THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1956

1957

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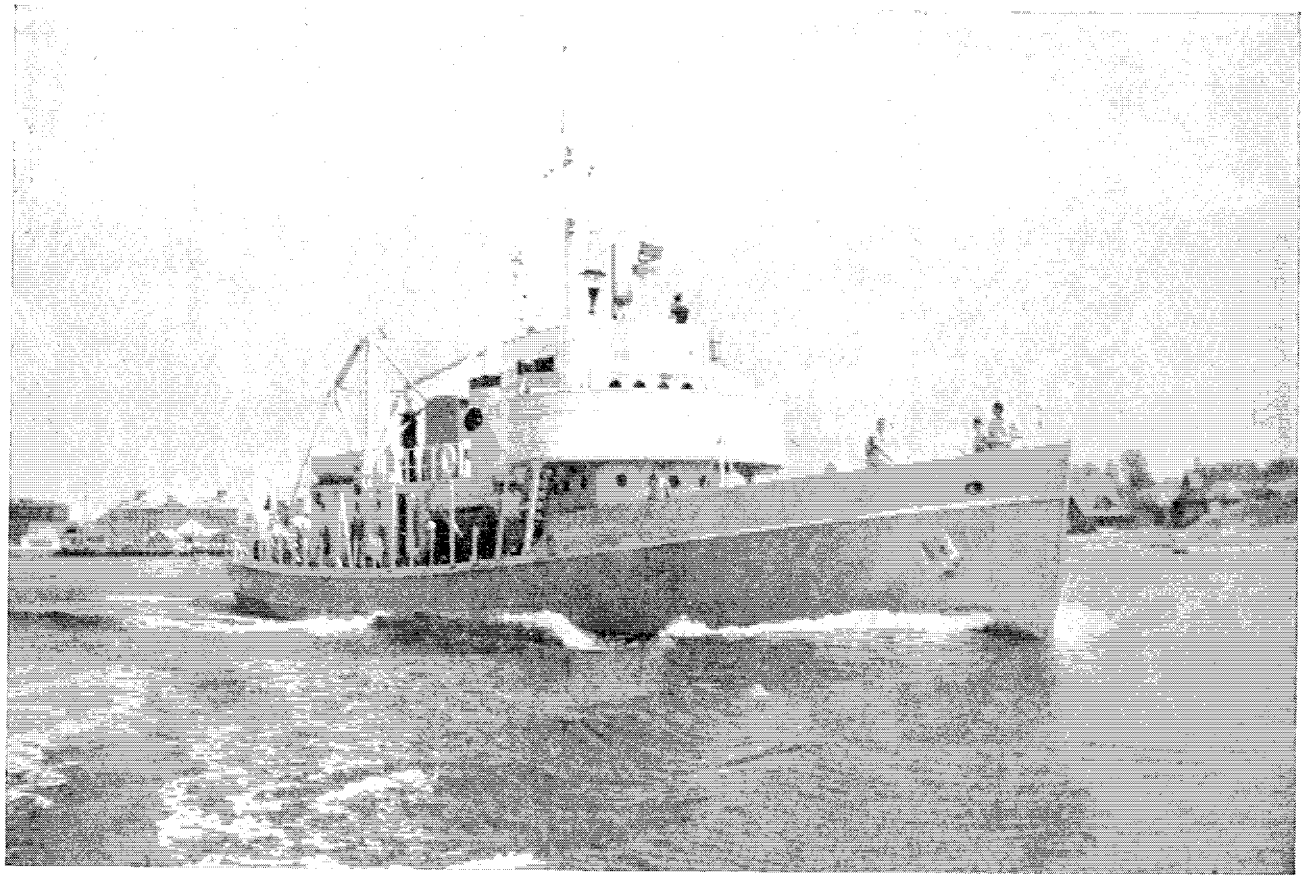

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ROSS G. HARRISON, Osborn Zoological Laboratory, Yale University, New Haven, Conn.

