Woods Hole on this important committee and now reports as the year ends that we can shortly expect to see the first fruits of these endeavors. There has been much talk of expansion in oceanography and of large sums of money to be made available for research in the earth sciences. Actually this year has seen very little real money resulting from these post-Sputnik discussions. The main evidence of improved solvency in oceanography is that, whereas it was impossible in the beginning of the year to prepare a budget, by the year's end a budget for 1959 had been prepared which in almost all respects was based on firm commitments of money. This budget was, however, only ten percent higher than the three million dollars expended during 1958.

In accordance with the Trustees' directive of the last Annual Meeting that the Institution plan for further orderly expansion while maintaining the high excellence of its scientific program, the Director has established committees for the design of new research vessels, for land acquisition, for a building program and an educational policy committee. The need for training of capable young people in marine science is very apparent and the educational

policy committee, although established late in the year, has been most active in reviewing our association with universities, in improving our fellowship program, in providing adequate teaching opportunities for our senior staff and in setting up training courses for the younger members.

The establishment of the Carl-Gustaf Rossby Memorial Fellowship by the Executive Committee in October is considered a fitting fulfillment of the Trustees' request for an appropriate memorial to our beloved Senior Meteorologist. Preference will be given to applicants interested in those areas of study, sufficiently numerous, which engaged Professor Rossby's own attention. As our contribution to the American Meteorological Society's Rossby Memorial, the Society was invited to name the first Rossby Fellow. Dr. P. M. Saunders of the Imperial College of Science and Technology in England, who will spend a year in Woods Hole working with Dr. Joanne S. Malkus, was selected.

In this, my first Annual Report, perhaps I may be permitted a few personal observations and initial impressions. Seldom, if ever, has a new Director of a research institution been so fortunate as to have available for advice and help all the previous directors. The helpful discussions with Dr. Bigelow, Admiral Smith and Dr. Redfield have been greatly appreciated by me. To have Dr. Iselin as my constant mentor has been a source of strength and a very great personal pleasure. He is filling the Henry Bryant Bigelow Chair of Oceanography with great distinction and continues to be an inspiring leader for all of us.

Although I had spent a little time each year during the past decade in visits to Woods Hole there appear to be a number of noteworthy changes and advances of which I was not wholly aware. The most obvious of these changes, and perhaps the most predictable, has been the introduction of new techniques and new instrumentation. The use of drift buoys and neutrally buoyant floats permitting a recording of data in the absence of an observer, the use of the tow chain permitting the virtually continuous recording of the thermal structure from a vessel underway at speeds up to 12 knots and the use of an airplane as a research vessel from which oceanographic observations are made are examples of such new techniques in physical oceanography.

A second and perhaps more significant change relates to the type of thinking which is being done today. The use of models, particularly in large-scale circulation studies and in wave investigations, and a much greater acceptance of theoretical studies are examples of such changes. The recent successful prediction by theory of the deep-water circulation pattern is perhaps one of the few examples of modern oceanography where theory has preceded experiment. This represents a degree of sophistication not previously available in oceanography and may indicate that we are about to evolve out of the

descriptive phase of the science into one in which the scientific methods will have more application. Finally, the inclusion on the staff of the excellent group engaged in beach studies, marine meteorology, hydrodynamics and theoretical work is undoubtedly the most significant change which has occurred during the past decade.

Today oceanography is occupying an increasingly important place as a major science. A number of the larger industrial companies are seeking assistance in studies involving either operational analysis or the feasibility of developing much improved high-performance weapon systems. Thus there is a sudden demand for the services of experienced physical oceanographers in industry. A course for industry in the "Environmental Factors Influencing the Performance of Naval Weapon Systems" was received with great enthusiasm.

The studies concerning the future of oceanography within the National Academy of Sciences and the Federal Government will undoubtedly bear much fruit. It is commonly assumed by these study groups that oceanography will expand very much in the near future. The only question appears to be how much and by what means. One of the most important decisions the Institution has ever had to make is what role it should play in this expansion. Everyone concedes that we should retain our well-established leadership in the field but it is not yet clear to what extent we should increase the size of our plant and staff. Undoubtedly it does mean increased stature for our staff members regardless of our total size. It is our strong opinion that our destiny should be determined by serious thought and planning in Woods Hole rather than in Washington.

The chief uncertainty at present is just how far-reaching a change will be made in the present method of selecting and supporting the kinds of basic research of interest to the Department of Defense and to the Federal Government in general. No doubt the changes will not go as far as some now hope. It is hoped that the thinking and planning for earth sciences in Washington will be able to keep up with events and to influence research budgets in sufficient time. Moreover, our reputation is such that, to a considerable degree, we should be able to influence the planning.

The health of the Institution appears to be excellent. With oceanographic data being compiled during the I.G.Y. at a rate greater than ever before in the history of the science and with the present excellence and enthusiasm of the staff, we can look to the future with great confidence. I am most happy for the opportunity to have a part in that future.

Physical Oceanography

The Institution's participation in the 1957–58 International Geophysical Year oceanographic program continued and expanded during 1958. This project has been directed by Dr. Columbus O'D. Iselin and is proving to have been one of the major contributions to the United States I.G.Y. oceanography program. We again joined with England's National Institute of Oceanography and together we have virtually completed a new systematic survey of the main body of the Atlantic Ocean. The sea-going part of the program would have been finished but for the engine break-down which prevented the ATLANTIS from going to the South Atlantic early in the year. Nevertheless over eight months of ship time were used on this program and an unprecedented number of successful, deep oceanographic stations were occupied during the year. This work, plus the painstaking task of evaluating and checking the data and preparing them for publication, occupied many man-hours of a group of scientists, technicians, secretaries, service personnel and the officers and crews of the CRAWFORD and DISCOVERY II.

In January Mr. Frederick C. Fuglister, after taking part in the second I.G.Y. cruise of the DISCOVERY II, visited the West German Hydrographic Office in Hamburg, the Service Hydrographique de la Marine in Paris and the National Institute of Oceanography in Surrey. In Germany he arranged for Mr. Karl E. Schleicher to take part in the German I.G.Y. survey, aboard the ANTON DOHRN, in Greenland waters during August and September. His visit to Surrey and Paris bore fruit in November when he and Mr. Arthur R. Miller joined the DISCOVERY II on its fourth I.G.Y. cruise. This cruise consisted of an intensive study, in the Bay of Cadiz, of the core of high salinity water flowing out from the Mediterranean Sea. Although the thermohaline data showed steady state conditions over a period of several weeks, observations made by Dr. John C. Swallow with his neutrally buoyant floats revealed the existence of currents that would have been plotted quite differently from a classical interpretation of the data.

Following this cruise, Mr. Fuglister went to the University of Kiel where he had been invited to give a talk on the Atlantic survey. An unusual feature of his talk was the fact that, although he had just left the DISCOVERY II, he was able to show completed temperature, salinity, oxygen and phosphate "profiles" and plots of direct current measurements for the Bay of Cadiz study. This was made possible by use of the newly developed conductivity bridge salinometer.

In June Mr. L. Valentine Worthington completed and distributed a report on the oceanographic data from the first and second I.G.Y. cruises aboard the R.R.S. DISCOVERY II. In August he again went aboard the

British ship to make four sections across the eastern basin of the North Atlantic. After this third I.G.Y. cruise of the DISCOVERY II he spent a month at the National Institute of Oceanography where he completed his joint paper with Dr. Swallow on the undercurrent of the Gulf Stream.

Mr. Worthington also completed a study of the "Eighteen Degree Water in the Sargasso Sea." In this paper he discusses some of the implications of the layer of water which lies at a depth of 300 meters and extends throughout the Sargasso Sea. He points out a parallel between the formation of this water and North Atlantic Deep Water. In both cases the water masses are considered to have been formed on the surface during the winter and to have sunk to their present depth due to increased densities as a result of the period of winter cooling.

Mr. William G. Metcalf spent a considerable portion of 1958 at sea on the I.G.Y. program. During February and March he took the CRAWFORD to the Caribbean Sea where he completed four meridional profiles. On the way to the Caribbean he made a section of oceanographic stations running from Bermuda to Hispaniola. In June Mr. Metcalf completed a report on the oceanographic data from CRAWFORD Cruise 16, obtained for the I.G.Y. during October and November 1957. He ended this busy year by successfully completing transatlantic sections in 24° South latitude and the Equator.

Oceanographic data were obtained from two bases on the ice in the Arctic Ocean for the I.G.Y. by Mr. John S. Farlow III. These observations, which were taken by Mr. Farlow during the fall of 1957 and the spring of 1958, further substantiated the clockwise circulation in the Beaufort eddy which had been postulated earlier by Mr. Worthington.

In addition to the oceanographic data obtained in the Atlantic, a total of 51 stations were occupied in the Mediterranean Sea, Red Sea and Indian Ocean during the summer. These stations were mostly concentrated in the Red Sea and the Straits of Bab-El-Manded connecting the Red Sea to the Gulf of Aden in the Indian Ocean.

A series of five short cruises, one each month from May to September, was made over the continental shelf and slope south of Martha's Vineyard and Nantucket. The purpose of these cruises was the study of the monthly and shorter period variations in the temperature and salinity of the cold wedge of water on the shelf and the transitional region between the coastal and slope water.

Mr. Arthur R. Miller made a study of the oxygen distribution in the Atlantic section of the Southern Ocean where he compared data taken by the METEOR and the DISCOVERY II. He found seasonal and geographical variations that led him to some new ideas on the formation of Antarctic Bottom Water by mixing of the brine from growing sea ice and subsurface water.

Mr. Joseph Chase used data obtained from east coast lightships and weather maps to show some relationships between wind patterns and the movement of water along the coast in the Chesapeake-Hatteras area. In the study of seasonal secular and long-term fluctuations, Mr. Dean F. Bumpus, assisted by Mr. C. Godfrey Day, has continued to compile synoptic temperature and salinity data from lightships, Texas Towers and shore locations along the coast from Maine to Georgia. Summertime intrusions of offshore water along the bottom as the result of offshore wind-driven surface movements along the Virginia and New Jersey coasts, which heretofore were not known to exist, are now commonly observed.

They have continued to study the circulation in the Gulf of Maine throughout the whole year using drift bottles. The effect of the coastal runoff has been observed to have a marked effect on the currents on the northern and western side of the Gulf of Maine. Fortunately, from the standpoint of experimentation, the runoff in 1957 which was much below normal gave way to a runoff much greater than average in 1958. Experiments with radio drift buoys on Georges Bank during the autumn suggest that the southwesterly set commonly observed there, March through July, gives way in the autumn to an easterly drift.

In addition to her duties of maintaining and adding to the WHOI Atlantic thermohaline data collection and keeping up the data tabulations of monthly mean temperatures and salinities, Miss Elizabeth H. Schroeder collaborated with Mr. Henry Stommel, Dr. David Menzel and Dr. W. H. Sutcliffe, Jr., on a paper dealing with the climatic stability of the 18° water at Bermuda. This paper deals with the same water mass as that studied by Mr. Worthington but concentrates its attention on observations made in the vicinity of Bermuda.

During May and June Dr. William S. von Arx, Mr. Bumpus and Mr. Day used the CRAWFORD to make 119 consecutive sections of the Gulf Stream off the coast of North Carolina as part of a second attempt to measure the short-period variations of the position and structure of the current. While the series of transverse sections was being made with the ship, the longitudinal changes were being plotted from the R4D aircraft by Dr. William S. Richardson and Mr. Charles H. Wilkins both visually and with the aid of the airborne radiation thermometer. These new data cover a period of one lunar month and give evidence that the Gulf Stream is moved bodily on and off the coast with the rise and fall of the local tide as well as possibly being pulsed by the tides in the Gulf of Mexico. The current was observed to change its regime of motion every seven and every fourteen days.

In the period from late August through the end of the year Dr. von Arx served as a member of the staff of the University Committee for Atmospheric

Research concerned with the preparation of plans for a National Institute for Atmospheric Research. This study was made at the suggestion of the Committee on Atmospheric Research of the National Academy of Sciences and sponsored by the National Science Foundation as part of an effort to facilitate research in the atmospheric and oceanographic phases of earth science.

During this year the last two of the four planned salinometers were completed by Mr. Karl E. Schleicher and Mr. Alvin L. Bradshaw. All four salinometers are available for active duty and the first instrument is now used to do all routine shore-based analyses at the Institution formerly done by Knudsen titration.

An attempt was also made to resolve the question of the accuracy of Copenhagen normal water as a sea-water conductivity standard by sending samples of this water to the Bureau of Standards for specific conductance determination and comparing these results with those of previous determinations on sea water. There was agreement within the experimental uncertainty of the comparison.

Mr. Schleicher was a guest aboard the German vessel ANTON DOHRN for a two months' cruise in the waters southwest of Iceland. One of the salinometers was used on this cruise to analyze the 3,000 salinity samples obtained. As a result of this trip the Germans have shown great interest in the instrument and are planning to build one of their own. As the September meeting of the Bureau du Conseil International pour L'Exploration de la Mer in Copenhagen a paper on the salinometer was read and a very encouraging amount of interest was demonstrated by the members of the Hydrographical Subcommittee. Personnel from the Lamont Geological Observatory were trained in the use of the salinometer and one of the instruments was loaned for the long cruise by the VEMA around the coast of South America.

Theoretical Oceanography

Dr. Allan R. Robinson and Mr. Henry M. Stommel have worked out a theoretical model of the oceanic thermocline and the associated thermohaline circulation. Previously, the only theories of oceanic circulation which had been reduced to a mathematical form were ones which attributed the cause of circulation to the prevailing wind systems. Now it is possible to compute various features of the circulation determined by the unequal heating of the ocean at the equator and poles; and for the first time we have a theoretical basis for explaining the vertical distribution of properties in the ocean.

Earlier in the year Mr. Stommel and Dr. Arnold B. Arons worked on the development of a theoretical model for the abyssal circulation which would

take into account the effects of lateral mixing and permit the extension of the original simpler theory to cover the observed distributions of temperature, salinity and oxygen in the deep water.

