

THE
WOODS HOLE OCEANOGRAPHIC
INSTITUTION

REPORT FOR THE YEAR
1955

1956

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PRESIDENT OF THE CORPORATION, 1950-1955

“He has given unstintingly of time and effort. His judgment, ability, and leadership have strengthened the Institution and brought it greatly increased recognition and support.” (*Excerpt from Board of Trustees’ Resolution of August 11, 1955.*)

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(As of December 31, 1955)

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To serve until 1956

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ALFRED C. REDFIELD, Woods Hole Oceanographic Institution, Woods Hole, Mass.
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EDWARD H. SMITH, Woods Hole Oceanographic Institution, Woods Hole, Mass.

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- HORACE S. FORD, 77 Massachusetts Avenue, Cambridge 39, Mass.
- JOHN A. GIFFORD, 14 Wall Street, New York 5, N.Y.
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- HUDSON HOAGLAND, Worcester Foundation for Experimental Biology, 222 Maple Avenue, Shrewsbury, Mass.
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- AUGUST B. KINZEL, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y.
- MILFORD R. LAWRENCE, Siders Pond Road, Falmouth, Mass.
- LAMAR R. LEAHY, 910 Park Avenue, New York, N.Y.
- ALFRED L. LOOMIS, Room 2420, 14 Wall Street, New York, N.Y.
- ARNAUD C. MARTS, 521 Fifth Avenue, New York, N.Y.
- ROBERT E. McCONNELL, 230 Park Avenue, New York, N. Y.
- 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.
- ALFRED C. REDFIELD, Woods Hole Oceanographic Institution, Woods Hole, Mass.
- LAWRASON RIGGS, Riggs, Ferris and Geer, Room 1201, 74 Trinity Place, New York 6, N.Y.
- GEORGE H. RICHARDS, 68 William Street, New York, N.Y.
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III. RESEARCH STAFF

(As of December 31, 1955)

Director

EDWARD H. SMITH

Senior Scientists

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

BOSTWICK H. KETCHUM, Senior Oceanographer.

ALFRED C. REDFIELD, Professor of Physiology, Harvard University; Senior Oceanographer.

Scientists

VAUGHAN T. BOWEN, Geochemist.

DEAN F. BUMPUS, Oceanographer.

ANDREW F. BUNKER, Meteorologist.

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

WILLARD DOW, Electronics Engineer.

FREDERICK C. FUGLISTER, Physical Oceanographer.

JOHN B. HERSEY, Physical Oceanographer.

JOANNE S. MALKUS, Meteorologist.

WILLEM V. R. MALKUS, Physical Oceanographer.

CHARLES B. OFFICER, JR., Geophysicist.

FRANCIS A. RICHARDS, Chemical Oceanographer.

WILLIAM S. RICHARDSON, Physical Chemist.

CARL-G. ROSSBY, Director, Institute of Meteorology, University of Stockholm; Meteorologist.

HAROLD E. SAWYER, Research Engineer.

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

MARY SEARS, Planktonologist.

HENRY M. STOMMEL, Physical Oceanographer.

HARRY J. TURNER, JR., Marine Biologist.

ALLYN C. VINE, Physical Oceanographer.

WILLIAM S. VON ARX, Physical Oceanographer.

ALFRED H. WOODCOCK, Oceanographer.

Research Associates

WILLIAM D. ATHEARN, Research Associate in Geology.

RICHARD H. BACKUS, Research Associate in Marine Biology.

DUNCAN C. BLANCHARD, Research Associate in Meteorology.

ROBERT H. BROCKHURST, Research Associate in Physics.

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

ELIZABETH T. BUNCE, Research Associate in Physics.

JOSEPH CHASE, Research Associate in Meteorology.

JOSEPH H. CONNELL, Research Associate in Marine Biology.
 ALAN J. FALLER, Research Associate in Meteorology.
 HARLOW G. FARMER, JR., Research Associate in Hydraulics.
 DAVID H. FRANTZ, JR., Research Associate in Engineering.
 HENRY R. JOHNSON, Research Associate in Underwater Acoustics.
 JOHN W. KANWISHER, Research Associate in Biophysics.
 SYDNEY T. KNOTT, JR., Research Associate in Engineering.
 ROBERT A. LUFBURROW, Research Associate in Physics.
 WILBUR MARKS, Research Associate in Physical Oceanography.
 FRANK J. MATHER III, Research Associate in Oceanography.
 WILLIAM G. METCALF, Research Associate in Physical Oceanography.
 ARTHUR R. MILLER, Research Associate in Physical Oceanography.
 DAVID M. OWEN, Research Associate in Underwater Photography.
 F. CLAUDE RONNE, Research Associate in Photography.
 JOHN H. RYTHER, Research Associate in Marine Biology.
 HOWARD L. SANDERS, Research Associate in Marine Biology.
 KARL E. SCHLEICHER, Research Associate in Physics.
 HERBERT SMALL, Research Associate in Electronics.
 ALLARD T. SPENCER, Research Associate in Engineering.
 RALPH F. VACCARO, Research Associate in Microbiology.
 ROBERT G. WALDEN, Research Associate in Electronics.
 GEOFFREY G. WHITNEY, JR., Research Associate in Physical Oceanography.
 L. VALENTINE WORTHINGTON, Research Associate in Physical Oceanography.
 RALPH F. WYRICK, Research Associate in Underwater Acoustics.
 JOHN W. ZEIGLER, Research Associate in Marine Geology.

Associate Scientists

ARNOLD B. ARONS, Professor of Physics, Amherst College; Associate in Physical Oceanography.
 JOHN C. AYERS, Assistant Professor of Oceanography, Department of Conservation, Cornell University; Associate in Marine Biology.
 DAVID L. BELDING, Professor of Bacteriology and Experimental Pathology (Emeritus), Boston University; Consultant, U. S. Fish and Wildlife Service; Associate in Marine Biology.
 HENRY B. BIGELOW, Professor of Zoology (Emeritus), Harvard University and Research Oceanographer, Museum of Comparative Zoology; Associate in Oceanography.
 CORNELIA L. CAREY, Associate Professor in Botany (retired), Barnard College; Associate in Marine Bacteriology.
 L. A. EARLSTON DOE, Associate in PHYSICAL OCEANOGRAPHY.
 WILLIAM MAURICE EWING, Professor of Geology, Columbia University; Director, Lamont Geological Observatory; Associate in Geophysics.
 CHARLES J. FISH, Professor of Marine Biology, University of Rhode Island and Director, Narragansett Marine Laboratory; Associate in Marine Biology.
 BERNHARD HAURWITZ, Professor of Meteorology and Chairman of the Department of Meteorology and Oceanography, New York University; Associate in Meteorology.
 LOUIS W. HUTCHINS, Associate in Marine Biology.
 BENJAMIN B. LEAVITT, Assistant Professor of Biological Sciences, University of Florida; Associate in Marine Biology.
 RAYMOND B. MONTGOMERY, Associate Professor of Oceanography, Chesapeake Bay Institute, Johns Hopkins University; Associate in Physical Oceanography.
 HILARY B. MOORE, Associate Professor in Marine Biology and Assistant Director, Marine Laboratory, University of Miami; Associate in Marine Biology.

- JAMES M. MOULTON, Assistant Professor of Biology, Bowdoin College; Associate in Marine Biology.
- JEROME NAMIAS, Chief, Extended Forecast Section, U. S. Weather Bureau, Associate in Meteorology.
- DANIEL R. NORTON, Chemist, Sprague Electric Company, North Adams, Mass.; Associate in Chemical Oceanography.
- MARY ALYS PLUNKETT, Associate Professor of Chemistry, Vassar College; Associate in Chemistry.
- ROY L. RATHER, JR., Associate in Underwater Acoustics.
- GORDON A. RILEY, Associate Professor of Marine Biology, Yale University; Associate in Marine Physiology.
- HELEN M. ROBERTS, Assistant Professor of Mathematics, University of Connecticut; Associate in Mathematics.
- MARSHALL SCHALK, Assistant Professor of Geology and Geography, Smith College; Associate in Geology.
- IRVING I. SCHELL, Department of Physics, Tufts College; Associate in Meteorology.
- WILLIAM E. SCHEVILL, Research Associate in Zoology, Museum of Comparative Zoology; Associate in Oceanography.
- PER F. SCHOLANDER, Professor of Zoophysiology, University of Oslo; Associate in Physiology.
- GEORGE T. SCOTT, Professor of Zoology, Oberlin College; Associate in Physiology.
- PAUL F. SMITH, Electronics Engineer, Rockefeller Institute for Medical Research; Associate in Physical Oceanography.
- FLOYD M. SOULE, Principal Senior Oceanographer, U. S. Coast Guard; Associate in Physical Oceanography.
- ATHELSTAN F. SPILHAUS, Dean, Institute of Technology, University of Minnesota; Associate in Physical Oceanography.
- THOMAS T. SUGIHARA, Assistant Professor of Chemistry, Clark University; Associate in Geochemistry.
- PARKER D. TRASK, Research Engineer, University of California; Associate in Submarine Geology.
- EDMOND E. WATSON, Professor of Physics, Queen's University, Kingston, Ontario; Associate in Physical Oceanography.
- RAYMOND WEXLER, Research Meteorologist, Harvard University and Massachusetts Institute of Technology; Associate in Meteorology.
- GEORGE P. WOOLLARD, Professor of Engineering Geology and Geophysics, University of Wisconsin; Associate in Geophysics.

ADMINISTRATIVE STAFF

EDWARD H. SMITH, Director
ALFRED C. REDFIELD, Associate Director.
RONALD A. VEEDER, Assistant to the Director.
JAN HAHN, Public Information.
JOHN MCGILVRAY, Business Manager.
NORMAN T. ALLEN, Administrator.
HARVEY MACKILLOP, Controller.
JOHN F. PIKE, Port Captain.
DELMAR R. JENKINS, Purchasing Agent.
OTIS E. HUNT, Laboratory Services.

IV. DIRECTOR'S REPORT

Introduction

WHEN one chronicles the important events of a year's work at an Institution such as ours, one often asks the question, how do the achievements of one year compare with the number and value of those of other years? Are we maintaining the rate of progress, and what, if anything, distinguishes the year 1955 from 1954, or from that of earlier years? What will 1956 yield in new discoveries as our ships bring home their collections of data and the laboratory conducts further experiments, practical and theoretical.

One barometer of the activity of an oceanographic institution is the number of days at sea of its research ships and the days in which its aircraft have been airborne. In this respect 1955 compares well with the others. ATLANTIS spent 234 days at sea, BEAR 147, CARYN 75, and the Institution's one research airplane was in flight some portion of each one of 114 days.

Another index of activity is the number of scientific papers which have been published during the course of the year. The total in 1955 of 72 exceeds by over 20 per cent that of 1954, and is nearly double the number of 1953 or 1952.