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

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THOMAS J. WATSON, JR., International Business Machines Corporation, 590 Madison Avenue, New York 22, N. Y.
FRANCIS C. WELCH, 73 Tremont Street, Boston, Mass.
E. BRIGHT WILSON, JR., Department of Chemistry, Harvard University, Cambridge 38, Mass.

III. RESEARCH STAFF

(As of December 31, 1956)

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WILLIAM D. ATHEARN, Research Associate in Geology.

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

RICHARD H. BACKUS, Research Associate in Marine Biology.

LINCOLN BAXTER II, Research Associate in Electronics.

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; Research Oceanographer, Museum of Comparative Zoology; Associate in Oceanography.

DUNCAN C. BLANCHARD, Research Associate in Meteorology.

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

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

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L. A. EARLSTON DOE, Associate in Physical Oceanography.

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

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

JOHN B. HERSEY, Geophysicist.

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RAYMOND B. MONTGOMERY, Associate Professor of Oceanography, Chesapeake Bay Institute, Johns Hopkins University; Associate in Physical Oceanography.
HILARY B. MOORE, 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, Research Chemist, Sprague Electric Company, North Adams, Mass.; Associate in Chemical Oceanography.
CHARLES B. OFFICER, JR., Associate Professor of Geology, Rice Institute; Geophysicist.
DAVID M. OWEN, Research Associate in Underwater Photography.
MARY ALYS PLUNKETT, Associate Professor of Chemistry, Vassar College; Associate in Chemistry.
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PAUL FERRIS SMITH, Electronics Engineer, Rockefeller Institute for Medical Research; Associate in Physical Oceanography.
FLOYD M. SOULE, Oceanographer, U. S. Coast Guard; Associate in Physical Oceanography.
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EDMOND E. WATSON, Professor of Physics, Queen's University, Kingston, Ontario; Associate in Physical Oceanography.
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IV. DIRECTOR'S REPORT

Introduction

IN his report to the Trustees in August the retiring director, Admiral Edward H. Smith, stressed the following accomplishments of the past year: a considerable increase in the number of papers published; the acquisition and reconditioning of the 125-foot diesel-powered CRAWFORD which marked a major investment in research vessels comparable to the building of the ATLANTIS 25 years ago; and the strengthening of the educational character of the Institution through an increased budget for lectureships, seminars, and fellowships. To this I would only like to add that we have also gradually become aware of the great importance of the future of oceanography of the International Geophysical Year. In fact, this was the main reason why I reluctantly agreed to resume temporarily the administrative responsibility for our research program.

While field observations will not officially start until July 1957, much effort has been devoted to planning and to preparatory observations during 1956. At this writing it is evident that with more than 60 vessels from 23 nations taking part, the International Geophysical Year could indeed become a milestone in oceanography.

When this major event in the earth sciences was first announced, most members of our staff, including myself, were not very enthusiastic. Individual researchers are more interested in short-term progress than in programs that will require the passage of several 25-year periods before the main objectives can bear much fruit. Why should we interrupt our present program to help gain a worldwide set of observations in the hope that 25 years from now a repeated survey will be possible? Surely by then interests and problems in oceanography will have very much changed. Can we today plan so large an operation and hope that the next generation of oceanographers will think that our objectives were wisely conceived.

Only gradually during the past year have most of us begun to realize that 25 years from now the Institution and the science of oceanography will still be in their infancy, and that we owe it to the future to help gain information on the long-period changes in geophysical phenomena. Furthermore, we have been slow to grasp what could be accomplished in the near future through real international cooperation in oceanography. During the past year it has finally become clear that the prospects are indeed exciting.

The following account of our activities during 1956 is about half taken from the report of Admiral Smith, which he prepared for the Annual Meeting of the Trustees in August. To this basic material, to which Dr. Alfred C. Redfield and I had also contributed, I have merely added some new

paragraphs to make the account more or less complete to the end of the calendar year.

It cannot be overemphasized how much the whole staff regrets the decisions of both Admiral Smith and Dr. Redfield to retire from full-time participation in the affairs of the Institution. As Trustees the help of both will continue to be available to us, but we will all miss their wise counsel on a day-by-day basis.