Dr. Arons spent a sabbatical year at the Institute of Meteorology of the University of Stockholm. During this period he continued his collaboration with Mr. Stommel on the development of a theoretical model of the abyssal circulation of the world ocean. He was also able to complete some interesting work on flows induced by source and sink distributions in a rotating tank. These studies, which were initiated by the theoretical group in Woods Hole in 1957, have provided experimental insight and verification of theoretical considerations which underlie the present concept of abyssal circulation.

Dr. George Veronis worked on an analysis of the finite amplitude behavior of a rotating fluid which is heated from below and cooled from above. An interesting result of this investigation is that the non-linear interactions of the fluid tend to offset the effects of the constraint of the imposed rotation. This result is of considerable interest in planetary flow problems where the rotational constraint is the principal mechanistic constraint which governs the flow. A generalization of this result is that the dual role of viscosity, viz., as an energy releasing mechanism, as well as the more familiar dissipative mechanism, is a necessary condition for the fluid to become unstable to finite amplitude disturbances before it becomes unstable to infinitesimal perturbations.

Dr. Alan J. Faller returned in June after a stimulating nine months at the Hydrodynamics Laboratory of the University of Chicago and resumed his experimental studies of simple analogues of the ocean circulation. While the circulations produced in these experiments resemble the features of the large-scale ocean currents to a remarkable degree they are of more general hydrodynamic interest and have been compared with secondary flows in curved pipes. Some new thermal-circulation experiments have been initiated in collaboration with Dr. Robinson, a WHOI Fellow at Harvard University, to test his theoretical predictions of thermal circulations in rotating systems.

Dr. Melvin Stern made use of the rotating apparatus to test his non-linear mathematical theory for the decay of the relative circulation when there is an abrupt change in the rate of rotation of a tank of water. During these experiments some interesting instabilities of the flow were evident and plans are being made to investigate these instabilities under more controlled conditions on the very large floating turntable built by Dr. von Arx.

A new member of our staff is Dr. Kirk Bryan, Jr., who joined us in August after spending a year in Sweden on a Swedish-American Fellowship. In order to study the instabilities of large-scale atmospheric circulations Dr.

Bryan has built a small temporary rotating table and uses two fluids of different density to simulate the thermal structure of the atmosphere.

Dr. Willem V. R. Malkus has been involved in a variety of projects which include a theoretical study on magneto-convection of a conducting fluid heated steadily from below and studies on thermal turbulence and investigations with Dr. Veronis on electro-convective processes in dielectric fluids. Experimental or observational confirmation of some of this work has already been achieved.

In theoretical and experimental work on electro-convection it is possible to deal with convective cells and transitions from one regime of flow to another under easily controlled and precisely measurable conditions. Aside from the fact that these flows are interesting in themselves, there also exists a direct analogy between such systems and the thermally convective ones which are of basic interest in meteorology and oceanography. For example, the electric potential is the analogue of temperature, electric current of heat flow, and the superposition of a magnetic field imposes forces which are analogous to Coriolis forces.

The work of the theoretical group at Woods Hole is becoming recognized as outstanding throughout several related areas of science. For example, the theory of turbulence set forth by Dr. Malkus over recent years is a significant fundamental contribution to the understanding of all flow processes and will undoubtedly prove of great value in oceanography, meterology and astronomy. The explanation of vertical temperature distribution in the ocean and the model for abyssal circulation by Mr. Stommel and others are conceptual developments that have proven to be immensely stimulating to physical oceanographers. The contributions to an understanding of non-linear phenomena are of far-reaching importance and can be expected to contribute immeasurably to the theoretical understanding of natural phenomenon. Over the past three years an inspiring series of colloquia have been held jointly with the Meterology Department of the Massachusetts Institute of Technology and have proven to be a source of stimulation for all concerned.

Marine Meteorology

The instrumentation of the Institution's R4D airplane was continued throughout the year and two flights were made to the Caribbean area in February and November to study turbulence, heat and water vapor flux and the effects of clouds upon the flux in the environment. Net radiation measurements were made at various altitudes in the trades by an airborne radiometer designed by Mr. David B. Clarke.

The turbulence and heat flux data reduction problem has been eased with the development of a vertical velocity computer by Mr. Andrew F.

Bunker for use in the aircraft and by programming these data for the Arthur D. Little, Inc., "Datatron" computer. These steps have reduced reduction time by a factor of eighty.

The relation of the vertical flux of heat in the air-to-air stability, the relative importance of the water vapor flux and the interpretation of these measurements as obtained from the field data are discussed by Mr. Bunker in a paper that has been submitted for publication.

The results of a 1957 CRAWFORD cruise were reported by Mr. Michael Garstang. This expedition brought back the first documentation of an early-stage tropical vortex in the low latitudes (5° N), unhampered by land effects. Many of the computations described in the report were not previously possible.

The analysis of the cloud films obtained by Dr. Joanne S. Malkus and Mr. F. Claude Ronne in flights over the Pacific Ocean in MATS Globemaster aircraft during the summer of 1957 progresses well. This work is being done in conjunction with Professor Herbert Riehl and associates of the University of Chicago who are carrying out an intensive synoptic study of the period investigated. Several exciting results have emerged, among them being (1) the controlling role on cumulus structure played by the large-scale flow patterns and (2) the degree of organization of oceanic cumulus clouds into lines, particularly in convergent regions.

Dr. Malkus has also been working with Dr. Riehl on a problem concerning the dynamics and energetics of the hurricane rain area and the question of how latent heat is released to establish the pressure gradients which maintain the flow against friction and maintain winds of hurricane strength.

Mr. Joseph Levine has evolved recently a theoretical model described in a paper entitled "Spherical Vortex Theory of Bubble-like Motion in Cumulus Clouds" which mathematically predicts bubble behavior (cumulus convection) under given conditions. Dr. Malkus has extended this model to hurricane clouds and with data furnished by the National Hurricane Research Project (West Palm Beach, Florida) has developed theoretical models of hurricane cumulonimbus convection. These cloud towers play a major role in the mass and heat budget of the storm and are vital in maintaining its pressure gradients. The accumulated work of this group under Dr. Malkus has resulted in a greatly improved understanding of hurricane formation and maintenance.

Work on the salt nuclei project has proceeded during 1958 with Mr. Alfred H. Woodcock, Mr. Duncan C. Blanchard and Mr. Allard T. Spencer being engaged in various phases of the study. Mr. Blanchard, who recently returned from M.I.T. where he has completed his course work for a doctor-

ate in meteorology, spent the summer months in the laboratory attempting to determine if the composition of droplets as they are initially ejected by bubbles bursting at a sea-water surface is identical to the composition of sea water. During the fall he began his present study of the origin of the charge which he had previously found on droplets ejected by bursting bubbles.

Mr. Woodcock and Mr. Spencer made two field trips with Mr. Bunker during the spring and fall on the R4D aircraft to the West Indian area. Their purpose was to add to our information on the distribution of salt particles as a function of altitude and wind force. The airborne flame photometer was used in testing some ideas about the effects of trade-wind cumulus clouds upon aerosol concentrations. The need for detailed exploration of the sea-salt load of the air in and around clouds originated from the idea that high concentrations of salt will significantly alter the humidity at which latent heat is released within masses of salt-laden air.

Mr. Spencer used most of his time in an attack upon the instrumental problems associated with the use of the flame spectophotometer within clouds. An effort to achieve a full recorder response to the great short-duration differences in signal strength from the photo-multiplier led to a modified approach to the problem of measuring the weight of sodium in cloud droplets and the number of these sodium-bearing droplets.

Mr. Woodcock expanded further his extensive data on the distribution of sea-salt particles in the atmosphere in order to learn more about the contribution of these particles to the well-known salt cycle (ocean-atmosphere-continent-ocean), and to explore further the precipitation mechanism in marine cumulus clouds by tracing the salts in the airborne particles to the salts in solution in the rains.

Geophysics, Underwater Acoustics and Geology

The year 1958 was a sea-going year for the underwater acoustics and geophysics group at the Institution. The Coast Guard Cutter YAMACRAW worked in the Gulf of Mexico during January and February, south of Cuba during April and in the Mediterranean from June to September. The YAMACRAW then made her last cruise for Woods Hole in October to the Tongue of the Ocean, returning to Savannah, Georgia, where all laboratory equipment was transferred to USNS CHAIN. The CHAIN's first cruise was from Savannah to Woods Hole in November making observations on the Blake Plateau en route. A December cruise of the CHAIN to Bermuda and return was shared with Dr. Ketchum's group to complete the year's cruises for the YAMACRAW and the CHAIN.

The ATLANTIS made an extended cruise to the Indian Ocean, the Red

Sea, and worked in the Mediterranean with the YAMACRAW and the VEMA of the Lamont Geological Observatory.

The BEAR was used by the group for a two-week cruise on the shelf of Long Island in August and made numerous short cruises near Woods Hole.

R/V ASTERIAS was used on many local cruises and also made several cruises to the Gulf of Maine for ambient noise studies.

The underwater acoustics work, headed by Dr. J. B. Hersey and Dr. Earl E. Hays, is providing a better understanding of sound propagation in the oceans by studying the effects of the water temperature structure, bottom topography and other associated features on sound transmission. Such studies were pursued on all these major cruises which are described in more detail below.

Dr. Hays led the two cruises to the Gulf of Mexico and Caribbean Sea which had the principal objectives of studying the relationship between sound transmission and the horizontal and vertical sound velocity variations in the ocean and in testing and making shallow temperature measurements with the new thermistor chain. The chain towed very successfully, but somewhat more time and effort were required to fit it to the winch than had been anticipated.

The four month cruise of the YAMACRAW in the North Atlantic and western Mediterranean Sea had a program of bathymetric, thermometric, acoustic and seismic measurements. Chief scientists for different portions of the trip were Drs. Hersey, Backus, Hays and Mr. Allyn C. Vine. Members of the scientific party included nine summer student employees. Introductory classes in oceanography were conducted daily for these students during the first Atlantic crossing. Later the party on the YAMACRAW worked with the ATLANTIS and the VEMA while they were returning from a cooperative cruise in the Indian Ocean and Red Sea.

On the westward passage of the Strait of Gibraltar, Mr. Roberto Frassetto of Hudson Laboratories, Columbia University, joined the ship to make observations of water exchange over the sill at Gibraltar. Mr. Vine made subsurface current measurements with the parachute drogue technique, but most of the available time was spent in making 78 north-south temperature sections across the straits with the thermistor chain. This operation placed heavy demands on the ship handler because of the confined waters, the heavy east-west traffic and a ship with an effective 600-foot draft. An excellent series of temperature sections spanning several tidal cycles resulted from this work, and we are most appreciative of the efforts of the captain and crew of the YAMACRAW for their considerable contribution to this difficult project. A clearer picture of the water flow between the Mediterranean Sea and the Atlantic Ocean has resulted from this work. A combination of information

from the Precision Graphic Recorder and the thermistor chain indicated that the lower boundary of the scattering layer stayed close to one of the isotherms.

Various staff members had a key role in the ATLANTIS cruise into the Gulf of Aden in the Indian Ocean by way of the Mediterranean and Red Seas. Mr. Thomas R. Stetson took charge of bathymetric measurements from Woods Hole to Suez. Dr. John W. Graham acted as chief scientist on a program of seismic refraction measurements with the VEMA, hydrographic and bathymetric measurements, and bottom photography from Suez to the Gulf of Aden and return. Mr. Richard S. Edwards supervised a program of seismic refraction measurements with the VEMA, sound transmission measurements with the YAMACRAW and continuous bathymetric observations from Suez to Cadiz, Spain. Mr. Jan Hahn supervised a program of bathymetric and bathythermograph measurements between Cadiz and Woods Hole.

During the fall, Dr. Hays supervised the general environmental study of the Tongue of the Ocean, Bahamas. This included bathymetric, temperature and sound-velocity measurements of the water and studies of reflection of sound from the bottom. Interesting observations of large internal waves were made with the continuous temperature recorder. These may have resulted from a hurricane which passed through the area shortly before the measurements were made.

The work with seismic reflection techniques has continued to expand and there has been considerable commercial interest in it as well. In particular Dr. Charles B. Officer, Jr., an Institution Associate and former staff member, applied for permission to use the WHOI "Seismic Profiler" for commercial exploration. Dr. Officer has pursued a vigorous program including surveys along the Gulf Coast, the West Coast, in the Great Lakes, in Nova Scotia, in the Persian Gulf, and off the Nigerian Delta and more recently in Alaska. As part of our agreement with Dr. Officer we will exchange technical improvement and he will report to us the scientific content of his findings.

Our own work with the Seismic Profiler has included completion of the Narragansett Bay survey for the Corps of Engineers, plans for which were reported last year. The field work was carried out by Mr. Don R. Fink and Miss Elizabeth T. Bunce. Mr. Sidney T. Knott, Jr., also made a most interesting series of profiles over the outer part of the continental shelf south of New England last summer, and several of our staff have assisted students in using the Seismic Profiler to help to understand problems of local submarine geology. Both Mr. Fink's and Mr. Knott's work clearly demonstrate the potential value as well as the several pitfalls of this technique as a tool for study of shallow water sediments. In Narragansett Bay the depth of bed-

rock could be measured over much of the west passage around Conanicut Island and along the sides of the east passage. The overlying sediment, probably largely deposited by glaciers but with a thinner deposit of recent sediments, was charted in some detail. Mr. Knott's study over the continental shelf indicates that the structure near the edge is dominated by bedding that dips seaward capped by nearly flat-lying beds. Profiles across the Hudson Canyon show that it is cut through flat-lying beds on the shelf.

Repeated attempts have been made to use the Seismic Profiler to record soundings below the bottom in deep water. While limited success has been achieved, it is evident that our present sound source is too weak to overcome the problems of depth and the sea noise which must be put up with if the ship is to move about while recording. Improvements are steadily being made in the sound source and in reducing noise, hence it is expected that echo sounders of the near future will allow charting of the bottom sediment structures as well as water depth in vast ocean areas.