Oceanography, dealing as it does with varied processes on a vast scale in nature, provides the scientist with an endless fund of interesting problems to solve. The subjects for investigation seem infinite, as the building blocks of today form the larger structures of tomorrow. This report records briefly the effort of one institution, in one year of research, as it strives to add more and more information to Man's store of knowledge of the sea.

Among the scientific tasks of 1955 which have engaged our attention are:

- (a) The Atlantis Marine Geological Expedition to Peru, 1955
- (b) Continued acoustical investigations of the ocean
- (c) Inauguration of long-range statistical studies of East Coast shelf waters
- (d) Continued field investigations of the western North Atlantic deep-water
- (e) Investigation of sea level changes accompanying severe gales and hurricanes
- (f) Continued theoretical studies of oceanic circulation.

A specific event, which over the years is bound to be reflected in future sea operations of the Institution, was the acquisition of, and title to, the ex-Coast Guard Cutter CRAWFORD. A further report is contained in the section devoted to vessels. Leading to this transaction, and also of equal if not

greater significance, was the recognition of the Institution by the Office of Education of the U. S. Department of Health, Education, and Welfare, as an accredited institution of higher education.

The financial status of the Institution continued to show satisfactory improvement as is evidenced by the Treasurer's report. The level of both income and expense witnessed an increase during the year, as the costs of salary increases and the new retirement plan, to mention two major items, became offset partially by new contracts with Government agencies both military and civilian. It was pleasing to note, furthermore, the additional support during the year from private sources, the most substantial of which came from the Associates of the Woods Hole Oceanographic Institution. More extended remarks on the subject of the Associates is contained in the section devoted to acknowledgments.

Research

So far as the circulation problem is concerned, during the past year advances have been made on several fronts, and we have begun to consider seriously the challenges and opportunities that will soon be presented to us by the International Geophysical Year. Although the oceanographic field work probably will not officially begin until November 1957, it may well be advisable to initiate some earlier exploratory work.

As now planned, the emphasis during I. G. Y. is to be on learning more exactly the rates of circulation in the deeper waters of the South Atlantic. As a first step we have been re-examining the pertinent existing North Atlantic data and the ATLANTIS has been in the process of securing more very deep sections and reoccupying old ones.

Mr. Stommel and Mr. Fuglister have recently been studying intensively the very complete north-south section from Nova Scotia to Venezuela occupied last year by Mr. Worthington. The problem is to locate the most probable depth of no motion. They have tried various mathematical tricks and are gaining considerable insight as to why these do not produce the desired result. This is the fundamental problem that must be cracked before we can go to the South Atlantic with any assurance that we can interpret the new observations more convincingly than the Germans were able to do roughly thirty years ago.

The geostrophic equation alone, no matter how complete the temperature and salinity data, does not enable one to calculate the deep transport with any certainty of arriving at a reliable result. Although the deep velocities are probably low, such huge quantities of water are involved that enormous transports can be found or the direction of motion can change, depending on the starting point of the calculations. We evidently need additional

information and the question is: just where in the system should this be obtained and what are the most practical sorts of new observations that might be secured?

From Mr. Worthington's standpoint the new deep sections are very satisfactory indeed, for they continue to show a steady and uniform loss of dissolved oxygen from the deep water over wide areas of the North Atlantic and Caribbean. The fact that his results indicate that the deep water is so much younger than claimed by those using the Carbon-14 techniques does not particularly worry him, for he has thousands of observations and as yet the Carbon-14 people have only a few of which they feel reasonably certain. In the end, of course, this discrepancy must be cleared up and preferably before the start of the International Geophysical Year. The carbon measurements indicate that the water increases in age with depth, the oxygen values show a rather uniform and much younger water mass everywhere below 2500 meters, and the text books say that the oldest water should be located well above the bottom. There have been many lively discussions on these matters during recent months. Mr. David Frantz has been busy developing new instruments which we hope can help to settle the problem one way or another.

Mr. Stommel spent most of the winter at The Institute for Advanced Study at Princeton working on various new mathematical models of ocean circulation and especially he was successful in interesting Dr. Charney, Dr. Veronis and others there to do likewise. Mr. Stommel and Dr. Veronis developed a theory of the response of the ocean to transient wind systems and have submitted it to the *Journal of Marine Research*. It is hoped that this theory will shed light on the dynamics of the ocean circulation in a way that will be helpful, and perhaps critical, in formulating plans for sea-level observations during the International Geophysical Year. Dr. Walter Munk of the Scripps Institution of Oceanography and Mr. Stommel have been corresponding about these matters.

Mr. Stommel's visit to the Institute also played a part in stimulating Dr. Jule G. Charney's new inertial boundary-layer theory of the Gulf Stream, a marked departure from the viscous boundary-layer theory of Munk, and it seems that this new theory has more physical plausibility than the old one. In addition, through collaboration with Mr. Stommel, Dr. George Morgan of Brown University re-examined the basic theoretical structure of our understanding of the wind-driven circulation, in particular the role of internal friction, stratification, and inertial terms. Dr. Morgan has also contributed some alternative formulations of the inertial boundary-layer Gulf Stream theory.

During the period January 1-April 1, Mr. Hodgson was in Bermuda

tending the thermometric cable. We now have 13 months of half-hourly temperature readings near the top of the main thermocline. It seems evident from these data that during the winter stormy period there are large internal waves traveling away from the storm centers at about 200 km/day. From a practical point of view these internal waves may be of importance in detecting the presence of hurricanes in the area between the Cape Verde Islands and the Windward Islands. Present plans are to maintain operation of the Bermuda cable in order to get more precise information concerning the disturbances set up in the main thermocline by isolated storms.

As part of his doctorate thesis at Massachusetts Institute of Technology Dr. von Arx successfully modeled the wind-driven circulation of the southern hemisphere oceans, using the seven-foot diameter flat basin. With the help of Mr. Faller and others he has also cleaned up a good deal of the theory of rotating hydraulic models. Due to limitations of funds he was forced to reconsider the design of the driving mechanism for the 24-foot rotating basin and this turned out to be fortunate, for he conceived a most clever and effective way of gaining absolutely steady rotation with no need for heavy bearings or a complex control of the driving motor's speed. The new system, which is basically a fluid clutch, is so much cheaper to construct that we were able to go ahead immediately and the large basin will soon be in operation. Incidentally, this most ingenious device seems to have important applications in astronomy, for it is capable of forming parabolic reflectors of almost any size.

The planning of a new, long-range program in coastal circulation is well advanced. The central core of continuing observations will be financed by funds supplied by the Fish and Wildlife Service through the Saltonstall-Kennedy Bill, but it is also expected that other parts of our over-all program can be modified so as to contribute additional support. Mr. Bumpus is organizing the new observational program. Assisted by Mr. Day he has also been working on the coastal currents south of Cape Hatteras.

Basically the problem is to find out under what circumstances coastal circulation is sufficiently changed so as to modify the environmental factors to a degree that is significant in the commercial fisheries. In coastal circulation the main energy source comes from the inflow of river water. How much does this have to vary before the current system is markedly disturbed? How much do the winds and the climate have to change to do likewise? A new paper by Dr. Ketchum on the cross-continental shelf mixing coefficients, provides a fine starting point to this problem, as well as do the new 400-day temperature recorders and current meters developed by Mr. Frantz. We are most hopeful of making a significant contribution to fisheries biology during the next few years.

Wave research continues to be active. Mr. Marks is reaching the end of the analysis of the RTSK observations secured more than a year ago. So far he has mainly been studying pitch and roll separately but recently he has begun to take up coupled motions. He has also spent considerable time working on the excellent wave pictures secured on Project SWOP when two airplanes obtained some stereo-pairs of a large area of the sea surface with waves 12 to 14 feet high. Mr. Farmer has been working on means of measuring the high-frequency end of the wave spectrum in preparation for a joint operation with representatives of the Naval Research Laboratory which was carried out off Bermuda in October. We have installed the British ship-borne wave recorder in the ATLANTIS, and this for the first time will give us reliable data on the opposite end of the wave spectrum.

Dr. Richardson has completed the development of a new tool for the study of near-surface physical phenomena. He has equipped a powered dory so that it can be operated as a drone, either from a plane or from a ship. He has given it sensitive, near-surface thermal probes. The dory both records and telemeters the incoming information. In this way we hope to explore convection cells, slicks, convergences, and other small-scale surface phenomena without the disturbing influence of a large hull.

The visit of Dr. Gifford Ewing last summer from Scripps has stimulated interest in the near-surface mechanisms whereby the sea takes up energy from the winds. We suspect that at least half a dozen effects are involved, some well established and some only dimly seen. Dr. Ewing has for some years been observing the surface of the Pacific from a plane and has studied especially the manner in which internal waves produce slicks. We hope that through his visit a more effective observational program of near-surface phenomena can be evolved.

Dr. Malkus and his wife remained in Europe until December. Their time was most profitably spent. During the autumn Mr. Ronne joined Dr. Joanne Malkus at the meteorological laboratory of the Imperial College in order to lend his special skills in photography to some laboratory studies of convective motions.

Mr. Woodcock and Mr. Blanchard have been busy with the extensive cloud data secured last winter at Hawaii. It will be remembered that this was a large-scale, cooperative assault on the physics of warm clouds. It will be some time before all the results are fully digested.

Mr. Bunker has continued to interest himself in the diffusion of heat and momentum into the lower atmosphere and its effects upon large-scale phenomena. The years spent in developing the PBY aircraft as a calibrated meteorological tool are now paying off in observations of heat flow and stress obtained over the open ocean. In the early part of the year numerous flights

were made over the Atlantic Ocean between the mainland and the island of Bermuda. While many of these observations are still being reduced, the few already studied are giving valuable information concerning the method of transport of heat by convective parcels in the region below the cloud level. These observations are serving as a check on the existing theories of heat flow and indicate new approaches to the study.

Mr. Ballenzweig, who joined the project for the year that Dr. Malkus was on leave of absence at Imperial College, has been working on the larger scale aspects of the heat flow problem over the ocean. His first study was of the modification of the air ahead of and behind cold fronts as they moved out from the continent over the waters of the Atlantic. One fact brought out by this study is that the local heating of the air by the warm waters in the vicinity of the Gulf Stream are of minor importance in producing Type A cyclogenesis which reaches its maximum in this area.

Under the terms of one of the contracts between the Woods Hole Oceanographic Institution and the Office of Naval Research, a continuing program of cooperation has been established between the Woods Hole Oceanographic Institution and the Institute of Meteorology of the University of Stockholm. This program is directed by Professor Carl-G. Rossby who divides his time between the two institutions.