Research

So far as physical oceanography and submarine geology are concerned there are not many new achievements to be reported since the last printed Annual Report. This does not mean that we have been idle, either in the field or in the laboratory. In general we have been casting around for new leads, digesting old data, and preparing the instrumentation for new assaults.

Dr. J. B. Hersey and his many co-workers were at sea during most of the winter. The ATLANTIS and the BEAR were much assisted by the PBY plane under the vigorous direction of Dr. William Richardson and Dr. Joanne Malkus. Thus, marine meteorology and underwater acoustics achieved a sort of marriage during the winter months in the Caribbean area. What emerged from this rather major effort is provocative but inconclusive. So far as the airplane is concerned it would "see" many "hot" streaks on the sea surface and nearly always the formation of cumulus clouds could be associated with the existence of these streaks or patches of slightly warmer water with sharp thermal boundaries. The vessels were able to show that these abrupt changes in surface temperature extended downward 100 feet or more, but neither ship nor airplane was able to map the full three-dimensional characteristics of these slight thermal boundaries. The net result is that on a microthermal scale the wind-stirred surface layer of the winter sea in the subtropics has much more structure than we had supposed and that the warmer patches may be the real thermal "roots" of the clouds. However, the finer points of these processes that might lead to a better understanding of the exchange of energy between the ocean and the atmosphere remain obscure. It is evident that towing strings of sensitive thermistors from a ship, which is advised about surface temperature distributions by a plane, can be profitable, but we can only conclude for the moment that the surface layer of the sea is much more complicated than we thought it was and that no doubt this complexity plays a part in near-surface sound transmission. Such is the inevitable outcome of advances in measuring techniques. We have been several years in achieving these advances.

Many people have contributed to these refinements in temperature measuring techniques. The sea surface radiation recorder in the PBY has been steadily improved by Dr. Richardson and his group. The basic means of

towing a string of thermistors from a ship has stemmed from the work of Mr. A. C. Vine. The underwater equipment is still rather crude and difficult to handle, but the rig is more sensitive by a whole order of magnitude than a bathythermograph. Additional equipment is being prepared for our other vessels.

Dr. Hersey and his assistants again took advantage of the voyage home in the spring from the West Indies to engage in seismic refraction observations over and along the margins of the Blake Plateau. Several long cores of the bottom sediments were also obtained. This is the third geophysical attack on the Blake Plateau. In time we will be able to report substantial advances in the understanding of the deep geology of the area.

Another strong team of students in geology and geophysics cruised in the Caribbean area during the early summer under the leadership of Dr. Charles B. Officer and Dr. John Ewing.

In preparation for the summer cruises of the CRAWFORD in the northern equatorial current Mr. F. C. Fuglister made a thorough review of the accumulated temperature measurements at the 100-meter level. Not only are the data entirely inadequate when subdivided on a monthly basis, but it is even difficult to show changes in the current pattern between winter and summer. The fact that so few vessels have visited the area during the summer months is strong justification for the recent operations of the CRAWFORD, even if no problems concerning hurricanes existed.

After many thousands of miles of cruising and after overcoming a considerable number of minor mechanical and electrical difficulties, during October in the central Caribbean the crew of the CRAWFORD finally witnessed the early stages of the development of a hurricane. The upper air observations were successful because the winds were light and the sea calm, but we have still to work out a satisfactory means of observing the winds aloft under more normal sea conditions.

Mr. L. V. Worthington, Mr. W. G. Metcalf, and Mr. David H. Frantz made a cruise during the early spring on the CARYN to the northern Caribbean. They were unsuccessful in establishing the sill depth of the Windward Passage due to rough weather, but other objectives of the cruise were fully achieved. An especially fine hydrographic section across the Yucatan Channel was secured. On the way home the axis of the Gulf Stream was followed from the Florida Staits to a point south of Woods Hole.