Relative to this same question of shallow sediment structures in deep water, our efforts to improve the resolving power of deep-water echo sounders have paid interesting dividends. Using our fish-shaped transducer on the YAMACRAW during the Mediterranean cruise it was found possible to sound at 10 knots cruising speed while employing an exceedingly short sound pulse or ping (0.5 milliseconds). Echoes the equivalent of two feet apart in travel path could thus be resolved. In places where the bottom is smooth-looking to the echo sounder we have frequently found that two or more echoes are consistently recorded in such a pattern as to suggest that the later ones are reflections from layers below the bottom. This interpretation of echo sounder records is best confirmed by sampling the bottom with long cores. Fortunately one series of such recordings was made in the Tyhrennian Sea off Naples by Dr. Hersey on the YAMACRAW last summer which are within 50 miles of a coring station of the Swedish Albatross Expedition. The reflections recorded by the echo sounder match very closely with volcanic ash beds in the log of this core. Elsewhere in the western Mediterranean, Dr. Richard H. Backus recorded many more of these multiple echo sequences, suggesting not only flat-lying sediment structures but also local slumping where the beds are sloping. While crossing the flat abyssal plains of the North Atlantic, YAMACRAW echo soundings frequently showed multiple echo sequences, suggesting thin bedding (two to ten feet) below the bottom; occasionally over the eastern part of the Atlantic passage multiple echo sequences were observed similar to those described for the Mediterranean.

The geological group headed by Dr. John M. Zeigler has also worked on several sedimentation problems. The interrelationship of water and sediment movement in the surf zone and nearshore areas has been studied in

collaboration with Professor Robert C. Miller of the University of Chicago. A point has been reached where it is possible to predict the sediment pattern from sea state and such predictions are being tested by comparing the predicted pattern with the actual depositional situation. Problems relating to the fall velocity of sand in water were examined by a specially designed settling tube which makes a rapid mechanical analyses of the sorting sands. Many of the problems related to the general operation of settling tubes have been examined and the mathematics have been condensed into graphs and tables. The geological aspects of the continental shelf off South America were investigated during a winter cruise on the ATLANTIS. This work has encouraged the Venezuelans to study oceanography and it appears they are going to establish an Oceanographic Department in the Government. Mr. William D. Athearn has examined most of the material from the Cariaco Trench and Dr. Zeigler is working on sediments from the Gulf of Venezuela. Interest of the various oil companies is quite high because of the possibility that this Gulf will one day be an important oil province.

Professor Raymond Siever of the Harvard University Geology Department is associated with the Institution's geology program. His investigations during the past year have been particularly concerned with the geochemistry of silica in the interstitial material in sediments. He has also continued to work up cores obtained by Mr. Henry C. Stetson on his last cruise on the ATLANTIS.

Dr. Graham has continued his interest in manganese nodules. His analysis of collections made on the Blake Plateau led him to re-examine the possibility of biological concentrating agents, an old approach which has not been entertained seriously in recent years. He has thus constructed an hypothesis which supposes the existence of nuclei of heavy ions chelated by organic molecules, such as the amino acids. These he supposes are absorbed as food by micro-organisms which dispose of the heavy ion, whether manganese, cobalt, iron or other elements in nodular form or as encrustations. Mr. Worthington has been collecting bottom samples in the course of his more recent hydrographic observations. These appear to support Dr. Graham's hypothesis.

Dr. Backus and Dr. Hersey have continued their study of the deep scattering layers, having received a grant from the National Science Foundation to this end. A new instrument which permits direct acoustical and photographic examination of individual sound scatterers was designed and built by Mr. Thomas H. Gifft. This makes use of a clever combination of directional effects in the receiving part of the acoustical apparatus to insure that a scatterer is near the center of view of an underwater camera when it is automatically triggered. Observations of sound scattering with explosive

sources have been extended by recording several dawn and sunset migration sequences of the layer both in the Atlantic and the Mediterranean. It is evident from these observations that dawn and sunset migrations are indeed different with respect to their depth/frequency relationships. Dr. Per F. Scholander has predicted that they would be different if the scattering is from the swim bladders of fishes as suggested, since the mode of accommodation to increasing and decreasing pressure would be expected to be different.

The investigation of sound scattering by fishes of the deep scattering layer, and the study of the sounds made by fishes and cetaceans which continue to interest Dr. Backus and Mr. William E. Schevill, have been greatly aided by the visible speech wave analyzers developed some years ago at the Bell Telephone Laboratories. The discoveries in oceanographic acoustics which these instruments facilitated have put such an analysis load on our staff that the original instruments have been made nearly obsolete. During the past year, several of the staff have examined ways of improving and speeding spectrum analysis of the transient sounds of interest here, and they are hopeful of putting together new equipment that is both better and within our means.

Geochemistry

Studies of the horizontal and vertical distribution of the fallout radioisotopes, strontium 90, antimony 125, cesium 137, cerium 144, and promethium 147, have been continued. This program, under the direction of Dr. Vaughan T. Bowen and Dr. Thomas T. Sugihara, is currently supported by contracts with the Atomic Energy Commission and the Office of Naval Research and by portions of the I.G.Y. funds from the National Science Foundation. A summary of the analytical data up to August 1, 1958 has been published as has a description of the analytical methods employed.

Sample collection for this program has continued at a rapid rate and has been stimulated by the construction of new samplers of an improved design. With these samplers four stations were made from the CRAWFORD in July between Woods Hole and Bermuda, one from the BEAR in September on the continental shelf south of Montauk, one from the PANULIRUS in October off Bermuda, two from the CRAWFORD in November on the equator, one from the CRAWFORD in March north of Bermuda and one from the PANULIRUS in April off Bermuda. Mr. Henri Caron and Dr. Sugihara supervised the last two stations and Dr. Bowen all the others.

The complicated and prolonged operations involved in chemical processing and low-level beta counting of these samples continues to produce a disheartening lag between collection and completed analysis. This has been significantly eased by having, since June, Mr. Caron to assist Dr. Sugihara on a full-time basis. The group now has, among other interesting sets of data,

three stations analyzed from the Sargasso Sea, July 1957, December 1957 and July 1958. The consistent shape of the curves for Sr^{90} from surface to 1,000 meters where it is now readily detectable indicate, as we hoped, that these data will provide a unique approach to the measurement of vertical mixing. Comparison of the surface values for December and for July indicates that these may provide a measure of the seasonal value for rainfall in remote ocean areas.

The ratios of Sr^{90}, Ce^{144}, Pm^{147} in surface samples even from low-productivity areas of open ocean indicate that some process — sedimentation on particle surfaces is postulated — rapidly removes the latter two isotopes from the upper layers of the sea. At 8° S, 7° E the cerium-promethium ratio at 300 meters indicated a decay time since production of about 2.7 years, and that at 800 meters a decay time of about 4.4 years, whereas surface values very rarely indicate more than one year of decay. Accumulation of more of this type of data, combined with analyses, already begun, of the isotope ratios in plankton and detritus in both shelf and offshore areas, should give us new insight into the relative importance and effective rates of biological and inorganic processes in sedimentation.

As a by-product of Dr. Herbert Curl's analyses of the composition of various plankton species, a large number of ash samples have been prepared for spectrographic analyses. One group of eleven samples was analyzed by Dr. Geoffrey D. Nicholls of the Department of Geology, University of Manchester, England, during his tenure of a fellowship at the Massachusetts Institute of Technology. The appointment of Dr. Nicholls as Associate in Geochemistry on the research staff of the Institution projects a continued collaboration in Manchester on this interesting work. This program is giving us new insight into the diversity of chemical behavior taking place within the various forms of planktonic life. Combined with the data on population composition and size being obtained as part of the broad plankton program under Dr. Ketchum, these analyses permit quantitative evaluation of the biota as factors in the marine geochemistry of the rarer elements.

A reliable and sensitive method for vanadium analysis has been worked out and Miss Sybil A. Campbell has been accumulating data, mostly relevant to radioactive tracer experiments made in 1957 by Dr. Bowen and Professor L. S. Ciereszko of the University of Oklahoma. Culture conditions are being established for several local tunicates, both accumulators of vandium and non-accumulators; also conditions for inducing production of larvae by some of these tunicates is being studied. In the next few months an intensive attack on the questions of uptake mechanisms for vandium, of vanadium-phosphate competition and metabolic cycles of vanadium and niobium in ascidia will be started.

The biological deposition of silica by diatoms and factors affecting its resolution after the cells die have been under investigation by Dr. Joyce C. Lewin. In order to gain information concerning the nature of the organic membrane upon which the silica is deposited by the living diatom cell, ultrathin sections of various species have been examined with the electron microscope. The physiology of *Phaeodactylum tricornutum*, an unusual marine diatom with unsilicified (or only partially silicified) cell membranes, has been studied in detail with a view to understanding and controlling the complete life cycle. For sustained growth of *Navicula pelliculosa* high concentrations of calcium are required, correlated with the observed fact that this cation is essential for silica deposition.

Studies have been carried out on the dissolution of silica at 20° C from marine plankton diatoms, from fresh-water diatoms grown in culture in the laboratory and from fossil diatom walls. The ability of certain cations to combine with the silica walls and inhibit their subsequent dissolution has been studied.

Vitamin requirements and heterotrophic growth studies on forty-four pure cultures of marine littoral diatoms have been completed.

Dr. Richard G. Leahy has continued the studies of atmospheric CO_2 variations which were begun early in the I.G.Y. Data collected along the eastern coast of North America have continued to indicate a high degree ot variability in CO_2 levels, and the records obtained are very similar to those reported by the Scandinavian network. These measurements have been made at both local ground stations and from the Institution R4D aircraft. The vertical profiles made in the aircraft indicate a greater range in CO_2 level than was expected before the sampling program was undertaken.

Biology and Chemistry

The studies of the biology and chemistry of marine plankton populations have been continued. In May 1958 two years of observations were completed at a series of stations which provided two cross sections of the continental shelf and some stations in the slope water just beyond the edge of the shelf. In these field observations the conditions ranged from coastal waters with depths of 30 meters to observations where the depth was greater than 2,000 meters. Thus a wide range of conditions was obtained. In 1958 the cruises were extended seaward on a section from Montauk Point, Long Island, to Bermuda. The inshore seven stations of this section repeat some of those previously occupied on the continental shelf, but the extension provides the opportunity to make studies of the deeper water, to observe the unique populations in the Gulf Stream and to include the truly oceanic conditions of the Sargasso Sea in our investigations.

This program continues to be supported jointly under a contract with the Atomic Energy Commission, by several grants with the National Science Foundation and by Institution funds. The work under the AEC contract is supervised by Dr. Bostwick H. Ketchum and Dr. Vaughan T. Bowen. Dr. Ketchum and Dr. John H. Ryther are principal investigators on the associated NSF grants.

At the Conference on the Peaceful Uses of Atomic Energy held in Geneva in September, Dr. Ketchum presented a paper prepared in collaboration with Dr. Bowen entitled "Biological Factors Determining the Distribution of Radioisotopes in the Sea." This was the only U. S. paper selected for presentation at the session dealing with the marine sciences. A paper by Dr. Bowen and Dr. Thomas T. Sugihara "Marine Geochemical Studies with Fall-out Radioisotopes" will be published in the proceedings of the Conference but was not presented orally at Geneva.

Studies of the distribution of the essential plant nutrients, particularly phosphorus and nitrogen, have been an integral part of our plankton investigations. A general description of the annual cycle in the coastal waters has been submitted for publication by Dr. Ketchum with Mr. Ralph F. Vaccaro and Mr. Nathaniel Corwin. Mr. Charles S. Yentsch and Mr. Vaccaro have completed and published the results of laboratory and field studies of the relationship between the available nitrogen and the chlorophyll content of the plant cells.

Dr. Mary Sears and Miss Constance W. Chadwick have continued the analysis of the zooplankton and Dr. Edward M. Hulburt is identifying species of phytoplankton collected during our coastal and Bermuda cruises. Dr. Sears has also done a splendid job of organizing the first International Oceanographic Congress which is sponsored by the American Association for the Advancement of Science in cooperation with UNESCO and the Special Committee for Oceanic Research (SCOR) of the International Council of Scientific Unions. This Congress will be held in September of 1959 at the United Nations headquarters in New York City. At least 600 oceanographers from all over the world are expected to participate in this Congress.

In the fall, Mr. John H. Steele of the Fisheries Laboratory at Aberdeen, Scotland, visited Woods Hole on one of our fellowships. He and Mr. Yentsch studied the effects of deficiencies of nutrients in algal cultures upon the sinking rate of the cells. They found the deficient cells sank more rapidly than those that were grown in adequate media. This observation may help to explain the accumulations of chlorophyll below the zone of optimum photosynthesis, frequently observed when the nutrient conditions in the water are poor. Also, in cooperation with Mr. Vaccaro, it was found that deficient cells excrete nitrite while assimilating nitrate from water. This observation

may help to explain the maximum concentrations of nitrite which are found below the illuminated zone in the summertime. It has previously been thought that these must be due to nitrifying bacteria, but our extensive studies of this process have failed to isolate the appropriate bacteria from the water. If the nitrite is formed by the phytoplankton rather than by bacterial action it may help to explain many of the poorly understood distributions of nitrogen compounds in the ocean.

Dr. Stanley W. Watson has continued his bacteriological studies and has determined, at several stations, the rate of oxygen consumption in samples of water collected from various depths. Direct observations of bacteria on fine filters have demonstrated many forms which are not found by previous methods of counting. Attempts will be made to isolate, culture and identify these unknown microscopic specimens.

Dr. Herbert Curl, Jr., has completed an extensive study of the environmental factors which influence the growth of an important coastal diatom, *Skeletonema costatum*. The results of this investigation on the interaction of nutrients, light and temperature appear to correlate closely with seasonal distribution of this common diatom. Dr. Curl has also continued the collection of plankton samples for spectrographic elemental analysis. The differences in the elemental composition of the various species will influence greatly the fate of radionucleides which may be added to the sea either through fall-out or as waste materials resulting from the development of atomic energy.