The work of the Stockholm group is concentrated on problems of numerical weather prediction by means of high-speed computers. This should ultimately lead to a technique for the prediction of wind stresses at the sea surface. In addition, work is now in progress on the development of a method for the prediction of storm tides along the North Sea coast (in cooperation with the Deutsches Hydrographisches Institut) and on the general theory of the dynamics of currents (air or ocean). One group of investigators at the Stockholm institute are now making detailed studies of the composition of atmospheric precipitation. These studies have raised important questions concerning the nature of the physical-chemical processes taking place in the surface layers of the ocean and may thus necessitate even closer research cooperations between the two institutions.

A new contract, with Dr. Arnold Arons as principal investigator, has recently been concluded with the Division of Biology and Medicine of the Atomic Energy Commission. Motivated by questions regarding physical processes and water motions taking place in the ocean depths (questions which have long been formulated but which are rapidly becoming more urgent and pressing because of speculation regarding deep ocean disposal of high-level radioactive wastes), this project will undertake fundamental research along lines which have not hitherto been pursued at the Institution.

The first stage of the work is now getting under way with Professor Bruce

Benson of Amherst College preparing to perform a systematic mass spectroscopic study of dissolved gases in ocean water. The Nier-type mass spectrometer, constructed in the Amherst College physics department, has been made available for this program. With the perfection of the technique and the eventual hiring of a full-time technician to run analyses, it is hoped to make the instrument available to other groups at the Institution as well. By a systematic study of isotope contents and fractionations in samples from different geographical locations and various depths, it is hoped to learn more about the time and space histories of various water masses.

Preliminary studies are also being made of certain instrumental problems such as the development of a scintillation counter for use in making *in situ* studies of radioactive background and for eventual general use in underwater tracer experiments, etc.

Dr. Officer and his associates are hard at work on the analysis of the refraction profiles secured last winter in the West Indian region. Such steady progress has been made in submarine geophysical techniques during recent years that there is little doubt that many new and exciting discoveries will come out of the study of last winter's extensive data, but it is too early to try to predict what these may be. Dr. Officer has accepted a promising position at the Rice Institute. Fortunately he will have considerable time for research during the winter and plans to return here next summer.

Dr. Hersey has had a very busy winter and spring. Not only has he had the responsibility of keeping our own acoustical research program on an even keel, but also as Chairman of the Navy's committee on deep ocean sound propagation he has had considerable influence on the national program in underwater acoustical research.

Mr. Zeigler has completed a paper on the recently discovered chain of sea mounts extending southeastward from Georges Bank. We hope very much that we can obtain permission for this to be declassified. He and Mr. Athearn have also been working up the Georges Banks' long cores obtained last summer. These are throwing much light on the recent geological history of this area. Additional material will be gained next summer as more permanent radar platforms are erected.

Mr. Zeigler will continue Mr. Stetson's study of the changes in the outer beaches of Cape Cod. Supplementary measurements on Martha's Vineyard have recently been undertaken. A parallel investigation on Arctic beaches is now in its second summer at Point Barrow, Alaska, under the direction of Dr. Marshall Schalk.

Each year the Institution endeavors to carry out at least one major sea expedition aimed at one of the five recognized fields of oceanographic activity. In 1955 this refers to "The Atlantis Marine Geological Expedition

to Peru and Chile, 1955" which explored the deep trenches that parallel the west coast of South America between Talara, Ecuador, in 5° south latitude, to 80 miles south of Antofagasta, Chile, in 25° south. Mr. Henry C. Stetson was the Chief Scientist on board the ATLANTIS until his unfortunate death at sea on December 3rd when the remainder of the cruise was carried out under the direction of Dr. Parker D. Trask. The primary object of the expedition was the collection of sediment cores, a total of 100 being secured along twelve profiles running normal to the coast distances as much as 90 miles offshore. The area, which had had little previous marine geological attention prior to our survey, is probably one of the most interesting regions in the world of recent and existing tectonic activity. Continuous soundings throughout the ATLANTIS' track with the precision echo-sounder recorder developed at the Institution by Mr. Sydney T. Knott, Jr., and others, testifies to the extremely rugged submarine topography. For example a trench 500 miles in length, three miles in width, and 25,000 feet deep, the walls of which rose 1,500 feet in one-fourth of a mile, was recorded on the fathometer trace. Balancing this deep escarpment towers the Andes to 20,000 feet above the sea less than 125 miles distance. The study of the data and the preparation of the scientific results for publication will require at least two years.

This is by no means a complete account of our physical and geological program, and it tends to give too optimistic a picture. We continue to uncover many more problems than we solve. The operation of our vessels drains off too much of the free funds. The income available for the development of instruments is entirely inadequate in view of the magnitude of the problems we are trying to solve and the limitations of the classical tools of physical oceanography. There is general awareness of these problems in the Office of Naval Research, but the factors resulting in "project research" are the stronger. We must resist this trend in every way that we can so that our staff can exercise imagination and enterprise, and not be too much influenced by budgetary considerations.

The cruise of the ATLANTIS to the Caribbean during the winter provided an opportunity for Dr. F. A. Richards and Mr. R. F. Vaccaro to examine the chemical conditions in the Cariaco Trench. This is a depression in the continental shelf of northern Venezuela, more than 1300 meters in depth, separated from the Caribbean by a sill with depths of about 120 meters. Unlike other similar depressions in the ocean floor the Cariaco Trench proves to be entirely stagnant, and the condition of the water approaches that found in the Black Sea and other smaller enclosed inland seas and bays. Dr. Richards obtained valuable information on the quantities of organic matter which have decomposed in this basin, quantities which proved to be

about 50 per cent more than found in the deep Atlantic, though much less than found in the Black Sea. A comparison of the productivity of the surface water of the Cariaco Trench determined by Dr. Ryther on this cruise with the accumulation of organic derivations at depth indicates that the water has remained *in situ* for at least 100 years. The Cariaco Trench should prove to be a valuable laboratory in which to study the processes of decomposition which take place in the deep sea. The constancy of the bottom temperature would make this a good place to measure the rate of heat transfer through continental rock, using the methods which have been employed for such measurements in the deep ocean.

With Grace (Creitz) Fraser, Dr. Richards has continued investigations of chlorophyll and other plankton pigments, relating their occurrence to nutrient supply and age in cultures and to phylogenetic groups and environmental conditions in natural populations. A paper describing improvements in the method for determining plankton pigments is now in press.

A study of oxygen-density relationships in the Caribbean and Gulf of Mexico has been undertaken by Miss Betty Ann Morse and Dr. Richards. The method appears to differentiate between Caribbean and Gulf of Mexico water emerging from the Straits of Florida.

On this same cruise Dr. Ryther found that the addition of the nutrients nitrogen and phosphorus to the nutrient poor surface waters increased the productivity of the water. The carbon 14 method of determining productivity gave lower values than the oxygen method for the nutrient poor water, but the enriched samples gave better agreement. This suggests that the nutrient deficiency explanation of the discrepancy between the two methods is applicable to oceanic conditions. Observations on the relationship between the rate of photosynthesis and light intensity have made it possible to calculate the relative rate of photosynthesis at various depths in the ocean. Measurement at sea of the transparency of the water and of photosynthesis at one light intensity can be translated to the total production of the entire water column.

Dr. Bowen has continued his studies of the neutron activation analysis of the rare earth content of sea water. Analysis of surface water samples has given significant counting rates on extracts but indicates that larger samples will have to be prepared in order to permit radiochemical identification of the fission products. A study of the production of organic phosphorus compounds by plankton algae in culture has been initiated. It is hoped that identification of these phosphorus compounds will be of value in interpreting the ecological cycle of phosphorus in the sea.

Many years ago the Institution pioneered in the study of the penetration of light into the ocean through Dr. George L. Clarke's efforts. Recently this

matter has received new interest as the result of the precise information being obtained by acoustical methods on the vertical migration of plankton in response to the daily variation in sunlight. Dr. Clarke has recently developed a new photometer employing a photomultiplier cell which is sensitive to light one thousand billionth as intense as sunlight. The instrument was tested from the Marine Laboratory of the University of Miami during the early winter. It measured sunlight to the greatest depths obtained, 1900 feet, and detected moonlight down to 1700 feet. Not only were the flashes of light produced by luminescent animals recorded for the first time but at extreme depths at night a general background of weak illumination was observed which is believed to be due to the combined effects of myriads of luminescent organisms.

During June Dr. N. G. Jerlov of the University of Göteborg, Sweden, an expert on submarine illumination, visited the Institution for two weeks. On the occasion of his visit a very profitable series of conferences were held at which the physical and biological problems relating to light penetration into the sea were discussed. Dr. James Snodgrass of the Scripps Institution of Oceanography and Dr. Hilary B. Moore of the University of Miami participated with Dr. Jerlov and members of the staff in these discussions.

The Institution's study of the hydrography of Lake Maracaibo being made for the Creole Petroleum Corporation has been completed. A final item in the investigation was an examination of the chemical composition of the bottom sediments of the Lake. The results throw additional light on the importance of the oxygen content of the water, and on the rate of sedimentation in the entrapment of organic matter in sedimentary deposits, and thus on the initial processes leading to the formation of petroleum. Mr. L. A. Earlston Doe, an associate on our staff, has been appointed Oceanographer by the Creole Petroleum Corporation and will continue the studies we have been making of Lake Maracaibo.

The hurricanes which visited Woods Hole last year called attention forcefully to oceanographic phenomena which have received little systematic attention; namely, the effects of such storms on sea levels. Dr. A. C. Redfield had collected some data on the storms of 1938 and 1944, and immediately after the current storms he and Mr. A. R. Miller gather such information as they could on the water levels developed by them. Because of the dense population of the shores affected, more detailed information now exists on the inundations caused by the New England storms than are available for any other parts of the world. A report summarizing their findings has been prepared at the request of the U. S. Weather Bureau and has been circulated for the use of weather forecasters during the present season. Mr.

Miller is continuing studies of the effects of wind on water levels under a contract with the Weather Bureau while Dr. Redfield has served as a consultant to both the Weather Bureau and the Beach Erosion Board in connection with their hurricane problems.

Dr. B. H. Ketchum has prepared a valuable paper on the circulation of the water on the continental shelf between Cape Cod and Cape Hatteras. By employing methods developed for studying the circulation of estuaries, in which the river water is used as a tracer, he has found that although the net movement of water along the coast is southward as a definite coastal current, a large part of the fresh water introduced by the rivers escapes directly to the outer sea by lateral mixing processes. This fresh water is replaced by saltier oceanic water to such an extent that the water of the coastal current actually becomes more saline as it progresses in spite of the continued addition of river water. With Dr. Richards he has continued the study of the distribution of plant nutrients in the equatorial Atlantic. They have developed a method to differentiate between the accumulations of local origin and those transported into the region. Collections of total phosphorus samples have been made on several recent cruises and have been analyzed by Mr. Nathaniel Corwin. The description of the distribution is now fairly complete for the western North Atlantic Ocean.