Dr. Ryther has continued his studies of the primary production of organic matter in the sea. Routine measurements of productivity have been made on all of the Woods Hole-Bermuda sections as part of the plankton program described above. In addition, Dr. Ryther has been directing a similar, though more limited, plankton investigation in the Sargasso Sea off Bermuda. This study has been carried out by Dr. David Menzel from the Bermuda Biological Station and has made use of their facilities including the Research Vessel PANULIRUS. It has involved routine hydrographic, chemical, and biological measurement at two-week intervals throughout the year at a station 15 miles southeast of Bermuda in 1500 fathoms of water. A unique record of the annual cycle of primary production and the related chemistry and hydrography of these semitropical waters has been obtained.

In addition to the measurement of primary production in these two areas, studies of the environmental physiology of the phytoplankton under natural conditions have been undertaken whenever possible. Examples of such work include two manuscripts currently in press, one dealing with light adaptation of the plankton algae living under conditions of low illumination at the lower limit of the euphotic zone, the other demonstrating that iron and/or

other trace metals and silicon, rather than nitrogen and phosphorus, may be the principal limiting factors to organic production in the nutrient-poor Sargasso Sea.

In the laboratory, Dr. Robert L. Guillard has developed a collection of some 75 species of plankton algae including representatives of all the major algal groups, mostly in bacteria-free or "pure" culture. This collection, probably unique in the world, has proved extremely useful both to biologists at Woods Hole and elsewhere and is becoming widely recognized. Dr. Guillard and Dr. Ryther are currently undertaking a study of the taxonomy and physiology of several closely related species of small diatoms collected from widely differing types of marine environments.

In addition to these specific research problems, Dr. Ryther has prepared two review papers on the productivity of the seas. The first was included as part of a symposium on "The Physiology of the Algae" sponsored by the AAAS at its annual meeting in Washington in December 1958. The second is part of an NSF-sponsored symposium on "The Ecology of the Algae" to be given at Pymatuning, Pa., in June 1959.

The extension of our cruises to include crossings of the Gulf Stream has permitted a study of the distribution of phosphorus compounds in the deeper waters of the North Atlantic Ocean. In general, organic compounds of phosphorus are not found in water much deeper than 1000 meters in the Atlantic Ocean. However, in water of depths greater than 2,000 meters directly below and to the south of the Gulf Stream, high concentrations of organic phosphorus have been found on all of our crossings. A similar observation was made for the first time in crossings of the Gulf Stream by Mr. David A. McGill during one of the I.G.Y. cruises in 1957. It is interesting that these concentrations of organic phosphorus occur in just the region where one would expect to find the recently described deep countercurrent below the Gulf Stream. The presence of the organic phosphorus at these depths suggests that the water is comparatively "new" and had recently been near enough to the surface to accumulate these organic compounds before sinking.

The cruises of the I.G.Y. have again given us an opportunity to extend our observations of the distribution of phosphorus throughout the North and South Atlantic Oceans. On these same cruises, samples of chlorophyll have been obtained in the surface layers so that estimates of the productivity of the different waters can be made. Mr. McGill accompanied the CRAWFORD on Cruise #22 when two sections were completed in the South Atlantic Ocean, one at approximately 24° S and the other on the Equator. Mr. John L. Shilling accompanied CRAWFORD Cruise #17 during which the eastern North Atlantic and the Caribbean were traversed by five sections.

Dr. Francis A. Richards and Dr. Curl accompanied a cruise to investigate

the hydrography and biological and chemical oceanography of the north coast of South America from Trinidad to the Gulf of Darren, and to repeat observations on the anaerobic basin, the Cariaco Trench. Dr. Richards has analyzed the data with particular attention to the nitrogen cycle. Ammonia, the only nitrogen compound found in the anaerobic water, was measured by a new method, and the nitrogen/argon ratio and the nitrogen isotope ratios have been determined by Dr. Bruce B. Benson of Amherst College. These data demonstrate the release, under anaerobic conditions in the Cariaco Trench, of free nitrogen from nitrogen of organic origin, permitting the striking of a nitrogen balance on the water column. Samples from the Dramsfjord in Norway have also been analyzed with similar results.

Dr. Richards has also completed an analysis of the distribution of silicate in the western Atlantic and Caribbean. In much of the water column, silicate concentrations are closely correlated with phosphate and nitrate concentrations, thus relating silicate to the biological cycles of phosphorus, nitrogen and oxygen.

As co-chairman of a special committee appointed by the editor of the Journal of Marine Research, Dr. Richards shared in the arrangements for the publication of a special volume of that journal honoring the 70th birthday of Professor Thomas G. Thompson of the University of Washington, and most of the editing of the volume was completed.

Dr. George L. Clarke and Mr. Lloyd R. Breslau obtained quantitative records of luminescent flashing of animals at great depths in the Mediterranean Sea during a visit to the Oceanographic Institute of Monaco. The amount of bioluminescence was found to be decidedly less than in the waters of the North Atlantic, but the vertical distribution of flashing organisms was similar in both locations. Additional observations with the light-triggered camera suggest that most of the flashing organisms in the depths are too small to be photographed. Some excellent photographic records of deep-water coelenterates and crustaceans have been obtained, however. A series of measurements of light conditions with records of bioluminescence was made from the CRAWFORD during August at stations to the south, east and north of Cape Cod. Luminescent flashing was encountered at every station from the shallowest on Georges Bank to the deepest in the Gulf Stream. The results indicate that bioluminescence occurs far more generally and is of greater ecological significance in the deep sea than previously supposed. A portable photometer suitable for use with a small boat but with the same degree of sensitivity as the larger bathyphotometer has been developed.

Drs. S. M. Marshall and A. P. Orr of the Marine Biological Station, Millport, Scotland, visited the laboratory in the spring on Institution fellowships. With Dr. Robert J. Conover, who joined the project in March, they com-

pleted a series of feeding, respiration and excretion studies on the copepod, *Calanus*. They found a surprisingly rapid excretion of phosphorus in these studies, suggesting that the importance of zooplankton in returning nutrients to the ecological cycle may have been underestimated. Dr. Conover is continuing these studies on neritic and oceanic zooplankton.

Dr. Raymond G. Stross held a fellowship from the National Institute of Health and worked in the Institution during 1958. His studies were concerned with the interrelationships between phytoplankton and zooplankton. Dr. Jack McLachlan, also an NIH Fellow, worked at the Institution on studies of the physiology of algal cultures.

Dr. Edward R. Baylor continued his investigations on dark adaptions in horseshoe crabs, copepods and honey bees and examined the dioptrics of marine invertebrate visual systems. He also has pursued the question of polarized light detection to satisfactory conclusions for the horseshoe crab (*Limulus*), the bee and a snail (*Nassa*).

Mr. Harry J. Turner has continued his studies of the commercial shellfish in local waters. The productivity of a large population of quahogs in the waters of Nantucket Sound was evaluated by bringing specimens into the laboratory, holding them under warmer conditions and attempting to stimulate spawning by adding suspensions of sperm. This system invariably produces spawning in breeding stocks of quahogs. However, the quahogs from the deepest parts of Nantucket Sound would not spawn under these conditions. It appears, therefore, that this population is not the source of new seed for commercial stocks of quahogs, although it was the opinion of the local clamdiggers that this was an important source. Studies were also made of the transplanting and growth of European oysters in local waters.

Mr. James E. Hanks has completed his course work for the Ph.D. degree at the University of New Hampshire and has been conducting his thesis research at the Institution under the direction of Mr. Turner. His problem is concerned with the breeding and early life history of three species of the clam drill, *Polynices*. It appears that in the natural environment the time of settlement of the drills is nicely synchronized with that of the shellfish. Because of the voracious appetite of the drills they consume enormous quantities of freshly settled shellfish, and this may be the explanation of the failure of many sets of clams to mature to the adult and edible size.

Dr. Howard L. Sanders has continued his investigations of the benthic animal communities in Buzzards Bay. He has recently completed a paper concerned with the structure of the animal assemblages present in the softer sediments. Dr. Sanders is also studying the morphology, development and ecology of the remarkable crustacean, *Hutchinsoniella macracantha* and its significance to the understanding of evolution of crustaceans. He presented

some of these findings last summer at the International Zoological Congress in London.

Dr. John W. Kanwisher has studied the carbon dioxide balance in sea water using an equilibration system and infrared analyzer. The CO_2 tension increases rapidly with increases in total carbonate and with temperature. At constant temperature, measurement of CO_2 tension gives a sensitive index of biological activity. These studies of the equilibrium between CO_2 and sea water indicate that the CO_2 released by the burnings of fossil fuels has been effective in increasing the atmospheric CO_2 content.

Dr. Wolfgang Wieser of the University of Vienna is making a study of quantitative distribution of nematodes using respiration measurements to assess their metabolic importance. A Cartesian diver system has been built capable of measuring the respiration of individual small animals. The distribution of a varied bottom fauna that can survive for weeks in the laboratory without oxygen is being correlated with the chemistry of the bottom habitat as defined by oxygen tension and oxidation reduction potential. We are haunted by the uncertain implications of taking animals from such an environment and measuring their oxygen uptake.

A paper by Dr. Henry B. Bigelow and Mr. William C. Schroeder describing four new species of skates from the Gulf of Mexico was published in July 1958 and they have completed an account of the family Osmeridae, the capelin and smelts, to be included in Part 3 of "Fishes of the Western North Atlantic." At present they are working on a very interesting collection of batoids (skates and rays) received from Mr. Harvey R. Bullis, Jr., collected by the U. S. Fish and Wildlife Service Research Vessel OREGON, chiefly between Trinidad and the Equator, in depths down to about 400 fathoms in a region that had not previously been fished with otter trawls. Mr. Schroeder completed a report on the offshore lobster fishery and the deep-water red crab, the latter as yet unexploited but which at some future time might prove of importance commercially.

The research program dealing with the biology of the larger pelagic fishes, supported by a grant from the National Science Foundation, has progressed under the direct supervision of Mr. Frank J. Mather III. The collection of biometric and other biological data has yielded desirable information especially for the tunas and the amberjacks. Sport fishermen have continued to cooperate in the tagging of pelagic gamefish. Mr. Mather conducted a research cruise to the southeastern Bahamas, sponsored by Mr. Louis E. Marron, an Associate of the Woods Hole Oceanographic Institution, carried out on his cruiser, EUGENIE VIII. In November Mr. Mather delivered a paper concerning the amberjacks (*Seriola*) of the western Atlantic at the International Gamefish Conference at Miami Beach, Florida.

Oceanographic Instrumentation

During the summer Mr. Allyn C. Vine undertook to design a deep-water mooring for an automatic weather station for the middle of the Gulf of Mexico. This boat-shaped buoy, 20 ft. by 12 ft., contained electronic weather sensing and telemetering equipment. The buoy was built by the David Taylor Model Basin and instrumented by the National Bureau of Standards. With the cooperation of the Coast Guard the mooring was set out in early September and promptly rode out near-hurricane force winds when Hurricane Ella passed within 50 miles of its position. This mooring utilizes the positive buoyancy of the new polypropylene line to minimize fouling and chafing on the bottom while using heavier-than-water dacron line to minimize it at the surface. Attacks by sharks are considered to be the only serious threat to this type of mooring.

The electronics group, under the direction of Mr. Robert G. Walden, spent about forty percent of its time on the installation and maintenance of navigation and communication equipment aboard the various vessels of our fleet. The remaining time was devoted to assistance in instrumentation for various projects and to the program in buoy development. A transponding telemetering buoy which is an exact copy of the one designed by Messrs. Walden, David D. Ketchum and David H. Frantz is now available commercially. This has relieved the electronics group of construction of these useful devices and more time has been spent on assisting various projects in using them and in working on new techniques of data transmission. The buoys now have a reliable telemetering range of over 100 miles.

Mr. Frantz has constructed a data processing system for these buoys which permits the storage and later transmission of eight temperature measurements. The temperature data are telemetered digitally and may be obtained at preselected times or at any desired time by radio interrogation. He has also continued his work on the "pop-up" buoy as an instrument vehicle and has been working on the problem of anchoring surface buoys in the deep sea.

Mr. Harlow G. Farmer, Jr., with the assistance of Mr. Ketchum, has continued his work on surface waves. During the summer a tower was set up in Buzzards Bay on which wave recording instrumentation was installed. This consisted of a series of fine wires whose resistance is changed by the passage of the waves. The information from the wires is telemetered to the laboratory by means of a VHF radio link and is processed to give a measure of wave height and slope. The data are automatically reduced to digital form and stored on punched tape for later conversion to IBM cards for machine computation of energy spectra.

Dr. Charles J. Hubbard and Dr. William S. Richardson have completed

an underwater spectrometer which records on deck the spectral distribution of underwater light. They also changed the recording system of the towed thermistor chain so that it automatically contours the depth of isotherms as the ship proceeds on course. This equipment was towed by the USCGC YAMACRAW to the Mediterranean during the summer and fall and on several coastwise cruises. During the late fall it was transferred to the USNS CHAIN and modifications to improve the electronics were started.

Mr. Gordon H. Volkmann has been engaged in the development of a neutrally buoyant "pinger" of the Swallow-type for use in the direct measurement of deep currents. During the sea tests two pingers were followed long enough to provide a measure of the current, one off Woods Hole and one off Eleuthera in the Bahamas. While of no significance in themselves, it is hoped that they will form part of a series of measurements of the deep currents along the western boundaries of the ocean. With the series in the central ocean areas planned by Mr. Henry M. Stommel and Dr. John C. Swallow, we hope for a better understanding of deep circulations.

For many years ocean seismographers have been thwarted in their attempts to observe near the bottom elastic waves that have traveled through the bottom. Mr. Willard Dow has successfully completed development of telemetering circuitry for a hydrophone that may be suspended to any ocean depth on a single conductor well-logging cable. This hydrophone has been tested and used routinely in receiving sounds at depths greater than 2000 fathoms. Thus this design is a promising candidate for a deep detector, and should prove extremely valuable in resolving some of the questions of sediment structures at shallow depth below the bottom in deep water.

The relative inaccessibility of the ocean floor for direct observation has long made underwater photography a valuable tool to the geologist, but he has been somewhat hampered and discouraged in its use by camera design, which limited the control he could exercise over his observations. The development by Dr. Harold E. Edgerton of the Massachusetts Institute of Technology of a repeating camera that can be positioned above the bottom by means of an acoustic link has greatly increased the attractiveness of this instrument. This year he has put together a stereoscopic camera designed with an improved acoustic link which Dr. John W. Graham employed in seven locations in the Indian Ocean and Red Sea from the ATLANTIS. Since several hundred pictures are commonly taken at each location, the results of this work are still being processed. It is evident from the detail and clarity of the resulting photographs that much can be learned with these instruments and that considerable effort to improve the ease and versatility of handling will be well repaid in scientific results.

The towed thermistor array, which was described last year by Dr. Iselin,

was used on the cruises of the YAMACRAW. On the Mediterranean cruise Dr. Richardson and Dr. Hubbard installed and tested a completely new recorder for the instrument. This recorder incorporates a computer which automatically feeds a series of pulses corresponding to integral and tenths of degrees centigrade to a facsimile recorder as the computer scans the series of 23 thermistors distributed equally in depth along the chain. By repeated and rapid scanning (1 scan per 8 to 10 seconds) the recorder presents a quasi-continuous plot of isotherms along the track of the ship if it is underway, or the variation of temperature with time at a place if it is standing still. This instrument demonstrates dramatically the large and small-scale variability of temperature in near-surface waters. Recordings from the Mediterranean cruise indicated that temperature variation with position is so rapid that even higher scan rates were required. Accordingly, Dr. Hubbard has designed a new recorder incorporating a choice of much higher scan rates.

For many years underwater acousticians have wanted a precise, reliable instrument for direct measurement of the velocity of sound in sea water. Many attempts have been made at developing such an instrument and from time to time our staff have assisted others in testing various models. A few years ago the National Bureau of Standards staff, under Dr. Martin Greenspan, completed a promising instrument which gave good results in shallow water. More recently Dr. Greenspan and Mr. Tschiegg of NBS have developed a similar instrument for use in any ocean depth. Dr. Earl Hays supervised the testing of this instrument on the Mediterranean cruise of the YAMACRAW and on subsequent cruises. The instrument is clearly capable of high precision and gives results that compare well with sound velocities computed from temperature and salinity data taken in the same region but at other times. Thus far it has not been possible to combine its use with hydrographic observations but it is hoped to do so in the near future.

Research Fleet

As may be noted from the accompanying tabulation of ship activities, the ATLANTIS spent 226 days at sea, the CRAWFORD 216, the BEAR 138, and the YAMACRAW and CHAIN combined 161 days. Thus, it has been an active, sea-going year for much of our staff.

During January and February what seemed to be an endless struggle with the ATLANTIS' main engine occurred. This started off by iron grit being found in the crankcase and ended up with the installation of a new crankshaft. In the end the grit turned out to be a red herring; the real trouble was caused by an "improvement" in the design of some new bearings which had been installed during the last two weeks in 1957.

The cost of all this was very heavy indeed but fortunately, in good part,

was covered by insurance. Not only did we have to buy and install a new crankshaft and several sets of new bearings but also our carefully laid plans to complete the re-survey of the South Atlantic during the winter months were disrupted. The ATLANTIS did not meet the VEMA in Cape Town as had been planned. The CRAWFORD was also delayed and could not undertake two tropical crossings of the Atlantic. Instead she was sent to the Caribbean while the ATLANTIS raced via the Mediterranean Sea to join the VEMA in the Indian Ocean. Fortunately, both of these operations appear to have been a complete scientific success.

Since the ATLANTIS is due for her quadrennial inspection in 1959 and since a decision was necessary concerning the proposed long cruise into the South Atlantic, a preliminary survey of her hull was made at the end of August. This inspection showed no excessive thinning of the hull plates and indicated that, for relatively nominal costs, we should be able to continue the ATLANTIS in service until June of 1960. At that time it is predicted that extensive repairs would be required. A preliminary estimate of the costs of these repairs indicates that an amount approximating the original construction cost ($218,000) may be required. On this basis it is now planned to keep the ATLANTIS in operation only until that time.

Knowing that the research days of the ATLANTIS are numbered, a research vessel design committee was set up under the direction of Mr. Francis Minot, who was one of the original designers of the ATLANTIS. Staff members representing all aspects of oceanography have shared the work of this very active committee. In all, preliminary designs of some ten types of research vessels have been drawn up and a design for the ATLANTIS' replacement has been selected. Work on this is still progressing but it appears that this vessel should be approximately 175 feet long and have a total displacement of about 1,000 tons. Special features include a center well, active stabilization devices, bow propulsion and special equipment for handling scientific gear at sea. The general hull form is a blend of the characteristics of the deep-sea trawler and the offshore Coast Guard cutter. The cost of this ship, together with final design, model testing and equipment, is estimated at three and one-half to four million dollars.

During June the efforts of the Office of Naval Research to secure some larger vessels for oceanographic research were successful. Emergency funds were secured in time to enable contracts to be signed before July first for the conversion of three ships from the mothball fleet. By November the USNS CHAIN was placed in service by the Military Sea Transportation Service to be operated in support of the Institution's scientific program.

The assignment of the CHAIN to oceanographic service is the result of accumulated pressures created by the Institution's deep-sea research pro-

grams. It was found to be increasingly difficult to operate with reasonable efficiency on our small ships, particularly in studying the relationship between shallow temperature structures and sound transmission and in submarine geophysics. Nor has it been possible to attack many problems at all in high latitudes where moderate to rough seas are to be anticipated much of the time. Another limitation has been the small working space available on our ships for the increasingly complex apparatus of modern oceanography. The thermistor chain is an obvious example, but it is only one of several developments which have to be carried on from larger ships.

Realizing that new ships especially designed for oceanography would inevitably not be available for several years, Mr. Vine collaborated with the Office of Naval Research in making a careful feasibility study of ships up to about 2,000 gross tons in size available for conversion. Many classes of naval and civilian service craft such as ocean-going tugs and re-supply ships were considered, but each had rather apparent shortcomings. Large trawlers and small freighters have many desirable characteristics which can be incorporated in a new design but the available types were not suitable for conversion. In the end the Navy salvage and rescue ARS-type ship was selected because it provided most of the features desired by the staff.

On the ARS space had been provided for quarters for the salvage crew as well as the operating crew. This in part provided for the scientific party. The large (28 by 40 foot) salvage workshop and several salvage storage spaces provided excellent laboratory and storage space. The large main deck aft provided excellent open deck working space and the versatile power plant included most of the power sources needed, both for our deck gear and electronics. Perhaps most important of all was the excellent sea-keeping ability reported by former officers.

In the spring of 1958 two ARS-type ships were assigned by the Navy Department through the Office of Naval Research, one for use by this Institution and the other for the Scripps Institution of Oceanography. The CHAIN (T-ARS-20) was assigned to Woods Hole to be put in service and operated for the first year by the Military Sea Transportation Service (MSTS).

The CHAIN is a 1,800 ton ship, 215 feet long, 40 foot beam, 14 foot draft with a twin-screw diesel electric power plant. Plans for her conversion were worked out jointly by members of the Institution staff with representatives of MSTS and ONR. Mr. Edwards represented the Institution at the Savannah Machine and Foundry Company during her conversion and his efforts were an important factor in making the conversion a successful one for science. The CHAIN has been fitted with four large laboratories and an explosives magazine. She also has two somewhat smaller compartments reserved entirely for writing, reading or conferences. Her large afterdeck is

fitted with an excellent constant-tension winch for handling heavy steel cable for coring and trawling, a high-capacity hydraulically operated "A"-frame and various booms, winches and a heavy-duty capstan. Living accommodations provide for a scientific party of 26 and a crew of 39. These features all represent in one way or another completely new sea-going research facilities. We look forward with much anticipation to making use of this fine ship.

The CARYN was finally sold in December 1958 to Mr. Stephen H. Swift, Jr., of Milton, Massachusetts.

ATLANTIS ACTIVITIES FOR YEAR 1958

Cruise No.	Depart	Arrive	From	To	Days	Ch. Scientist
241	23 Jan.	27 Jan.	Woods Hole	St. Georges	5	Miller
	27 Jan.	14 Feb.	(Delayed in St. Georges for engine repairs)		18	
	14 Feb.	25 Feb.	St. Georges	Brooklyn, N.Y.	12	
	25 Feb.	29 Mar.	(In shipyard, Brooklyn for engine repairs)		33	
	29 Mar.	30 Mar.	Brooklyn	Woods Hole	2	
242	3 Apr.	4 Apr.	Woods Hole	Earle, N. J.	2	Stetson (Medit. and Red Seas)
	5 Apr.	9 Apr.	Earle	St. Georges	5	
	11 Apr.	25 Apr.	St. Georges	Gibraltar	15	
	28 Apr.	28 Apr.	Gibraltar	Ceuta (Rota)	1	
	28 Apr.	8 May	Ceuta	Alexandria	11	
	12 May	13 May	Alexandria	Port Said	2	Graham
	13 May	21 May	Port Said	Aden, Arabia	9	
	23 May	7 June	Aden	Aden	16	
	10 June	20 June	Aden	Port Sudan	11	
	21 June	29 June	Port Sudan	Suez	9	
	29 June	30 June	Suez	Port Said	2	
	1 July	4 July	Port Said	Alexandria	4	
	7 July	18 July	Alexandria	Naples	12	Edwards
	23 July	2 Aug.	Naples	Ceuta (Rota)	11	
	2 Aug.	3 Aug.	Ceuta	Cadiz	2	
	7 Aug.	12 Aug.	Cadiz	Ponta Delgada	6	Hahn
	14 Aug.	25 Aug.	Ponta Delgada	St. Georges	12	
	28 Aug.	31 Aug.	St. Georges	Woods Hole	4	
243	4 Sept.	4 Sept.	Woods Hole	Chelsea	16	Shipyard overhaul/repairs
	18 Sept.	19 Sept.	Chelsea	Woods Hole		
244	20 Sept.	20 Sept.	Woods Hole	Woods Hole	1	WHOI Associates Cruise
245	13 Oct.	13 Oct.	Woods Hole	Woods Hole	1	Student Cruise
246	15 Oct.	24 Oct.	Woods Hole	Port-of-Spain	10	Zeigler
	27 Oct.	6 Nov.	Port-of-Spain	Willemstad, Curaçao	11	
	9 Nov.	16 Nov.	Willemstad	Amuay	8	
	16 Nov.	17 Nov.	Amuay	Maracaibo	2	
	19 Nov.	19 Nov.	Maracaibo	Maracaibo	1	
	20 Nov.	24 Nov.	Maracaibo	Barranquilla	5	
	27 Nov.	1 Dec.	Barranquilla	Cristobal, C.Z.	5	
	3 Dec.	15 Dec.	Cristobal	Woods Hole	13	

CRAWFORD ACTIVITIES FOR YEAR 1958

Cruise No.	Depart	Arrive	From	To	Days	Ch. Scientist
17	6 Feb.	9 Feb.	Woods Hole	Bermuda	4	Metcalf
	11 Feb.	17 Feb.	Bermuda	St. Thomas	7	
	21 Feb.	6 Mar.	St. Thomas	Kingston	14	
	11 Mar.	20 Mar.	Kingston	Cristobal	10	
	25 Mar.	28 Mar.	Cristobal	Guantanamo	4	
17D	1 Apr.	9 Apr.	Guantanamo	Guantanamo	9	Gendreau of
	11 Apr.	23 Apr.	Guantanamo	Guantanamo	13	Daystrom Corp.
	25 Apr.	30 Apr.	Guantanamo	Woods Hole	6	
18	15 May	19 May	Woods Hole	Morehead City	5	von Arx
	19 May	2 June	Morehead City	Morehead City	15	
	3 June	18 June	Morehead City	Morehead City	16	
	19 June	21 June	Morehead City	Woods Hole	3	
19	7 July	12 July	Woods Hole	St. Georges	6	B. Ketchum
	14 July	19 July	St. Georges	Woods Hole	6	
	20 July	20 July	Woods Hole	Chelsea	1	Shipyard, repairs
	11 Aug.	11 Aug.	Chelsea	Woods Hole	1	
20	14 Aug.	20 Aug.	Woods Hole	Woods Hole	7	Clarke
21	28 Aug.	28 Aug.	Woods Hole	Chelsea	1	Shelter from
	30 Aug.	30 Aug.	Chelsea	Woods Hole	1	Hurricane Daisy
22	3 Sept.	10 Sept.	Woods Hole	Port-of-Spain	8	Metcalf
	13 Sept.	26 Sept.	Port-of-Spain	Rio de Janeiro	14	
	1 Oct.	5 Oct.	Rio de Janeiro	Rio de Janeiro	5	
	8 Oct.	26 Oct.	Rio de Janeiro	Walvis Bay	19	
	29 Oct.	1 Nov.	Walvis Bay	Luanda	4	
	5 Nov.	14 Nov.	Luanda	Monrovia	10	
	17 Nov.	1 Dec.	Monrovia	Belem	15	
	10 Dec.	15 Dec.	Belem	St. Thomas	6	
	16 Dec.	21 Dec.	St. Thomas	Woods Hole	6	