Mr. William C. Schroeder has written a report of the results of the exploration of the continental slope for fishes, which has engaged his attention during recent years. It will be recalled that these expeditions which have extended from Nova Scotia to the offing of Cape Charles have not only brought to light information on the distribution of many species of scientific interest, but have also led to the discovery of potential fishery resources for the redfish, red crab, and lobster.

Mr. Frank J. Mather III participated in a cruise of the Fish and Wildlife Service in the Gulf of Mexico and western Caribbean Sea to determine the effectiveness of long-line fishing in those waters. It was discovered that the Atlantic big-eye tuna, formerly known only from east of the Azores, occurred in the Caribbean Sea and that the true albacore, the most valuable of all the tunas, was present in fair abundance. Mr. Mather has been granted a leave of absence to enable him to make fishery studies for the government of the Virgin Islands. During his absence the program of studies on the migration of tuna will continue under the guidance of Mr. William C. Schroeder.

Dr. Richard H. Backus, with Mr. Stewart Springer of the Fish and Wildlife Service, has prepared a paper on the natural history of the white-tipped shark. This fish is ubiquitous in the warm waters of the ocean beyond the 100-fathom contour and is perhaps one of the most abundant species of shark in the

sea. With Mr. Malcolm S. Gordon he has published a valuable report on the fishes of Labrador.

Dr. Scholander and Dr. William E. Schevill have written a very interesting account of the vascular arrangements which prevent excessive heat loss from the fins of whales when in cold water.

Dr. Scholander and Dr. John W. Kanwisher visited Hebron, Labrador, in March in order to supplement the studies made the preceding summer on the resistance of fish and other marine organisms to freezing. Dr. Kanwisher took part in an extensive cruise of the R. V. HORIZON of the Scripps Institution of Oceanography to the tropical Pacific during the fall in order to make physiological studies of oceanic animals.

It is to be regretted greatly that Dr. Scholander has given up his position at the Institution to become Professor of Zoophysiology at the newly-founded Zoophysiology Institute, University of Oslo. Dr. Levie Van Dam has resigned his position as Research Associate in Physiology to become associated with the Academy of Natural Sciences in Philadelphia and to serve as Chief Biologist at the Philadelphia Aquarium.

Mr. H. J. Turner's report to the Commonwealth of Massachusetts on work done on shellfisheries this year contains a final account of his studies on the rock crab fishery of Boston Harbor. Of particular interest are the results of experiments in which large numbers of marked crabs were recovered after release, which show that this crab, unlike some others, does not indulge in extensive migrations. The study as a whole provides the Commonwealth with valuable information for use in regulating this fishery.

On June 22-23 a conference was held in the Laboratory of Oceanography on the Disposal of Radioactive Wastes at Sea. This conference, arranged by Professor C. E. Renn of Johns Hopkins University as a follow-up on a similar meeting last summer, brought together representatives of this and other oceanographic institutions, of the Atomic Energy Commission, and of other agencies concerned with evaluating the problem of sea disposal of the wastes expected to result from the industrial development of atomic power.

A collection of scientific papers, prepared under the editorship of Dr. Mary Sears, was published in honor of Professor Henry B. Bigelow. The volume contains contributions from Dr. Bigelow's many scientific associates and students, not only at Harvard and at Woods Hole but throughout the scientific world. It has been published as a supplement to the current volume of *Deep-Sea Research*. Because of his close association with the Woods Hole Oceanographic Institution, from its founding to the present day, it is planned to distribute copies of this volume as Part II of *Collected Reprints* of the Institution for 1955.

Among the biologists who have worked at the Institution during the present year the following may be mentioned:

Dr. Benjamin B. Leavitt, Associate Professor at the University of Florida, who studied the zooplankton associated with the scattering layer; Dr. Milton A. Miller, Associate Professor at the University of California at Davis, who is examining the isopods collected from navigation buoys during the wartime fouling surveys; Dr. James B. Moulton, Assistant Professor at Bowdoin College, who investigated the acoustical responses of fish; Dr. Emil Witschi, Professor of Zoology at State University of Iowa, who is studying the auditory mechanisms of aquatic vertebrates; Dr. Mary A. Plunkett, Associate Professor of Chemistry at Vassar College, who is examining the chemical composition of marine sediments; Dr. Leon S. Cierieszko, Associate Professor of Chemistry at University of Oklahoma, who is interested in the organic substances present in marine animals; and Dr. Colm O'h Eocha of University College, Galway, who is interested in the pigments of the red algae.

Mr. Joseph H. Connell and Dr. Howard L. Sanders joined the staff as Research Fellows in Biology in September.

During the autumn Dr. John C. Ayers of Cornell University spent a sabbatical leave at the Institution. He has written a very valuable paper on the application of the methods of dynamic oceanography to the circulation of fresh-water lakes.

Publications

Seventy-two papers bearing contribution numbers have been published in 1955.

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Several semi-popular scientific articles have appeared in periodicals under the authorship of members of the staff. To list a few from among these:

STOMMEL, HENRY M., Anatomy of the Atlantic Ocean. *Scientific American*, January 1955, Vol. 192, No. 1, pp. 30-36.

STETSON, HENRY C., The Continental Shelf. *Scientific American*, March 1955, Vol. 192, No. 3, pp. 82-86.

The pamphlet OCEANUS has been published by the Institution quarterly throughout the year to keep the Associates in touch with the activities and research at Woods Hole. Although numerous requests have been received for subscription privileges, it is desired, at least for the present, to keep OCEANUS primarily for the Associates and for their continued interest in our scientific studies of the sea.

After a lapse of more than a decade the practice of issuing an Annual Announcement by the Institution was resumed. Among other features the Announcement, which was distributed to the principal colleges and uni-

versities, informed them of the opportunities for students to gain a practical training and education in oceanographic research.

The Authors' Index listing all Contributions of the Institution, first published in 1950, is being re-issued to include all papers through 1955. It is cross-indexed by subjects to facilitate reference.

Vessels and Airplanes

Winter-time operations in northern waters can accomplish little with our small and weak-powered ships. One of the strong reasons advocating the construction of modern seaworthy oceanographic ships is the need of winter-time observations.

Following the practice of recent years, the field work was shifted south when ATLANTIS and CARYN sailed the middle of January on a two and one-half months geophysical reconnaissance of the island arc of the Caribbean Sea. A series of seismic profiles were made as ATLANTIS and CARYN alternated in shot and listening positions until the completion of the survey in March when they parted company off St. Thomas.

The ATLANTIS, developing a reflection profile north of the Greater Antilles, proceeded to Charleston, South Carolina, out of which port she operated with BEAR until entering Munro's Yard, Boston, the first week in May.

Again ATLANTIS was at sea at the end of June recording wave observations off the island of Bermuda. The end of the year found her cruising the west coast of South America engaged in a two months marine geological expedition. This was ATLANTIS' debut in the Pacific. During the year she was at sea a total of 234 days.

The CARYN, on parting company with ATLANTIS in March, returned home to Woods Hole arriving on April 15th. Due largely to the stringency of boat operating funds the CARYN was decommissioned at the Institution's waterfront pier, where she remained for the balance of the year. The fact that she had always been marginal with respect to her limitations on space, speed, and cruising radius, caused the further retention of CARYN to be questionable. She was offered for sale but the year's end witnessed her still at the dock with no purchaser in view.

The BEAR departed Woods Hole on 31 January to join the Hudson Laboratory's ship ALLEGHANY and to work out of Guantanamo with a submarine on acoustical studies. From there she proceeded to Charleston, South Carolina, in company with the VEMA, and then joined ATLANTIS returning with her to Woods Hole the first week in May. For the remainder of the year BEAR made short trips out and into Woods Hole, first to assist in surveying bottom sites on Georges Bank and later to engage in many

sound transmission studies south of Martha's Vineyard. The BEAR, with her relatively spacious main deck for electronic equipment, has proved a useful, short cruising craft for the Institution.

The PBY airplane also proved its worth as an oceanographic tool. Operations were interrupted in February and March by the need to replace PBY-6A 46683 with a rebuilt airplane of the same type, number 64107, but a full schedule ensued thereafter for the remainder of the year. Among the missions carried out mention is made of several flights to photograph the changing outline of ocean beaches on which project studies are being conducted. Airborne radiation surveys of the Gulf Stream, low-level turbulence meteorological observations of coastal air masses, and other dynamic studies were some of the varied and interesting field operations. From August until the middle of October the airplane was especially active in conducting an extensive magnetometer reconnaissance of the West Indies-Caribbean area, and thence the entire coastal United States from Texas to Maine.

The smaller Stinson airplane was used on short flights in connection with sea-salt nuclei field investigations. In order to carry out this work special equipment is installed similar to the larger observational PBY.

ASTERIAS, the smallest of our fleet, was employed on short trips out of Woods Hole. The ASTERIAS would be used more by the staff were it available at a lower per diem cost. The high cost tends to discourage its use and this unfortunately in turn raises the price.

The need to replace our vessels with those especially designed for oceanographic field service has witnessed certain limited progress this year. Members of the Staff have participated in the deliberations of a steering committee organized by the Office of Naval Research; preliminary drawings and a general description have been prepared. As the year ends it is rumored that the Navy is including funds for more detailed design studies in its annual ship construction appropriation for an oceanographic research ship.

Plant

The Institution's property in land and buildings has received usual care and maintenance. The stringency of funds, however, experienced during a part of this year reduced somewhat expenditures on alterations and improvements.

No new property was added during the year but there is, however, an awareness noted to provide for the future growth of the Institution by taking advantage of real estate opportunities whenever they may appear. The Scientific Advisory Committee in its report to the Board of Trustees recommended the appointment of a Special Committee on Long Range Growth, and the Chairman, Mr. Milford R. Lawrence, made the first report to the

Trustees at their Annual Meeting in August, 1955. Certain sites were suggested as being advantageous for the Institution to acquire but no action was taken other than to request the committee to continue its investigations.

The East Boston water-front property of the Institution, which was reported last year as a donation by the General Foods Corporation, was offered for sale at a reduced price in order to attract a buyer. The valuation of \$276,000 established on the property for taxation purposes by the City of Boston was reduced to \$168,000 and this action assisted to facilitate in the sale of a small parcel to the New Street Realty Company in December for the sum of \$5,000.

Last year a report was made of the damage inflicted to our water-front property by Hurricane Carol, August 31st. During the winter of 1955, while the vessels were absent in the south, repair of the pier was accomplished. The cost, totaling somewhat less than \$25,000, covered not only the actual hurricane damage but included additional repairs necessitated by deterioration over the years. The small pier extending from the west sea wall was enlarged to provide safer berthing accommodations for small craft.

The hurricane damage to our structures on the land at Nonamessett Island leased for the storage of explosives, was repaired with the exception of the small pier still being worked on as the year ended.

Speaking of hurricanes, we became quite conscious of them — Connie on August 10–13; Diane on August 15–18; and Ione on September 17–20. Earlier in the season a hurricane bill indicating the precautions to be taken prior to, and on arrival of, a hurricane was distributed to the personnel. As a result of the three threatening hurricanes, much valuable time was lost from regular pursuits, both in the securing of our plant property and in the removal of our ships to safer harbors.

In the main laboratory building the oil heating furnaces were refitted to gas installation,— the anticipated saving in fuel costs amounting to approximately one-half that of the oil-type burners.

The former grocery store, a part of the so-called "Hall property" across the street from our main building, is now utilized as a storage for equipment and supplies. It serves as a more convenient place than the "barn" on the rear of our village property which is used for dead storage and heavier equipment.

The cafeteria at Challenger House remained closed throughout the year except for the reception and lunch provided for the Trustees on August 11.

Personnel

At their twenty-sixth Annual Meeting the Members of the Corporation re-elected the following Trustees to serve until 1959; namely,

JAMES S. COLES
CARL H. ECKART

ROSS G. HARRISON
MILFORD R. LAWRENCE

HARLOW SHAPLEY
FRANCIS C. WELCH

At the Trustees' Meeting, which followed immediately that of the Corporation, the resignation of Dr. Arnaud C. Marts as President of the Corporation was accepted with much regret. Mr. Raymond Stevens, whose name was placed in nomination, was elected unanimously and by acclamation as President of the Corporation. The following was entered upon the record:

"Resolved that the Board of Trustees of the Woods Hole Oceanographic Institution at this their 26th Annual Meeting make formal recognition of their great appreciation for the service rendered the Institution by Arnaud C. Marts as President from August 1950 to August 1955. Throughout this period, when other demands on him have been abnormally heavy, he has given unstintingly of time and effort. His judgment, ability and leadership have strengthened the Institution and brought it greatly increased recognition and support. The Trustees wish to record the affection and respect he has inspired and in forwarding a copy of this resolution to him convey their good wishes."

The Board re-elected Dr. Henry B. Bigelow as Chairman of the Board, and the following were elected as new members of the Corporation:

C. LLOYD CLAFF
KENNETH S. COLE
HENRY B. DUPONT

HUDSON HOAGLAND
AUGUSTUS B. KINZEL
JULIUS A. STRATTON

J. H. VAN VLECK
THOMAS J. WATSON, JR.

The Research Staff in 1955 numbered 217. As of July 1, 1955 the persons associated with the Institution were tabulated as follows:

RESEARCH STAFF	1954	1955
Full time:		
Scientists and Technicians:		
At Woods Hole.....	94	86
Off Campus.....	21	17
Secretaries and Clerks.....	7	7
Part time:		
At Woods Hole.....	44	43
Off Campus.....	37	37
Fellowship Holders.....	20	21
Visiting Investigators.....	6	6
	229	217*
SUPPORTING PERSONNEL		
Administrative:		
Department Heads and Assistants.....	10	11
Secretaries and Clerks.....	12	12
General Maintenance and Service Personnel.....	63	52
Crews of Vessels.....	47	41
	132	116
Grand Total.....	361	333

* Includes 90 Staff Appointees

It is with pleasure that we record the names of the following persons to the Research Staff for a period of one year from September 1:

WILLIAM D. ATHEARN.....	Research Associate in Geology
JOSEPH H. CONNELL.....	Research Associate in Marine Biology
ALAN J. FALLER.....	Research Associate in Meteorology
JAMES M. MOULTON.....	Associate in Marine Biology
MARY ALYS PLUNKETT.....	Associate in Chemistry
HOWARD L. SANDERS.....	Research Associate in Marine Biology

During the year we accepted with regret the resignations of Dr. Per F. Scholander, Dr. Levie Van Dam, Mr. Earl W. Barrett, Mr. E. M. Ballenzweig, and Mr. Gunther K. Wertheim. Dr. Scholander has accepted an honorary appointment as Associate in Physiology on the Institution's Staff.

Reappointments for one- and three-year terms, as authorized by the Board of Trustees, were made to all Staff Members whose terms expired on September 1.

Death came unexpectedly December 3, 1955 to one of the members of the original Staff of the Institution, Mr. Henry C. Stetson, Submarine Geologist, while he was at sea off the coast of Chile serving as Chief Scientist on board the Research Vessel ATLANTIS. Under an early agreement with Harvard University Mr. Stetson's services were shared with this Institution, — an arrangement which resulted over the years in a most productive scientific career. His passing is grieved by his colleagues and removes from the Institution a scientist who stood high in the field of submarine geology.

Captain Arvid Karlson, a veteran seaman, who for many years sailed as mate on the ATLANTIS and more recently served as master of the CARYN, passed away on October 18, 1955. He represented one of those we call "of the old school" whose seamanship was expert. In accordance with his wishes his last remains were put to rest at sea in the presence of the full crew of the ATLANTIS.

Various members of the Staff made trips abroad during the year. Dr. J. B. Hersey visited England May 29 to June 13 to attend a conference on underwater sound. Following these meetings Dr. Hersey visited several of the Royal Naval Establishments where sea acoustics are being studied. During August 1 to 9 he attended a sound propagation committee meeting held at Greenock, Scotland.

Drs. Edward H. Smith and Columbus O'D. Iselin attended a meeting of a Working Group on Oceanography, a subcommittee of the Special Committee of the International Geophysical Year, in Brussels, Belgium, on September 8 to 10.

Mr. Allyn C. Vine gave a paper at a Regional Symposium on Physical

Oceanography held at Tokyo, Japan, on October 19 to 22 under the auspices of the United Nations Economic and Scientific Congress Organization.

Dr. Willem V. R. Malkus and Joanne S. Malkus returned early in December after spending a year abroad. The wife lectured and studied at the Imperial College of Science in London and the husband continued his research at the National Institute of Oceanography near London. Both of these scientists gave several technical papers before various royal societies in England during their profitable visit.

Dr. Gifford C. Ewing, Assistant Research Oceanographer, Scripps Institution of Oceanography, was appointed the Woods Hole Oceanographic Associates' Lecturer for 1955. Following an interesting series of illustrated lectures to the Staff on the usefulness of aerial reconnaissance in interpreting the physical processes in the upper mixed layer of the ocean, Dr. Ewing participated in certain phases of the Institution's research, particularly that of aerial sea observations.

The following were awarded grants or fellowships during the year:

BERMUDA BIOLOGICAL	BENJAMIN B. LEAVITT	RODERIC B. PARK
STATION FOR RESEARCH	CONRAD MALICOAT	GORDON A. RILEY
LAWRENCE K. COACHMAN	MILTON A. MILLER	RAYMOND G. STEVENS
ALBERT P. CRARY	ROBERT L. MILLER	EUGENE J. TYNAN
GEORGE M. CRESWELL	RAYMOND B. MONTGOMERY	W. A. VAN BERGEIJK
HAROLD EDGERTON	JAMES R. MOORE III	GEORGE VERONIS
GIFFORD C. EWING	JAMES M. MOULTON	BERNARD VONNEGUT
HELEN B. FINK	JOHN R. NICHOLSON	GILBERT L. VOSS
BERNHARD HAURWITZ	COLM 'OH EOCHA	BRUCE A. WARREN
PETER HUGHES	WALDEMAR OHLE	E-AN ZEN
ROBERT B. HULSMAN	CARL H. OPPENHEIMER	

This year marked the inauguration by the Institution of a fellowship program supported by the Associates. An appropriation is set aside annually from the endowed income of the Institution and from contributions of the Woods Hole Oceanographic Associates to provide grants and fellowships for properly qualified students and visiting investigators. Each holder of a fellowship will be expected to submit a written report on his work at the expiration of his appointment. No application for a second term will be accepted unless this report be considered satisfactory.

The persons whose names follow were members of the Institution (additional to those otherwise listed) for a period of six months or more during the calendar year 1955.

RESEARCH ASSISTANTS, ENGINEERS, AND TECHNICIANS

ANDERSON, NELLIE E.	DINGWELL, PAUL E.	POOLE, STANLEY E.
BALDWIN, ELIZABETH E.	DUNKLE, WILLIAM M., JR.	PURINTON, CHARLES S.
BALLENZWEIG, EMMANUEL M.	EDWARDS, MELVILLE E.	RAICHE, SHIRLEY A.
BARSTOW, ELMER M.	EDWARDS, RICHARD S.	ROSE, JOHN C.
BENNETT, PAUL E.	FEE, FRANCES M.	RUTSTEIN, MILTON S.
BERGSTROM, STANLEY W.	FRASER, GRACE C.	SCHROEDER, ELIZABETH H.
BERRY, AUDREY W.	FRASER, JOHN G.	SHEARER, BARBARA J.
BRADSHAW, ALVIN L.	HAYES, CARLYLE R.	SHULTZ, WILLIAM S.
CAIN, HENRY A.	HODADLEY, LLOYD D.	SODERLAND, ELOISE M.
CAMPBELL, SYBIL A.	HODGSON, SLOAT F.	THAYER, LAWRENCE A.
CANGIAMILA, ANGELO	KAHLER, YOLANDE A.	THAYER, MARY C.
CARTER, ALWYN L.	LAVIN, DELIA M.	TORPHY, SHANNON R.
CHUTE, EDWARD H.	MOSS, WILLIAM M.	VACCARO, MARTHA W.
COLBURN, BARBARA A.	MOREHOUSE, CLAYTON B.	WILKINS, CHARLES H.
CORWIN, NATHANIEL	PASLEY, GALE G., JR.	WITZELL, WARREN E.
DAY, C. GODFREY		

TECHNICAL CLERKS AND SECRETARIES

ALLEN, ETHEL B.	ENGLISH, JEAN	ROGERS, M. DOROTHY
BARBOUR, ROSE L.	GLAESER, FLORENCE E.	SCHARFF, MARGARET
BERGSTROM, EILEEN S.	MELLOR, FLORENCE K.	SOUZA, CECILIA
BRADLEY, MABEL D.	ORTOLANI, MARY	THATCHER, BEVERLY J.
CASILES, ANN E.	OSTIGUY, BETTY P.	VEST, DOLORES R.
DOW, EVELYN	PHILLIPS, HELEN F.	WILSON, ESTHER N.