BEAR ACTIVITIES FOR YEAR 1958

Cruise No.	Depart	Arrive	From	To	Days	Ch. Scientist
182	21 Jan.	24 Jan.	Woods Hole	St. Georges	4	B. Ketchum
	26 Jan.	28 Jan.	St. Georges	Woods Hole	3	
183	6 Mar.	10 Mar.	Woods Hole	Woods Hole	7	Ryther
184	19 Mar.	25 Mar.	Woods Hole	Ft. Lauderdale	7	Daystrom
	26 Mar.	29 Mar.	Ft. Lauderdale	Guantanamo	4	
	1 Apr.	9 Apr.	Guantanamo	Kingston	9	
	11 Apr.	20 Apr.	Kingston	Guantanamo	10	
	21 Apr.	25 Apr.	Guantanamo	Charleston	5	
	28 Apr.	1 May	Charleston	Woods Hole	4	
185	12 May	16 May	Woods Hole	Woods Hole	5	B. Ketchum
186	21 May	26 May	Woods Hole	Woods Hole	6	Cresswell
187	3 June	3 June	Woods Hole	Woods Hole	1	Compass adjustment
188	10 June	11 June	Woods Hole	Woods Hole	2	Frantz/Fraser
189	18 June	25 June	Woods Hole	Woods Hole	8	Cresswell
190	15 July	17 July	Woods Hole	Woods Hole	3	Frantz/Walden
191	18 July	24 July	Woods Hole	Woods Hole	7	Cresswell
192	4 Aug.	15 Aug.	Woods Hole	Woods Hole	12	Schevill/Knott
193	19 Aug.	28 Aug.	Woods Hole	Woods Hole	10	Cresswell
194	28 Aug.	28 Aug.	Woods Hole	Chelsea	1	Shelter from
	30 Aug.	30 Aug.	Chelsea	Woods Hole	1	Hurricane Daisy
195	5 Sept.	8 Sept.	Woods Hole	Woods Hole	4	Bowen
196	15 Sept.	19 Sept.	Woods Hole	Woods Hole	5	Yentsch
197	20 Sept.	21 Sept.	Woods Hole	Woods Hole	2	Voorhis
198	23 Sept.	28 Sept.	Woods Hole	Woods Hole	6	Cresswell
199	6 Oct.	8 Oct.	Woods Hole	Woods Hole	3	Voorhis
200	20 Oct.	21 Oct.	Woods Hole	Woods Hole	2	Voorhis
201	4 Nov.	8 Nov.	Woods Hole	Woods Hole	5	Volkmann
202	12 Nov.	12 Nov.	Woods Hole	Chelsea	1	Shipyard, repairs
	30 Dec.	30 Dec.	Chelsea	Woods Hole	1	

USCGC YAMACRAW ACTIVITIES FOR YEAR 1958

Cruise No.	Depart	Arrive	From	To	Days	Ch. Scientist
8	27 Jan.	3 Feb.	Woods Hole	Key West	8	E. Hays
	3 Feb.	9 Feb.	Key West	Havana	7	
	12 Feb.	13 Feb.	Havana	Key West	2	
	13 Feb.	18 Feb.	Key West	Boston	5	
9	25 Mar.	31 Mar.	Woods Hole	Galveston	7	Hersey
	3 Apr.	9 Apr.	Galveston	Guantanamo Bay	7	
	11 Apr.	18 Apr.	Guantanamo Bay	Kingston	8	
	18 Apr.	23 Apr.	Kingston	Kingston	6	
	25 Apr.	26 Apr.	Kingston	Guantanamo Bay	2	
	27 Apr.	3 May	Guantanamo Bay	Newport, R. I.	7	
	5 May	5 May	Newport	Woods Hole	1	
10	21 June	1 July	Woods Hole	Ponta Delgada	11	Hersey
	3 July	7 July	Ponta Delgada	Gibraltar	5	
	7 July	11 July	Gibraltar	Palma	5	
	14 July	19 July	Palma	Naples, Italy	6	
	23 July	4 Aug.	Naples	Cadiz, Spain	13	
	8 Aug.	11 Aug.	Cadiz	Rota, Spain	4	
	12 Aug.	14 Aug.	Rota	Lisbon	3	
	17 Aug.	24 Aug.	Lisbon	Belfast, Ireland	8	
	29 Aug.	6 Sept.	Belfast	Argentia	9	
	6 Sept.	9 Sept.	Argentia	Boston	4	
11	28 Sept.	5 Oct.	Woods Hole	Jacksonville	8	Hersey
	7 Oct.	16 Oct.	Jacksonville	Savannah	10	

USNS CHAIN ACTIVITIES FOR YEAR 1958

Cruise No.	Depart	Arrive	From	To	Days	Ch. Scientist
(17 November 1958—Placing in service ceremonies. WHOI staff members attended.)						
1	18 Nov.	24 Nov.	Savannah	Woods Hole	7	
2	8 Dec.	13 Dec.	Woods Hole	Bermuda	6	Hersey
	17 Dec.	20 Dec.	Bermuda	Woods Hole	4	
3	23 Dec.	23 Dec.	Woods Hole	East Boston	1	Shipyard, repairs

R4D-6R, BUNO 39106 ACTIVITIES FOR YEAR 1958

Flight No.	Departure and Return	Days Duration	Bases	Scientist in Charge
	2 Jan.–18 Jan.	3	Local flights	
87	19 Jan.		Otis to Charleston AFB	Zeigler
	20 Jan.		Charleston AFB to Key West	
	22 Jan.		Key West to New Orleans	
	23 Jan.		New Orleans local	
	24 Jan.		New Orleans to Brownsville	
	25 Jan.		Brownsville local	
	26 Jan.		Brownsville to Memphis NAS	
	27 Jan.		Memphis to Chicago (Glenview)	
	29 Jan.	11	Glenview NAS to Otis	
88	31 Jan.		Otis to Kindley	Pike
	3 Feb.	4	Kindley to Otis	
	4 Feb.–7 Feb.	2	Local flights	
91	8 Feb.		Otis to Kindley	Pike
	9 Feb.	2	Kindley to Hyannis	
	12 Feb.–14 Feb.	2	Local flights	
94	17 Feb.		Otis to Charleston AFB	Bunker
	18 Feb.		Charleston to Guantanamo	
	19 Feb.		Guantanamo NAS to San Juan	
	20 and 22 Feb.		San Juan local	
	23 Feb.		San Juan to Piarco	
	24 to 28 Feb.		Daily — Piarco local	
	1 Mar.		Piarco to San Juan	
	2 Mar.		San Juan to Miami	
	3 Mar.	15	Miami to Otis	
	5 Mar.–21 Mar.	2	Local flights	
97	24 Mar.		Otis to Savannah	Redfield and
	25 Mar.		Savannah to Glynco NAS	group to attend
	26 Mar.		Glynco local	conference
	27 Mar.		Glynco to Savannah	
	28 Mar.		Savannah local	
	29 Mar.	6	Savannah to Otis	
	31 Mar.–2 May	11	Local flights	
108	5 May		Otis to Moncton N. B.	Bunker/Leahy
	6 May		Moncton to Argentia	
	7 May		Argentia local	
	9 May	5	Argentia to Otis	
	13 May–15 May	3	Local flights	
115	18 May		Otis to Cherry Point	Richardson
	19 to 24 May		Daily — Cherry Point local	
	25 May	8	Cherry Point to Otis	
123	27 May		Otis to Cherry Point	D. Ketchum
	28 May to 1 June		Daily — Cherry Point local	
	2 June	7	Cherry Point to Quonset	
	6 June	1	Local flight	

R4D-6R, BUNO 39106 ACTIVITIES FOR YEAR 1958 (CONTINUED)

Flight No.	Departure and Return	Days Duration	Bases	Scientist in Charge
131	7 June		Otis to Cherry Point	Walden/ Wilkins
	8 to 14 June		Daily — Cherry Point local	
	15 June	9	Cherry Point to Otis	
	17 June–22 Aug.	24	Local flights	
164	25 Aug.		Otis to Kindley	Leahy
	26 Aug.	2	Kindley to Otis	
	3 Sept.-3 Oct.	16	Local flights	
182	4 Oct.		Otis to Miami	Walden/Frantz
	7 and 10 Oct.		Miami local	
	11 Oct.	8	Miami to Otis	
	14 Oct.–7 Nov.	6	Local flights	
192	11 Nov.		Otis to Miami	Bunker/ Woodcock
	12 Nov.		Miami to San Juan	
	13 and 14 Nov.		San Juan local	
	15 Nov.		San Juan to Trinidad	
	16 to 21 Nov.		Trinidad local	
	22 Nov.		Trinidad to San Juan	
	23 Nov.		San Juan to Miami	
	24 Nov.	14	Miami to Otis	
	2 Dec.–8 Dec.	4	Local flights	
197	11 Dec.		Otis to Kindley	Woodcock
	13 Dec.	2	Kindley to Otis	
	17 Dec.–23 Dec.	3	Local flights	

STINSON N-408 ACTIVITIES FOR 1958

January	13	Local flights		
February	3	Local flights		
March	27	Local flights		
April	27	Local flights		
May	34	Local flights		
Passenger flight	19 May		Falmouth to New London	Walden/Vine
			New London to Atlantic City	Walden
			Atlantic City to Kellam, Md.	
			Kellam to Morehead City	
	20 May		Morehead City to Kellam	
			Kellam to Monmouth, N. J.	
			Monmouth to Coonamessett	
June	11	Local flights		
Ferry flight	1 June		Falmouth to Monmouth	
			Monmouth to Kellam, Md.	
			Kellam to Morehead City	
	2 June		Morehead City to Elizabeth City	
			Elizabeth City to Whitehouse, Del.	
			Whitehouse to Cape May	

STINSON N-408 ACTIVITIES FOR 1958 (CONTINUED)

	3 June	Cape May to Westerly	
		Westerly to New Bedford	
		New Bedford to Coonamessett	
July	23 Local flights		
August	15 Local flights		
September	9 Local flights		
Passenger flight	9 Sept.	Falmouth to Bedford	Watkins/Schevill
Passenger flight		Bedford to Portland	
Whale searching		Portland local	Schevill
Whale searching	10 Sept.	Portland local	Backus
Radio check		Portland local	Watkins
Whale searching	11 Sept.	Portland local	Schevill
Whale searching	Sept.	Portland local	Schevill
Whale searching	12 Sept.	Portland local	Schevill/Watkins/Backus
Passenger flight		Portland to Bedford	Schevill/Watkins/Backus
Passenger flight		Bedford to Falmouth	Watkins/Backus
October	9 Local flights		
Ferry flight	6 Oct.	Falmouth to Bedford	
Passenger flight		Bedford to Old Town	Schevill
Passenger flight		Old Town to Caribou	Schevill
Passenger flight		Caribou to Mont Joli	Schevill
Passenger flight		Mont Joli to Forestville	Schevill
Whale hunting	7 Oct.	Forestville local	Schevill
Whale hunting		Forestville local	Schevill
Passenger flight	10 Oct.	Forestville to Mont Joli	Schevill
Passenger flight		Mont Joli to Caribou	Schevill
Passenger flight		Caribou to Portland	Schevill
Passenger flight		Portland to Bedford	Schevill
Ferry flight		Bedford to Hyannis	
Ferry flight	22 Oct.	Falmouth to Portland	Backus/Johnson/Watkins
Ferry flight		Portland to Biddeford	
Passenger flight		Biddeford to Coonamessett	Watkins
Ferry flight		Coonamessett to Portland	
Ferry flight	30 Oct.	Portland to Biddeford	
Whale spotting		Biddeford to Portland	Schevill
Ferry flight		Portland to Biddeford	
Whale spotting	31 Oct.	Biddeford to Portland	Schevill
Whale spotting		Portland local	Schevill
Whale spotting	1 Nov.	Portland local	Schevill
Whale spotting		Portland to Biddeford	Schevill
Whale spotting	2 Nov.	Biddeford to Portland	
Whale spotting		Portland local	
Whale spotting	4 Nov.	Portland local (twice)	
Whale spotting	5 Nov.	Portland local (twice)	
Ferry flight	5 Nov.	Portland to Hyannis	
November	4 Local flights		
December	16 Local flights		

Publications

During 1958, forty-nine papers bearing contribution numbers were published. See Author, Subject-Locality, Taxonomic Index published in 1957 for a complete list up to 1956.

No. 784 ALFRED C. REDFIELD. Preludes to the Entrapment of Organic Matter in the Sediments of Lake Maracaibo. In: Habitat of Oil. Amer. Assoc. Petrol. Geologists, June, 1958.

No. 849 DUNCAN C. BLANCHARD. Electrically Charged Drops from Bubbles in Sea Water and their Meteorological Significance. *Jour. Meteorol.*, Vol. 15, No. 4, pp. 383–396. 1958.

No. 874 J. B. HERSEY. Electronics in Oceanography. (Dated 1957.) In: Advances in Electronics and Electron Physics. Vol. 9, pp. 239–295. Academic Press, Inc., New York. 1957.

No. 877 FLOYD M. SOULE and J. E. MURRAY. Physical Oceanography of the Grand Banks Region and the Labrador Sea in 1956. (Dated 1957.) *U. S. Coast Guard Bull.*, No. 42, pp. 35–100. 1957.

No. 900 ARTHUR R. MILLER. The Effects of Winds on Water Levels on the New England Coast. *Limnol. and Oceanogr.*, Vol. 3, No. 1, pp. 1–14. 1958.

No. 906 JOHN H. RYTHER and CHARLES S. YENTSCH. Primary Production of Continental Shelf Waters off New York. *Limnol. and Oceanogr.*, Vol. 3, No. 3, pp. 327–335. 1958.

No. 915 JOANNE S. MALKUS. On the Structure and Maintenance of the Mature Hurricane Eye. *Jour. Meteorol.*, Vol. 15, No. 4, pp. 337–349. 1958.

No. 920 A. H. WOODCOCK. The Release of Latent Heat in Tropical Storms due to the Fall-Out of Sea-Salt Particles. *Tellus*, Vol. 10, No. 3, pp. 355–371. 1958.

No. 923 ALFRED C. REDFIELD. The Inadequacy of Experiment in Marine Biology. In: Perspectives in Marine Biology. Symposium held at Scripps Inst. of Oceanogr., Univ. Cal., March 24–April 2, 1956. 1958.