ADMINISTRATIVE AND SECRETARIAL PERSONNEL

BACKUS, JEANNE M.	CASILES, PHYLLIS M.	HATZIKON, KALERROY L.
BEHRENS, HENRY G.	CROCKER, MARION W.	LOPES, MARY D.
BROADBENT, MADELINE P.	FERRIS, ALICE H.	SANDBLOM, JOHN D.
BRYANT, EDWIN T.	FERRIS, GEORGE A.	YOUNG, ANITA W.
CAMPER, BARBARA B.	GRIFFIN, T. S. PERRY	

TECHNICAL SERVICES PERSONNEL

BAILEY, FRANK A.	FISHER, STANLEY O.	PENNIMAN, NORMAN
BLAKE, FORREST W.	GALLAGHER, GLORIA S.	PERRY, ALLISON E.
BODMAN, RALPH H.	GALLAGHER, WILLIAM F.	RENNIE, THOMAS D.
BOWMAN, WARREN O.	GASKELL, FRED	SHANAHAN, HUGH J., JR.
BRIGHAM, ROBERT K.	GIFFORD, JAMES E.	SPOONER, CHARLES E.
DAY, ROBERT L.	GRANT, CARLTON	STIMPSON, JOHN W.
DIMMOCK, RICHARD H.	HODGKINS, HARRY L.	WEEKS, ROBERT G.
ELDRIDGE, STANLEY N.	HOWLAND, MYRON P., JR.	WING, CARLETON R.
FELDMAN, JOEL	MORRISON, KENNETH	

MAINTENANCE, HOUSING AND CUSTODIAL PERSONNEL

BACKUS, HAROLD	SOLBERG, OTTO	TURNER, CATHERINE
CHRISTIAN, JOHN A.	SOUZA, MATTHEW R.	WILDE, PHILLIPS B.
CONDON, J. WILLIAM	SPARKS, ELIZABETH C.	WOODWARD, FRED C., JR.
FIELDEN, FREDERICK E.	STANSFIELD, RICHARD	YORK, JAVAN D.
SALTHOUSE, JAMES	TOMETICH, LOUIS J.	

OFFICERS AND CREWS OF VESSELS, BOATS, AND AIRCRAFT

BACKUS, CYRIL	FOURNIER, RICHARD A.	MYSONA, EUGENE J.
BISAILLON, RALPH	GINGRASS, NORMAN	NAILOR, DAVID A.
BRAY, W. SCOTT	GRAFFAM, ROBERT	PIERCE, SAMUEL F.
BUMER, JOHN G.	HOWARTH, WALTER G.	RODERICK, MILTON
CABRAL, JOHN V.	HOWE, PAUL M.	ROSE, LAWRENCE
CALLAN, THOMAS P.	HOWLAND, PAUL C.	SALTHOUSE, JAMES E.
CASILES, DAVID F.	HURWITZ, ROBERT K.	SEIBERT, HARRY H.
CAVANAUGH, JAMES J.	KARLSON, ARVID (deceased)	SHIELDS, WILLIAM J.
COLBURN, ARTHUR D., JR.	LAMBERT, JOSEPH L.	SMITH, JOHN J.
COOK, HANS	LESLIE, JOHN E.	SPEIGHT, CARL W.
COPESTICK, LOUIS B.	MACKEY, MALCOLM R.	SUTHERLAND, PETER A.
COUGHLIN, BROOKS W.	MATTHEWS, FRANCIS S.	TUCKER, WILLIAM G.
DAY, JOSEPH V.	MCCANN, CLEMENT L., JR.	WILLIAMS, DAVID H.

The Retirement Plan which was established in 1954 covered a total of 117 employees at the end of 1955, 24 of them having come into the Plan at the latter time. The Retirement Committee which administers the Plan lost one member, Evangeline T. Wilkins, through resignation and the Executive Committee elected Mary Ortolani to fill the vacancy. The other members are Dean F. Bumpus, Stanley O. Fisher, John McGilvray, and John F. Pike.

Acknowledgments

Again this year it is desired to record the support and consideration extended in the form of contracts in behalf of the Institution's research program by the U. S. Navy Department's Office of Naval Research, Bureau of Ships, Bureau of Aeronautics, Bureau of Ordnance, Hydrographic Office, and other agencies. We also have two small contracts with the U. S. Air Force.

During the year contracts were initiated with the following civilian agencies of the Federal Government, viz., U. S. Weather Bureau and the Atomic Energy Commission.

The Commonwealth of Massachusetts, Division of Marine Fisheries, renewed its grant to the Institution in support of shell fish investigations of state waters.

Due appreciation is also made to the following for their cooperation and support of the Institution's program in education and research:

ATLANTIC TUNA CLUB	ROBERT EARLL McCONNELL FOUNDATION
BENDIX AVIATION CORPORATION	
BENJAMIN FUND	NATIONAL SCIENCE FOUNDATION
CREOLE PETROLEUM CORPORATION	RESEARCH CORPORATION
EDO FOUNDATION	ROCKEFELLER BROTHERS FUND
ESSO RESEARCH AND ENGINEERING COMPANY	ROCKEFELLER FOUNDATION
JAMES FOUNDATION OF NEW YORK, INC.	SHELL COMPANIES FOUNDATION
LIFE SAVING BENEVOLENT ASSOCIATION OF NEW YORK	SOCONY MOBIL OIL COMPANY, INC.

In making acknowledgment to the several organizations which are assisting with the support of the research and education in oceanography, none stands higher than the Associates of the Woods Hole Oceanographic Institution. During the past two and one-half years this group, which had its inception in the Woods Hole summer colony, now includes several of the largest industrial corporations of the country.

The past year has witnessed the support of the Associates in the following projects of the Institution: (a) a spectrographic study of sea-water samples collected world-wide, tracing the physical and chemical changes produced by the cycle of evaporation and precipitation and return to the ocean; (b) the establishment of an annual summer lectureship to bring a distinguished visiting scientist to Woods Hole; (c) the establishment of a series of doctoral fellowships in the earth sciences; (d) the partial underwriting of an ocean geophysical expedition to the island arc of the West Indies, (e) financial participation in a pelagic game fish tagging cruise to the Caribbean Sea, and (f) similarly sponsored "The Atlantis" Marine Geological Expedition to Peru and Chile, 1955.

The Associates of the Woods Hole Oceanographic Institution held their Third Annual Dinner April 19 at the New York Yacht Club at which time they were addressed by Mr. Robert H. Simpson of the U. S. Weather Bureau on the subject of hurricanes.

The annual meeting of the Associates was held in connection with the Open House day of the Institution August 8th. Several changes in the officers took place with Mr. Gerard Swope, Jr. becoming Chairman of the Board, Mr. Noel B. McLean, President, and Mr. John A. Gifford continuing as secretary. Mr. Charles F. Adams, Jr. accepted the Chairmanship of the Corporate Committee. At the end of the year the organization recorded a total enrollment of 142 Individual Members and 26 Corporation Members. The support which the Associates are giving to the advancement of the

Institution's research and educational programs has in a few short years become substantial indeed.

The Endowment Committee of the Institution appointed a few years ago in an effort to form a tangible force to encourage donations and bequests to the capital endowment of the Institution regretted to report no contributions for the year.

V. TREASURER'S REPORT

THE accounts for the year 1955 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds, including cash and advance to current funds, at December 31, 1955 was \$3,135,361, of which \$715,941 represents the accumulated net gains from sales of investments, and \$2,419,420 represents the original value of endowment funds. The market value of endowment assets on the same date was \$4,554,396. Schedule D shows an analysis by major groups of securities of the endowment investments, and the income received therefrom.

The income received on endowment assets, including interest charged on the advance to current funds was \$158,743 for the year ending December 31, 1955, compared with \$149,255 for the calendar year 1954. This income represents a return on the endowment investments of 3.5% on the year-end market value, 5.1% on the book value, and 6.6% on the original value of the endowment.

The executive committee, upon the recommendation of the finance committee, voted to allocate for 1955 operating expenses from the endowment income 5.3% of the original book value of the endowment, which amounted to \$128,229. The balance of endowment income, \$30,514, was transferred to the income and salary stabilization reserve. The rate was the same as voted in 1954.

The advance to current funds from endowment funds was reduced from \$175,000 to \$50,000 during the year. Interest on this advance at $2\frac{1}{4}\%$ is credited to endowment income and charged to current expense.

Deferred charges amounting to \$59,153 represent 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 grants for research are shown in Schedule C; in addition, contributions of the Woods Hole Oceanographic Associates as yet not specifically allocated amount to \$32,296.

The Institution's 1955 contribution to the new Woods Hole Oceanographic Institution Employees Retirement Plan and Trust amounted to \$52,698 and appears on the balance sheet as a current liability as of December 31, 1955. The amount so constituted is held in a separate trust fund administered by three trustees. The balance remaining in the old retirement fund, which is in the custody of the Treasurer, amounted to \$61,713 as at December 31, 1955.

During the year we received from the individual and corporate members of the Woods Hole Oceanographic Associates a total of \$32,160, and \$33,200 was allocated to lectureships, fellowships, and various research projects.

On the following pages you will find the auditor's certificate, balance sheet and income statement, with the supporting schedules. Schedules A and B show details of direct costs of research activity, general and administrative expenses, and expenses of plant operation. Schedule C gives a summary of gifts and receipts for research, and Schedule D a summary of the endowment investments. It is interesting to note that for each dollar spent 77.3 cents were spent for direct costs of research activity, 16.7 cents for general and administration expenses and 6.0 cents for plant operation and miscellaneous. It is also interesting that total administrative salaries amounted to only 7.2 cents of each dollar of total expense.

BALANCE SHEET As at December 31, 1955

ASSETS		LIABILITIES	
ENDOWMENT FUND ASSETS:		ENDOWMENT FUNDS:	
Investment securities (Schedule D):		Unrestricted.....	
Bonds (market quotations \$1,851,275).....	\$1,855,499	For upkeep of plant.....	\$2,000,000
Stocks (market quotations \$2,579,873).....	1,156,614	Accumulated net gain on sale of investments ..	419,420
Cash.....	3,012,113		715,941
Advance to current funds.....	73,248		<u>3,135,361</u>
	50,000		
	<u>3,135,361</u>		
PLANT ASSETS (note A):		FUNDS INVESTED IN PLANT.....	
Laboratory plant and equipment.....	\$524,014		1,050,538
Vessels and equipment.....	364,983	CURRENT LIABILITIES AND FUNDS:	
Other property.....	161,541	Accounts payable and accrued expenses	42,836
	<u>1,050,538</u>	Contribution payable to employees' retirement plan and trust.....	52,698
CURRENT FUND ASSETS:		Advance from endowment funds.....	50,000
Cash.....	102,049	Unexpended balances of gifts and grants:	
Accounts receivable:		For research (Schedule C).....	40,362
U. S. Government.....	\$9,049	Oceanographic Associates.....	32,296
Tax abatement.....	15,451	General Fund:	
Other.....	4,998	General plant and equipment reserve.....	\$158,450
Unbilled costs on research contracts:		Income and salary stabilization reserve.....	75,173
U. S. Government.....	224,521	(Deficit).....	224,799
Other.....	5,471		<u>442,991</u>
Supply inventories.....	22,299		<u>\$4,628,890</u>
Deferred charges (note B).....	59,153		
	<u>442,991</u>		
	<u>\$4,628,890</u>		

Notes: A — Since 1945 the Institution has provided for depreciation of plant assets other than vessels at annual rates of 2% on buildings and 5% to 33 $\frac{1}{3}$ % on equipment, carrying the amounts to general plant and equipment reserve.

B — Real estate received as a gift in 1954 and held for sale at December 31, 1955 is not included in assets; it will be added to current fund assets when sold at the net amount of the proceeds from sale. Deferred charges include \$12,580 net expenses in connection with this property.

STATEMENT OF INCOME, OPERATING EXPENSES
AND UNAPPROPRIATED GENERAL FUND

For the Year Ended December 31, 1955

INCOME:

Reimbursement of sponsored research activity:		
For direct costs.....	\$1,272,164	
For indirect costs.....	403,849	
		<u>1,676,013</u>
Endowment income after amortization of bond premiums (Schedule D).....	\$158,743	
Less amount added to income and salary stabilization reserve.....	30,514	128,229
		<u>1,448</u>
Miscellaneous.....		<u>1,805,690</u>
Total income availed of.....		<u>1,805,690</u>

OPERATING EXPENSES:

Direct costs of research activity (Schedule A):		
Salaries and wages.....	700,977	
Vessel operations.....	345,996	
Materials and services.....	267,168	
Travel.....	92,704	
		<u>1,406,845</u>
Indirect costs:		
General and administration (Schedule B).....	304,995	
Plant operation (Schedule B).....	105,736	
Miscellaneous.....	3,187	413,918
		<u>1,820,763</u>
Total operating expenses.....		<u>1,820,763</u>

EXCESS OF OPERATING EXPENSES..... 15,073

Additions to plant from current funds:

Books and equipment purchased.....	11,862	
Less equipment charged to general plant and equipment reserve.....	4,862	7,000
		<u>22,073</u>

UNAPPROPRIATED GENERAL FUND, JANUARY 1, 1955..... 13,249

DEFICIT IN UNAPPROPRIATED GENERAL FUND, DECEMBER 31, 1955..... \$8,824

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1955

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. GOVERNMENT CONTRACTS	\$581,667	\$308,744	\$204,882	\$79,220	\$1,174,513
OTHER SPONSORED RESEARCH	44,028	14,000	34,427	5,196	97,651
Total direct costs of sponsored research . . .	625,695	322,744	239,309	84,416	1,272,164
INSTITUTION RESEARCH	75,282	23,252	27,859*	8,288	134,681
Total direct costs of research	<u>\$700,977</u>	<u>\$345,996</u>	<u>\$267,168</u>	<u>\$92,704</u>	<u>\$1,406,845</u>

* Includes \$20,531 grants and fellowships.

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND
EXPENSES FOR PLANT OPERATION*For the Year Ended December 31, 1955*

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:

Staff benefits:

Contributions to retirement plan	\$52,698
Social security taxes	18,014
	<u>70,712</u>
Shop services	52,995
Housing, net	1,973

ADMINISTRATION EXPENSES:

Salaries and wages	\$131,365
Insurance, travel, supplies and other	47,950
	<u>179,315</u>
	<u>\$304,995</u>

PLANT OPERATION

SALARIES AND WAGES	\$43,151
PROVISION FOR DEPRECIATION (credited to general plant and equipment reserve)	22,578
OTHER REPAIR COSTS	\$27,813
HEAT, LIGHT AND POWER	18,523
OTHER	3,671
	<u>50,007</u>
	115,736
Less repairs charged to general plant and equipment reserve	10,000
	<u>\$105,736</u>

WOODS HOLE OCEANOGRAPHIC INSTITUTION

SCHEDULE C
SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH
Year Ended December 31, 1955

	Unexpended Balance January 1, 1955	Received	Expended Direct Costs	Indirect Costs	Other Charges or (Credits)	Unexpended Balance December 31, 1955
American Bureau of Shipping.....		\$2,000	\$941	\$616		\$443
American Society of Limnology and Oceanography		706	560	146		
Arctic Institute of North America:						
Buoyancy control in fish.....		1,037	789	248		2,392
Freezing of living tissue.....		2,500	107	1		45
Barataria Bay model.....	\$130		85			
Bermuda Biological Station for Research.....		536	531	5		
Boat Lemming.....		113	94	19		
Bigelow volume.....		2,748				2,748
Commonwealth of Massachusetts.....		20,000	9,550	5,358		14,203
Creole Petroleum Corporation.....	9,111	2,651	1,141	717	\$793 ⁽¹⁾	
Eso Research and Engineering Company.....		5,300	1,796	1,144	147 ⁽¹⁾	2,213
Manufacture, sale, and calibration of instruments		3,241	8,452	3,947	(9,158) ⁽²⁾	
Massachusetts Institute of Technology.....		600	565			35
Motion picture on oceanography.....		19,559	19,559			
Munitalp Foundation.....	5,800				5,800 ⁽²⁾	
National Science Foundation:						
Biological and chemical productivity.....		2,444	2,125	319		
Buoyancy control in fish.....		3,127	2,574	553		
Measurement of light in the sea.....		8,500	2,652	398		5,450
Nitrification in sea water.....		6,900	4,532	680		1,688
Penetration of light.....	1,083		822	261		
Properties of chlorophyll.....	2,486	2,000	3,429	514		543
Oceanographic Associates:						
Deuterium studies.....	4,358		3,588	366		404
Peruvian expedition.....		15,000	7,443	2,079		5,478
Other.....	1,406	18,200	18,200		(826) ⁽¹⁾	2,220
Research Corporation.....		12				
Rockefeller Foundation:						
Marine physiology.....	5,450		5,450			
Meteorological research.....	1,042		1,042			
Socony-Vacuum Laboratories.....		2,500				2,500
U.S. Coast Guard Oceanographic Unit.....		1,655				
	<u>\$30,866</u>	<u>\$121,317</u>	<u>\$97,651</u>	<u>\$17,890</u>	<u>(\$3,720)</u>	<u>\$40,362</u>

⁽¹⁾ Credited or (charged) to income.⁽²⁾ Equipment and calibration services charged to other projects.⁽³⁾ Payments to designated award recipients.⁽⁴⁾ Receipts from sales.

SCHEDULE D
SUMMARY OF INVESTMENTS

As at December 31, 1955

	Book Amount	% of Total	Market Quotation	% of Total	Income
BONDS:					
U.S. Government.....	\$492,340	16.34	\$479,920	10.83	\$11,193
Railroad.....	499,924	16.60	507,919	11.46	19,737
Public utility.....	192,201	6.38	183,075	4.13	8,932
Industrial.....	332,497	11.04	342,375	7.73	8,692
Financial and investment...	338,537	11.24	337,986	7.63	7,847
Total bonds.....	<u>1,855,499</u>	<u>61.60</u>	<u>1,851,275</u>	<u>41.78</u>	<u>\$56,401</u>
STOCKS:					
Preferred.....	<u>323,843</u>	<u>10.75</u>	<u>371,101</u>	<u>8.37</u>	<u>\$16,904</u>
Common:					
Public utility.....	274,370	9.11	455,638	10.28	\$19,192
Industrial.....	417,491	13.86	1,475,718	33.31	52,271
Miscellaneous.....	<u>140,910</u>	<u>4.68</u>	<u>277,416</u>	<u>6.26</u>	<u>11,609</u>
Total common stocks	<u>832,771</u>	<u>27.65</u>	<u>2,208,772</u>	<u>49.85</u>	<u>83,072</u>
Total stocks.....	<u>1,156,614</u>	<u>38.40</u>	<u>2,579,873</u>	<u>58.22</u>	<u>99,976</u>
Total investments....	<u>\$3,012,113</u>	<u>100.00</u>	<u>\$4,431,148</u>	<u>100.00</u>	<u>156,377</u>
INTEREST ON ADVANCE TO CURRENT FUNDS CHARGED TO MISCELLANEOUS OPERATING EXPENSE.....					<u>2,366</u>
TOTAL ENDOWMENT FUND INCOME.....					<u>\$158,743</u>

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1955 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.

In our opinion, the accompanying financial statements present fairly the position of Woods Hole Oceanographic Institution at December 31, 1955 and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts
May 15, 1956

APPENDIX

ATLANTIS

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist— Remarks
213	19 Jan.	23 Jan.	Woods Hole	Bermuda	5	H. Johnson
	28 Jan.	2 Feb.	Bermuda	St. Thomas	6	H. Johnson
	5 Feb.	15 Feb.	St. Thomas	Martinique	11	C. Officer
	18 Feb.	20 Feb.	Martinique	Barbados	3	C. Officer
	20 Feb.	28 Feb.	Barbados	Trinidad	9	C. Officer
	3 Mar.	13 Mar.	Trinidad	Roosevelt Rds.	11	C. Officer
	14 Mar.	15 Mar.	Roosevelt Rds.	St. Croix	2	C. Officer
	15 Mar.	23 Mar.	St. Croix	St. Thomas	9	H. Johnson
	28 Mar.	3 Apr.	St. Thomas	Charleston	7	H. Johnson
	7 Apr.	8 Apr.	Charleston	Charleston	2	H. Johnson
	9 Apr.	10 Apr.	Charleston	Charleston	2	H. Johnson
	13 Apr.	21 Apr.	Charleston	Charleston	9	H. Johnson
	23 Apr.	5 May	Charleston	Woods Hole	13	R. Edwards
214	7 May	7 May	Woods Hole	Boston	1	To Boston for annual
	24 May	24 May	Boston	Woods Hole	1	drydocking
215	7 June	14 June	Woods Hole	Bermuda	8	V. Worthington
	16 June	23 June	Bermuda	Nassau	8	V. Worthington
	26 June	6 July	Nassau	Woods Hole	11	V. Worthington
216	17 July	23 July	Woods Hole	Woods Hole	7	W. Dow-G. Clarke
217	28 July	1 Aug.	Woods Hole	Bermuda	5	F. Fuglister
	3 Aug.	22 Aug.	Bermuda	Bermuda	20	F. Fuglister
	25 Aug.	28 Aug.	Bermuda	Woods Hole	4	F. Fuglister
218	30 Aug.	30 Aug.	Woods Hole	Boston	1	To shipyard for
	16 Sept.	16 Sept.	Boston	Woods Hole	1	engine overhaul
219	22 Sept.	27 Sept.	Woods Hole	Woods Hole	6	W. Dow
220	3 Oct.	6 Oct.	Woods Hole	Bermuda	4	H. Farmer
	9 Oct.	15 Oct.	Bermuda	Bermuda	7	H. Farmer
	17 Oct.	18 Oct.	Bermuda	Bermuda	2	H. Farmer
	19 Oct.	21 Oct.	Bermuda	Bermuda	3	H. Farmer
	22 Oct.	26 Oct.	Bermuda	Bermuda	5	H. Farmer
	29 Oct.	29 Oct.	Bermuda	Bermuda	1	J. Hahn
	29 Oct.	5 Nov.	Bermuda	Cristobal	7	Passage to Panama Canal
221	6 Nov.	6 Nov.	Cristobal	Balboa	1	Transit of Panama Canal
	9 Nov.	9 Nov.	Balboa	Balboa	1	J. Zeigler
	9 Nov.	14 Nov.	Balboa	Talara	6	J. Zeigler
	15 Nov.	23 Nov.	Talara	Callao	9	H. Stetson
	25 Nov.	3 Dec.	Callao	Antofagasta	9	H. Stetson
	6 Dec.	11 Dec.	Antofagasta	Antofagasta	6	P. Trask
	13 Dec.	19 Dec.	Antofagasta	Callao	7	P. Trask
	26 Dec.	29 Dec.	Callao	Talara	4	R. Lufburrow
Total					234	