No. 928 H. BARNES and MARGARET BARNES. The Rate of Development of *Balanus balanoides* (L.) Larvae. *Limnol. and Oceanogr.*, Vol. 3, No. 1, pp. 29–32. 1958.

No. 930 WILLIAM S. VON ARX. "Dister": A Displacement Sequence Stereoscope. *Jour. Meteorol.*, Vol. 15, No. 2, pp. 230–231. 1958.

No. 931 WILLIAM S. VON ARX. Synoptic Photography. *Weather, Royal Meteorol. Soc.*, London, pp. 179–197. 1958.

No. 932 HENRY B. BIGELOW and WILLIAM C. SCHROEDER. Four New Rajids from the Gulf of Mexico. *Bull. Mus. Comp. Zool.*, Vol. 119, No. 2, pp. 201–233. 1958.

No. 933 G. VERONIS. On the Transient Response of a β-plane Ocean. *Jour. Oceanogr. Soc. Japan*, Vol. 14, No. 1, pp. 1–5. 1958.

No. 934 WILLIAM S. RICHARDSON and CHARLES H. WILKINS. An Airborne Radiation Thermometer. *Deep-Sea Research*, Vol. 5, pp. 62–71. 1958.

No. 935 JOYCE C. LEWIN, R. A. LEWIN and D. E. PHILPOTT. Observations on *Phaeodactylum tricornutum*. *Jour. Gen. Microbiology*, Vol. 18, No. 2, pp. 420–426. 1958.

No. 936 JOYCE C. LEWIN. The Taxonomic Position of *Phaeodactylum tricornutum*. *Jour. Gen. Microbiology*, Vol. 18, No. 2, pp. 427–432. 1958.

No. 938 HARRY J. TURNER. The Effect of Nutrition on the Color of the Callus of *Polinices duplicatus*. *The Nautilus*, Vol. 72, No. 1, pp. 1–3. 1958.

No. 939 HENRY STOMMEL, A. B. ARONS and A. J. FALLER. Some Examples of Stationery Planetary Flow Patterns in Bounded Basins. *Tellus*, Vol. 10, No. 2, pp. 179–187. 1958.

No. 940 HOWARD L. SANDERS. Benthic Studies in Buzzards Bay. I. Animal-Sediment Relationships. *Limnol. and Oceanogr.*, Vol. 3, No. 3, pp. 245–258. 1958.

No. 942 FRANK J. MATHER, III and ROBERT H. GIBBS, JR. Distribution of the Atlantic Bigeye Tuna, *Thunnus obesus*, in the Western North Atlantic and the Caribbean Sea. *Copeia*, 1958, No. 3, pp. 237–239. 1958.

No. 943 W. V. R. MALKUS and G. VERONIS. Finite Amplitude Cellular Convection. *Jour. Fluid Mech.*, Vol. 4, Pt. 3, pp. 225–260. 1958.

No. 944 J. B. HERSEY and M. S. RUTSTEIN. Reconnaissance Survey of Oriente Deep (Caribbean Sea) with a Precision Echo Sounder. *Bull. Geol. Soc. Amer.*, Vol. 69, pp. 1297–1304. 1958.

No. 945 ALAN J. FALLER. An Optical Method for the Measurement of Surface Waves in the Laboratory. *Trans. Amer. Geophys. Union*, Vol. 39, No. 4, pp. 716–720. 1958.

No. 946 BOSTWICK H. KETCHUM, JOHN H. RYTHER, CHARLES S. YENTSCH and NATHANIEL CORWIN. Productivity in Relation to Nutrients. *Rapp. et Proc.-Verb., Cons. Internat. Explor. de la Mer*, Vol. 144, pp. 132–140. 1958.

No. 949 H. BARNES and MARGARET BARNES. Further Observations on Self-Fertilization in *Chthamalus* sp. *Ecology*. Vol. 39, No. 3, p. 550. 1958.

No. 951 TAKASHI ICHIYE. A Theory of Vertical Structure of Density in the Ocean. *Jour. Oceanogr. Soc. Japan*, Vol. 14, No. 2, pp. 35–40. 1958.

No. 952 TAKASHI ICHIYE. Tsunami Waves — What are known about them — How we have studied them. *The Port Engineer*, Vol. 7, No. 1, pp. 5–19 [1–14]. Calcutta, India. 1958.

No. 953 HENRY STOMMEL. Letter to the Editors: The Abyssal Circulation. *Deep Sea-Research*, Vol. 5, pp. 80–82. 1958.

No. 955 G. C. MCLEOD. Delayed Light Action Spectra of Several Algae in Visible and Ultraviolet Light. *Jour. Gen. Physiol.*, Vol. 42, No. 2, pp. 243–250. 1958.

No. 957 JAMES M. MOULTON. The Acoustical Behavior of some Fishes in the Bimini Area. *Biol. Bull.*, Vol. 114, No. 3, pp. 357–374. 1958.

No. 958 ROBERT L. MILLER and JOHN M. ZEIGLER. A Model Relating Dynamics and Sediment Pattern in Equilibrium in the Region of Shoaling Waves, Breaker Zone, and Foreshore. *Jour. Geology*, Vol. 66, No. 4, pp. 417–441. 1958.

No. 959 FLOYD M. SOULE and R. M. MORSE. Physical Oceanography of the Grand Banks Region and the Labrador Sea in 1957. *U. S. Coast Guard Bull.*, No. 43, pp. 81–131. 1958.

No. 960 JAMES M. MOULTON. A Summer Silence of Sea Robins, *Prionotus* spp. *Copeia* 1958, No. 3, pp. 234–235. 1958.

No. 963 TAKASHI ICHIYE. The response of a Stratified Bounded Ocean to Variable Wind Stresses. *Oceanogr. Mag.*, Vol. 10, No. 1, pp. 19–63. Tokyo, Japan. 1958.

No. 965 THEODORE J. SMAYDA. Biogeographical Studies of Marine Phytoplankton. *Oikos*, Vol. 9, No. 2, pp. 158–191. 1958.

No. 968 BOSTWICK H. KETCHUM and VAUGHAN T. BOWEN. Biological Factors Determining the Distribution of Radio-isotopes in the Sea. Proc. 2nd Internat. Conference on the Peaceful Uses of Atomic Energy, Geneva, Sept. 1–15, 1958. Paper UN402-01C724, 11 pp. 1958.

No. 969 JOANNE STARR MALKUS. On the Structure of the Trade Wind Moist Layer. *Papers in Physical Oceanography and Meteorology*, Vol. 13, No. 2, pp. 1–47. 1958.

No. 970 VAUGHAN T. BOWEN and T. T. SUGIHARA. Marine Geochemical Studies with Fallout Radioisotopes. Proc. 2nd Internat. Conference on the Peaceful Uses of Atomic Energy, Geneva, Sept. 1–15, 1958. Paper UN403-01C902, 12 pp. 1958.

No. 972 CHARLES S. YENTSCH and RALPH F. VACCARO. Phytoplankton Nitrogen in the Oceans. *Limnol. and Oceanogr.*, Vol. 3, No. 4, pp. 443–448. 1958.

No. 976 ALFRED C. REDFIELD. The Biological Control of Chemical Factors in the Environment. *Amer. Scientist*, Vol. 46, No. 3, pp. 205–222. 1958.

No. 977 C. GODFREY DAY. Surface Circulation in the Gulf of Maine Deduced from Drift Bottles. U. S. Fish and Wildlife Service, Vol. 58, *Fish. Bull.* 141, pp. 443–472. 1958.

No. 978 JOHN H. RYTHER, CHARLES S. YENTSCH and RALPH F. VACCARO. The Dynamics of a Diatom Bloom. *Biol. Bull.*, Vol. 115, No. 2, pp. 257–268. 1958.

No. 979 A. T. SPENCER and D. C. BLANCHARD. A Portable Raindrop Recorder for Semi-Continuous Determination of Size Distributions. *Trans. Amer. Geophys. Union*, Vol. 39, No. 5, pp. 853–857. 1958.

No. 981 TAKASHI ICHIYE. On Convective Circulation and Density Distribution in a Zonally Uniform Ocean. *Oceanogr. Mag.*, Vol. 10, No. 1, pp. 97–135. Tokyo, Japan. 1958.

No. 983 P. F. SCHOLANDER. Counter Current Exchange: A Principle in Biology. *Hvalrådets Skrifter*, No. 44, 24 pp. Oslo. 1958.

No. 994 GILBERT L. VOSS. The Cephalopods Collected by the R/V Atlantis during the West Indian Cruise of 1954. *Bull. Mar. Sci., Gulf and Caribbean*, Vol. 8, No. 4, pp. 369–389. 1958.

No. 998 H. BARNES. Regarding the Southern Limits of *Balanus balanoides* (L.) *Oikos*, Vol. 9, No. 2, pp. 139–157. 1958.

No. 1001 L. R. BRESLAU and H. E. EDGERTON. The Luminescence Camera. *Jour. Biol. Photogr. Assoc.*, Vol. 26, No. 2, pp. 49–58, 1958.

Personnel

The following persons were awarded grants, honoraria or fellowships during 1958:

JOHN P. BARLOW	Cornell University
DUNCAN C. BLANCHARD	Massachusetts Institute of Technology
HENRI CARON	Clark University
WILLIAM A. DAWSON	Harvard University
JOHN L. EDGAR	Antioch College
MICHAEL GARSTANG	Florida State University
ILMO HELA	Institute of Marine Research, Helsinki, Finland
BRUCE HOPPER	Alabama Polytechnic Institute
TAKASHI ICHIYE	Central Meteorological Observatory, Tokyo, Japan
ALEXANDRE IVANOFF	École Supérieure de Physique et de Chimie, Paris, France
JAMES B. LACHEY	University of Florida
BENJAMIN B. LEAVITT	University of Florida
JOSEPH LEVINE	Massachusetts Institute of Technology
FREDERICK C. MARLAND	Agricultural and Mechanical College of Texas
SHEINA MARSHALL	Marine Station, Millport, Isle of Cumbrae, Scotland
GEORGE C. MATTHEISSEN	Harvard University
GUY C. MCLEOD	Harvard University
SIGERU MOTODA	Hokkaido University, Hokkaido, Japan
DANIEL R. NORTON	Sprague Electric Company
ANDREW P. ORR	Marine Station, Millport, Isle of Cumbrae, Scotland
PETER D. PARKER	Amherst College
OWEN PHILLIPS	The Johns Hopkins University
CAROL ANN REICHERT	Antioch College
ALLAN R. ROBINSON	Harvard University
ELLEN RUBY	Antioch College
RUDOLF S. SCHELTEMA	University of North Carolina
DAVID H. SHONTING	Massachusetts Institute of Technology
THEODORE J. SMAYDA	University of Oslo
JOSEPH STAMPFLI	University of Michigan
JOHN H. STEELE	Marine Laboratory, Aberdeen, Scotland
EDWARD D. STROUP	The Johns Hopkins University
T. FERRIS WEBSTER	Massachusetts Institute of Technology
PETER WANGGERSKY	Yale University
JUDITH WITKIN	Hunter College

We were honored during the year by receiving visits from distinguished colleagues from other countries. Among these the following spent a considerable period of time:

Dr. Bruce B. Benson	Amherst College
Mr. Thanon Charenlarb	Royal Thai Navy, Thailand
Mr. Charles P. Cook	Commercial Products, Inc.
Dr. Edgar L. Deacon	Commonwealth Scientific and Industrial Research Organization, Australia
Dr. G. E. R. Deacon	National Institute of Oceanography, England
Mr. Robert L. Erath	Grumman Aircraft Corporation
Mr. Richard Fay	United States Weather Bureau
Dr. Sadahyo M. Hori	Japanese Hydrographic Office
Dr. Kiyashi Horikawa	University of Tokyo, Japan
Dr. S. Ishiguro	Nagasaki Marine Observatory, Japan
Dr. Alexandre Ivanoff	École Supérieure de Physique et de Chimie, Paris, France
Dr. Sheina M. Marshall	The Marine Station, Millport, Scotland
Mr. Jack McLachlan	Oregon State College
Dr. Sigeru Motoda	Hokkaido University, Japan
Mr. Donald G. Murphy	Oregon State College
Dr. Andrew P. Orr	The Marine Station, Millport, Scotland
Dr. Alberto Sáez	National University of Zuila, Venezuela
Dr. Rolf Heinz Siepmann	Kiel, Germany
Mr. Norman Dennis Smith	National Institute of Oceanography, England
Mr. Gordon L. Stamm	Naval Research Laboratory
Dr. Raymond G. Stross	University of Wisconsin
Mr. John H. Steele	The Marine Laboratory, Aberdeen, Scotland
Dr. Roman Vishniac	New York City
Dr. George C. William	Michigan State University
Dr. Jacques S. Zaneveld	Caraibisch Biologisch Institut, Curaçao, Netherlands West Indies

The following personnel, in addition to those otherwise listed, were in the employ of the Institution for the twelve-month period ending December 31, 1958.