see p. 117-119

CARYN

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist— Remarks
89	19 Jan.	23 Jan.	Woods Hole	Bermuda	5	J. Ewing
	28 Jan.	2 Feb.	Bermuda	St. Thomas	6	J. Ewing
	5 Feb.	15 Feb.	St. Thomas	Martinique	11	H. Johnson
	18 Feb.	20 Feb.	Martinique	Barbados	3	H. Johnson
	20 Feb.	28 Feb.	Barbados	Trinidad	9	H. Johnson
	3 Mar.	13 Mar.	Trinidad	Roosevelt Rds.	11	H. Johnson
	14 Mar.	15 Mar.	Roosevelt Rds.	St. Croix	2	H. Johnson
	15 Mar.	23 Mar.	St. Croix	St. Thomas	9	H. Johnson
90	31 Mar.	8 Apr.	St. Thomas	Charleston	9	J. Hahn
	10 Apr.	15 Apr.	Charleston	Woods Hole	6	J. Hahn
91	21 Apr.	21 Apr.	Woods Hole	Woods Hole	1	To embark editors at New Bedford and return W. H.
92	9 Aug.	10 Aug.	Woods Hole	Boston	2	Hurricane precaution
	24 Aug.	24 Aug.	Boston	Woods Hole	1	Return passage
Total.....					75	

* On voyage No. 91, Hahn, Athearn and Fuglister were on board demonstrating equipment.

BEAR

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist — Remarks
112	14 Jan.	14 Jan.	Boston	Woods Hole	1	Return from shipyard
113	31 Jan.	5 Feb.	Woods Hole	Bermuda	6	Passage to Ber-
	10 Feb.	14 Feb.	Bermuda	St. Thomas	5	muda for oil then to St. Thomas to pick up scientists
	15 Feb.	18 Feb.	St. Thomas	St. Thomas	4	J. Hersey
	21 Feb.	26 Feb.	St. Thomas	Mayaguez, P.R.	6	J. Hersey
	28 Feb.	11 Mar.	Mayaguez, P.R.	Charleston	12	J. Hersey
	14 Mar.	21 Mar.	Charleston	Charleston	8	R. Wyrick
	23 Mar.	3 Apr.	Charleston	Charleston	12	R. Wyrick
	7 Apr.	8 Apr.	Charleston	Charleston	2	J. Hersey
	9 Apr.	10 Apr.	Charleston	Charleston	2	J. Hersey
	13 Apr.	21 Apr.	Charleston	Charleston	9	J. Hersey
	23 Apr.	4 May	Charleston	Woods Hole	12	J. Hersey
114	16 June	16 June	Woods Hole	Woods Hole	1	W. Richardson
115	17 June	17 June	Woods Hole	Woods Hole	1	L. Hoadley
116	20 June	22 June	Woods Hole	Woods Hole	3	J. Zeigler
117	28 June	1 July	Woods Hole	Woods Hole	4	W. Richardson
118	7 July	16 July	Woods Hole	Woods Hole	10	J. Zeigler
119	21 July	21 July	Woods Hole	Woods Hole	1	J. Zeigler
120	22 July	22 July	Woods Hole	Woods Hole	1	R. Walden
121	25 July	29 July	Woods Hole	Woods Hole	5	J. Zeigler
122	1 Aug.	3 Aug.	Woods Hole	Woods Hole	3	J. Zeigler
123	8 Aug.	8 Aug.	Woods Hole	Woods Hole	1	L. Thayer
124	8 Aug.	10 Aug.	Woods Hole	Boston	3	D. Bumpus
	14 Aug.	14 Aug.	Boston	Woods Hole	1	D. Bumpus
	14 Aug.	17 Aug.	Woods Hole	Woods Hole	3	D. Bumpus
	18 Aug.	22 Aug.	Woods Hole	Woods Hole	5	D. Bumpus
125	6 Sept.	10 Sept.	Woods Hole	Woods Hole	5	G. Clarke
126	12 Sept.	12 Sept.	Woods Hole	Woods Hole	1	D. Grey
127	14 Sept.	14 Sept.	Woods Hole	Woods Hole	1	D. Grey
128	11 Oct.	14 Oct.	Woods Hole	Woods Hole	4	R. Backus
129	18 Oct.	18 Oct.	Woods Hole	Woods Hole	1	Gyro calibration
130	24 Oct.	24 Oct.	Woods Hole	Woods Hole	1	J. Hahn
131	26 Oct.	27 Oct.	Woods Hole	Cape May, N.J.	2	To pick up Craw-
	31 Oct.	2 Nov.	Cape May, N.J.	Woods Hole	3	ford to tow to Woods Hole
132	15 Nov.	19 Nov.	Woods Hole	Woods Hole	5	R. Backus
133	6 Dec.	6 Dec.	Woods Hole	Woods Hole	1	S. Knott
134	14 Dec.	14 Dec.	Woods Hole	Woods Hole	1	To Vineyard Sound to pick up recording buoy
135	15 Dec.	15 Dec.	Woods Hole	New Bedford	1	To shipyard
Total.....					147	

PBY-6A BUNO 46683

Flight No.	Dates	From	To	Days	Chief Scientist—Remarks
181-187	3 Jan.-18 Jan.	Otis — local		7	
188	18 Jan.	Otis	Bermuda		Bunker
	20 Jan.	Bermuda	Bermuda		Bunker
	22 Jan.	Bermuda	Otis	3	Bunker
189	25 Jan.	Otis	Pensacola		Airworthiness check
	26 Jan.	Pensacola	Pensacola		
	4 Feb.	Pensacola	Otis	3	Ferry to Otis
190	24 Feb.	Otis — local		1	To Quonset for maintenance
191	25 Feb.	Otis — local		1	To Quonset for maintenance
192	19 Mar.	Otis	NAS Columbus		Ferry flight to return
	20 Mar.	NAS Columbus	NAS St. Louis		PBY-6A 46683 for storage
	22 Mar.	NAS St. Louis	Wichita, Kan.		
	23 Mar.	Wichita	El Paso, Tex.		
	24 Mar.	El Paso	Litchfield Park Arizona	5	

PBY-6A BUNO 64107

Flight No.	Dates	From	To	Days	Chief Scientist—Remarks
1	30 Mar.	Pensacola	Otis	1	Ferry flight
2	31 Mar.	Otis	Quonset	1	For acceptance check
3	8 April.	Quonset	Otis	1	Ferry flight
4-33	11 Apr.-18 July	Otis — local		30	
34	19 July	Otis	Daytona		W. Schevill
	21 July	Daytona	Otis	2	
35	22 July	Otis	Quonset	1	120-hour check
36	16 Aug.	Quonset	Quonset	1	Test hop
37	17 Aug.	Quonset	Otis	1	Return Ferry
38	20 Aug.	Otis — local		1	Brigham-Davidson
39	21 Aug.	Otis	Atlantic City		First leg of magnetometer flight. Davidson, Chief Scientist
	22 Aug.	Atlantic City	Cherry Point		
	23 Aug.	Cherry Point	Jacksonville		
	24 Aug.	Jacksonville	Miami		
	26 Aug.	Miami	San Juan		
	28 Aug.	San Juan	San Juan		
	29 Aug.	San Juan	San Juan		
	1 Sept.	San Juan	San Juan		
	2 Sept.	San Juan	Antigua		
	4 Sept.	Antigua	Antigua		
	5 Sept.	Antigua	Trinidad		

PBV-6A BUNO 64107 (*Continued*)

Flight No.	Dates	From	To	Days	Chief Scientist—Remarks
39 (cont)	6 Sept.	Trinidad	Trinidad		Davidson (Cont.)
	8 Sept.	Trinidad	St. Lucia		
	9 Sept.	St. Lucia	Barbados		
	11 Sept.	Barbados	Antigua		
	12 Sept.	Antigua	Antigua		
	13 Sept.	Antigua	San Juan		
	16 Sept.	San Juan	San Juan		
	17 Sept.	San Juan	San Juan		
	18 Sept.	San Juan	Curacao		
	19 Sept.	Curacao	Haiti and Guantanamo		
	20 Sept.	Guantanamo	Havana		
	21 Sept.	Havana	Corpus Christi		
	24 Sept.	Corpus Christi	Harlingen AFB, Texas		
	25 Sept.	Harlingen	Houston		
	26 Sept.	Houston	Pensacola		
	27 Sept.	Pensacola	Pensacola		
	8 Oct.	Pensacola	Mobile, Ala.		
	9 Oct.	Mobile	Tampa, Fla.		
	10 Oct.	Tampa	Cherry Point		
	11 Oct.	Cherry Point	Otis AFB		
	14 Oct.	Otis — local			To Bar Harbor area
	17 Oct.	Otis — local		33	To New Jersey area — final tow
40	20 Oct.	Otis	Bermuda		Fraser
	21 Oct.	Bermuda	Otis	2	
41	25 Oct.	Otis — local		1	Brigham
42	28 Oct.	Otis	Bermuda		Fraser
	29 Oct.	Bermuda	Otis		
	1 Nov.	Otis	Bermuda		
	2 Nov.	Bermuda	Bermuda		
	3 Nov.	Bermuda	Otis	5	
43-49	12 Nov.-1 Dec.	Otis — local		7	
50	5 Dec.	Otis	Bermuda		Bunker
	7 Dec.	Bermuda	Otis	2	
51	10 Dec.	Boston	Norfolk		Gulf Stream Survey
	11 Dec.	Norfolk	Pensacola		To Pensacola for check
	22 Dec.	Pensacola	Pensacola		Test flight
	23 Dec.	Pensacola	Otis	4	Ferry flight
52	30 Dec.	Otis — local		1	To Quonset for parts
Total				114	