Ethel B. Allen	Elmer M. Barstow	Warren O. Bowman
Nellie E. Andersen	Martin R. Bartlett	Mabel D. Bradley
Judith A. Ashmore	Edward R. Baylor	Alvin L. Bradshaw
Nadine N. Athearn	Henry G. Behrens	W. Scott Bray
Cyril Backus	James S. Bercaw	Joseph C. Brown
Harold Backus	Stanley W. Bergstrom	Edwin T. Bryant
Jeanne M. Backus	Robert N. Betterley	John Q. Bumer
Rose L. Barbour	Forrest W. Blake	Charles A. Burnham
Ann H. Barrett	Ralph H. Bodman	John P. Cabral
Joseph R. Barrett, Jr.	Georg Boltz	John V. Cabral

Henry A. Cain
Sybil A. Campbell
Angelo Cangiamilia
Alwyn L. Carter
David F. Casiles
James J. Cavanaugh
Constance W. Chadwick
Margaret A. Chaffee
Agnes C. Chalmers
John A. Christian
Edward H. Chute
William H. Clarkin
Arthur D. Colburn, Jr.
J. William Condon
Hans Cook
Jerome M. Cotter
Brooks W. Coughlin
Marion W. Crocker
Elizabeth S. Curl
Lee C. Davis
C. Godfrey Day
Joseph V. Day
Charles D. Densmore
Richard H. Dimmock
Paul E. Dingwell
William M. Dunkle, Jr.
Stanley N. Eldridge
Davis A. Fahlquist
Louis F. Fernandez
Alice H. Ferris
George A. Ferris
Frederick E. Fielden
Don R. Fink
Stanley O. Fisher
Richard A. Fitzgerald
Donald B. Foster
John G. Fraser
Gloria S. Gallagher
Rosemary Gallagher
William F. Gallagher
Fred Gaskell
James E. Gifford
Barbara L. Gill
Norman Gingrass
Florence E. Glaeser
Carlton W. Grant
James E. Hanks
Kaleroy L. Hatzikon
Carlyle R. Hayes
George L. Hilton
Lloyd D. Hoadley
Harry L. Hodgkins
Sloat F. Hodgson
Paul M. Howe
Myron P. Howland, Jr.
Paul C. Howland
Charles J. Hubbard
Otis E. Hunt
Charles S. Innis, Jr.
Delmar R. Jenkins
Alfred C. John
Barbara Johnson
David C. Johnson
Henry R. Johnson
Yolande A. Kahler
Richard L. Keeler
Willard E. Ketchen
John A. Kostrzewa
Joseph L. Lambert
Delia M. Lavin
Joseph Levine
Thomas Lyon
Colin Dhu Macafee
Duane E. Maddux
George E. Martin
Francis S. Matthews
Clement L. McCann, Jr.
Margaret McCloskey
Eileen M. McCormack
Joseph M. McElliott
David A. McGill
Florence K. Mellor
Francis Minot
Juanita A. Mogardo
Wendell Mordy
Clayton B. Morehouse
Kenneth Morrison
Robert G. Munns
Eugene J. Mysona
James S. Nicolson
Richard V. Olson
Mary Ortolani
Betty P. Ostiguy
Michael Palmieri, Jr.
Gale G. Pasley, Jr.
Helen F. Phillips
Samuel F. Pierce
John M. Pimental
Stanley E. Poole
Mary Dorothy Rogers
Nicholas Rosa
Lawrence Rose
Michael Rosetti
James E. Salthouse
John D. Sandblom
Margaret Scharff
John L. Schilling
Elizabeth H. Schroeder
Harry H. Seibert
William Shields
William S. Shultz
Luther V. Slabaugh
David Snowman
Eloise M. Soderland
Otto Solberg
James H. Souza
Matthew R. Souza
Elizabeth C. Sparks
Charles E. Spooner
Robert J. Stanley
Richard Stansfield
Thomas R. Stetson
Stephen L. Stillman, Jr.
John W. Stimpson
Thomas O. L. Sutcliffe
Herman Tasha
Louis J. Tometich
Wendell K. Tripp
Carl R. von Dannenberg
Jean D. Walker
Robert H. Walker, Jr.
Robert G. Weeks
Phillips B. Wilde
Charles H. Wilkins
George A. Williams
Edward Wilson
Esther N. Wilson
Carleton R. Wing
Warren E. Witzell
Fred C. Woodward, Jr.
Javan D. York
Anita M. Young

V. TREASURER'S REPORT FOR THE YEAR 1958

The accounts for the year 1958 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds at December 31, 1958 was $3,389,617, of which $954,054 represented accumulated net gains from sales of investments. The market value of endowment assets on the same date, including real estate at book amount, was $5,091,900. Endowment fund investments and income received therefrom are summarized in Schedule D.

Income received on endowment assets, including interest charged on the advance to current funds, was $178,607 for the year ended December 31, 1958, compared with $180,593 the previous year. This income represented a return on endowment fund assets of 3.5% at year-end market quotation, 5.3% on the book amount and 7.3% on the contributed amount of the endowment fund.

Endowment income was allocated for 1958 operating expenses at the rate of 5.5% of the book amount of original endowment funds, or $133,129. Of the balance of endowment income, $45,478, there was transferred to the income and salary stabilization reserve $44,810 and to unexpended balance of gifts from Oceanographic Associates as income from investment of life memberships $668. Advances were made from endowment funds to current funds during portions of the year, but all such advances were paid off prior to the end of the year.

Deferred charges amounting to $239,364 (see balance sheet for breakdown) represented expenditures for the benefit of future years. A proportionate part of these charges will be added to current costs, or other appropriate accounts, as the benefits accrue.

The details of unexpended balances of gifts and receipts for research, other than Government, are shown in Schedule C. The income from Woods Hole Oceanographic Associates for the year amounted to $49,606. Expenditures and allocations to specific projects of $15,261, plus $4,042 of life memberships transferred to endowment assets, increased the balance on hand of $59,615 at December 31, 1957 to $89,918 at December 31, 1958.

The Institution's 1958 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to $76,344. The trust is administered by three trustees. The balance of the old Retirement Fund, administered by the Treasurer, amounted to $68,140 as at December 31, 1958. This balance consisted of amounts on deposit in sixteen savings bank accounts held in trust for ten members of the plan. No contributions to the old plan were made in 1958. Interest totalling $2,167 was credited to the savings accounts during the year.

In the financial statements that follow it is interesting to note that for each dollar spent 79.4 cents was spent for direct costs of research activity, 15.8 cents for general and administration expenses and 4.8 cents for plant operation and miscellaneous. Administrative salaries amounted to only 6.4 cents of each dollar of total expense. Included in the 15.8 cents for general and administration expenses was 3.6 cents for staff benefits (group insurance, social security taxes, and contributions to retirement plan).

BALANCE SHEET

As at December 31, 1958

ASSETS

Endowment Fund Assets:		
Investments (Schedule D):		
Bonds (market quotations $1,765,105)		$1,847,508
Stocks (market quotations $3,196,478)		1,411,792
Real estate		128,417
		3,387,717
Cash		1,900
		3,389,617
Plant Fund Assets (note):		
Laboratory plant and equipment		602,429
Vessels and equipment		266,707
Other property		161,541
Total plant		1,030,677
Cash	$185,654	
Receivable from sale of securities	132,685	318,339
		1,349,016
Current Fund Assets:		
Cash		38,735
Accounts receivable:		
U. S. Government	$300,734	
Other	14,719	315,453
Unbilled costs on research contracts:		
U. S. Government	325,628	
Other	42,043	367,671
Supply inventories		28,700
Deferred charges:		
Reconditioning boat Crawford	190,468	
Electronic equipment	24,844	
Other	24,052	239,364
		989,923
		$5,728,556

LIABILITIES

Endowment Funds:		
Unrestricted		$2,016,143
For upkeep of plant		419,420
Accumulated net gain on sale of investments		954,054
		3,389,617
Plant Funds:		
Invested in plant		1,030,677
Fund for purchase and reconditioning of boat Aries		318,339
		1,349,016
Current Liabilities and Funds:		
Accounts payable and accrued expenses		163,336
Contribution payable to employees' retirement plan and trust		76,344
Unexpended balances of gifts and grants for research:		
Government	$174,817	
Other (Schedule C)	98,825	273,642
General fund:		
General plant and equipment reserve	244,084	
Income and salary stabilization reserve	211,399	
Unappropriated	21,118	476,601
		989,923
		$5,728,556

Note — Since 1945 the Institution has provided for depreciation of plant assets other than vessels at annual rates of 2% on buildings and 5% to 33⅓% on equipment, carrying the amounts to general plant and equipment reserve.

STATEMENT OF INCOME, OPERATING EXPENSES AND UNAPPROPRIATED GENERAL FUND

For the Year Ended December 31, 1958

INCOME:		
Receipts for sponsored research:		
For direct costs		$ 2,260,277
For indirect costs		561,294
Fees for use of facilities		102,389
		2,923,960
Endowment income (Schedule D)	$178,607	
Less amounts added to income and salary stabilization reserve ($44,810) and unexpended balance of gifts from Oceanographic Associates as income from investment of life memberships ($668)	45,478	133,129
Miscellaneous		10,129
Total income availed of		3,067,218
OPERATING EXPENSES:		
Direct costs of research activity (Schedule A):		
Salaries and wages		1,043,073
Vessel operations		593,330
Materials and services		637,693
Travel		132,696
		2,406,792
Indirect costs:		
General and administration (Schedule B)	480,467	
Plant operation (Schedule B)	138,207	
Miscellaneous	7,269	625,943
Total operating expenses		3,032,735
EXCESS OF INCOME		34,483
Additions to plant from current funds — books and equipment purchased		25,212
		9,271
UNAPPROPRIATED GENERAL FUND, JANUARY 1, 1958		11,847
UNAPPROPRIATED GENERAL FUND, DECEMBER 31, 1958		$ 21,118

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1958

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. GOVERNMENT CONTRACTS	$ 923,938	$563,005	$548,482	$121,685	$2,157,110
OTHER SPONSORED RESEARCH	42,861	3,993	49,340	6,973	103,167
Total direct costs of sponsored research.	966,799	566,998	597,822	128,658	2,260,277
INSTITUTION RESEARCH	76,274	26,332	39,871	4,038	146,515
Total direct costs of research	$1,043,073	$593,330	$637,693*	$132,696	$2,406,792

*Includes grants and fellowships:

Other sponsored research	$11,750
Institution research	20,375
	$32,125

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1958

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:		
Staff benefits:		
Contributions to retirement plan		$76,344
Social security taxes		27,309
Group insurance		5,133
		108,786
Shop services		90,202
Housing, net		3,477
ADMINISTRATION EXPENSES:		
Salaries and wages	$192,587	
Insurance, travel, supplies and other	85,415	278,002
		$480,467

PLANT OPERATION

SALARIES AND WAGES		47,251
PROVISION FOR DEPRECIATION (credited to general plant and equipment reserve)		31,449
OTHER REPAIR COSTS	17,851	
HEAT, LIGHT AND POWER	22,140	
AMORTIZATION OF COST OF ELECTRONIC EQUIPMENT	6,211	
OTHER	13,305	59,507
		$138,207

SCHEDULE C

SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH

Year Ended December 31, 1958

	Unexpended Balance January 1, 1958	Received	Expended		Other Charges or (Credits)	Unexpended Balance December 31, 1958
			Direct Costs	Indirect Costs		
American Society of Limnology and Oceanography		$ 605	$ 478	$ 127		
Bermuda Biological Station for Research		3,143	3,025	118		
Commonwealth of Massachusetts — shellfish propagation	$ 1,783	20,144	13,941	7,986		
Esso Research and Engineering Company — foraminifera cataloging		2,892	1,773	1,119		
Manufacture, sale, and calibration of instruments		38,650	44,090	9,496	($8,329) (a) (6,605) (b) (2) (c)	
Lou Marron science fund — pelagic fish studies	254	4,000	3,853	15		$ 386
Massachusetts Institute of Technology — Institute for Atmospheric Research		9,112	6,592	2,520		
Munitalp Foundation — meteorological research	1,700		1,550	150		
National Academy of Sciences:						
Project Nobska		183	183			
Project Piccard		596	596			
National Lead Company		4,755	4,581	174		
David Nutt — Blue Dolphin		75	75			
Oceanographic Associates:						
Deuterium studies	697		466	180		51
Peruvian core analysis	3,106		2,843	263		
Fellowships		11,750	11,750			
Other		2,250	2,250			
Unappropriated	59,615	49,606 (14,000)			4,042 (d) 1,261 (e)	89,918
Research Corporation — instrument fund	2,402				(285) (c)	2,687
Sundry work for others		5,156	4,026	1,130		
Towns of Brookhaven and Islip, New York — Great South Bay Survey		2,000	1,095	122		783
Other gifts		5,000				5,000
	$69,557	$145,917	$103,167	$23,400	($9,918)	$98,825

(a) Charged to income. (b) Charged to other projects. (c) Sales. (d) Life memberships added to endowment. (e) Miscellaneous expenditures.

SCHEDULE D

SUMMARY OF INVESTMENTS

As at December 31, 1958

	Book Amount	% of Total	Market Quotation	% of Total	Income
BONDS:					
U. S. Government	$ 383,796	11.33	$ 375,385	7.37	$ 6,361
Railroad	505,337	14.92	471,581	9.27	20,958
Public utility	395,684	11.68	373,720	7.34	17,571
Industrial	407,654	12.03	385,843	7.58	13,287
Financial and investment	155,037	4.58	158,576	3.12	8,957
Total bonds	1,847,508	54.54	1,765,105	34.68	67,134
STOCKS:					
Preferred	252,508	7.45	239,325	4.70	14,003
Common:					
Public utility	370,056	10.92	772,523	15.18	24,244
Industrial	608,731	17.97	1,819,663	35.75	55,084
Miscellaneous	180,497	5.33	364,967	7.17	13,706
Total common stocks	1,159,284	34.22	2,957,153	58.10	93,034
Total stocks	1,411,792	41.67	3,196,478	62.80	107,037
REAL ESTATE	128,417	3.79	128,417*	2.52	2,845
Total investments	$3,387,717	100.00	$5,090,000	100.00	177,016
INTEREST ON ADVANCE TO CURRENT FUNDS CHARGED TO MISCELLANEOUS OPERATING EXPENSE					1,591
TOTAL ENDOWMENT FUND INCOME					$178,607

*At book amount.

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1958 and the related statement of income, operating expenses and unappropriated general fund for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances; however, it was not practicable to confirm receivables from United States Government departments, as to which we have satisfied ourselves by means of other auditing procedures.

In our opinion, the accompanying financial statements present fairly the position of Woods Hole Oceanographic Institution at December 31, 1958 and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

Boston, Massachusetts
April 28, 1959

LYBRAND, ROSS BROS. & MONTGOMERY