During the late autumn months in the ATLANTIS Mr. Worthington and his most skillful assistants accomplished the impossible; namely, a complete north-south profile of temperature, salinity, and dissolved oxygen from the Grand Banks to the equator. At all 56 stations observations were successful down to within a few meters of the bottom. It has taken many years of

patient effort to learn how to do this and we are now confident that we can carry out our share of gathering similar very deep observations over even wider areas during the International Geophysical Year.

During the autumn months also we benefited greatly through the extended visits of Professor Georg Wüst and Dr. C. -G. Rossby. The former gave us a notable series of lectures on the circulation of the South Atlantic as deduced from the classical survey of the METEOR and the latter, as always, greatly stimulated our efforts to develop more satisfactory mathematical models of oceanic circulations.

As far as new instrumentation is concerned, the importance of two different lines of development has been fully demonstrated. The two new salinity bridges designed and constructed by Mr. Alvin L. Bradshaw and Mr. Karl E. Schleicher have been at sea enough to demonstrate not only that salinities can be determined by one man on shipboard as rapidly as the samples are collected, but also an accuracy of approximately one more decimal place can be maintained. The new radio-telemetering drift buoys, developed by Mr. Robert G. Walden and Mr. David H. Frantz, have been given a thorough trial in the Gulf of Maine under the energetic leadership of Mr. Dean F. Bumpus. They survived and functioned well during late autumn weather in the Bay of Fundy. They could be relocated frequently, either from a vessel or a plane. It is clear that such equipment can greatly aid in the solution of the many baffling problems of coastal currents. Basically we have achieved a practical "drift bottle" whose movements can be followed on a day-to-day basis, and which can be set out in sufficient number to reveal quite small-scale patterns in the horizontal water movements.

Work in the new hydraulics laboratory has been pursued vigorously by Mr. Allan J. Faller and Dr. W. S. von Arx. Unfortunately the very ingenious drive for the large rotating basin has to some extent lost one of its best features due to a slow sinking of the westerly end of the building. The loss of fill through the bulkhead seems to be a slow, continuous process. To correct this situation will be expensive and in any case would greatly delay the results. Dr. von Arx is carrying on as best he can until it becomes more evident how best to correct the situation. As account of this experimental program follows.

Reconstruction of the torsion balance for the measurement of wind stress on smooth water surfaces is well along toward completion. The revised apparatus consists of an annular trough 10 cm. wide and of 1-meter mean radius, over which a succession of hexagonal cells (louvers for fluorescent lighting fixtures) are supported, with 2 mm. clearance, by cars and motor-truck assembles for model electric trains running on a circular track. The model train drive permits the tangential velocity of the cells to reach 1

meter per second. The entire apparatus will be enclosed in a pliofilm envelope so that the effects of different mixing ratios and temperature contrast across the air-water interface can be studied. Miss Betty Ann Morse spent the summer months running this apparatus.

In addition to the evaluation runs performed to determine the stability and suitability of the 4-meter main tank and its accessories, three preliminary experiments have been completed which are directed toward a study of the ocean circulation. These have involved the circulation within generalized ocean compartments separated by four meridional barriers forming apex angles of 30, 60, 90, and 180°, respectively. The experiments have concerned the barotropic mode of motion under the influence of a monotonic wind field and that occurring with the addition of trade winds. This change amounts to an increase in the wind curl which was adjusted to be maximum at latitude 30°. The experiments differed in the manner in which the tracers were introduced. It was found that detailed motions could be traced by simply allowing droplets of dye to fall into the model at rates of between 1 and 5 per second at each of four latitudes equatorward of the latitude of maximum wind curl. A magenta color produced by potassium permanganate solution and a blue color produced by fountain pen ink were introduced in alternate rings so that the streamlines produced after the droplets had lost their identity could be traced throughout an entire circuit of the circulation in each compartment.

The relationships were discerned; namely, that the velocity of motion in the zone of westward intensification was proportional to the apex angle of the compartment, that the westward intensified circulation separated from the coast line poleward of the latitude of maximum wind curl at a latitude inversely related to the apex angle, and that for the first time countercurrents were produced along the seaward margin of the westward intensified currents. These experiments were interesting in one other respect in that the water moving eastward from countercurrents neighboring the zone of westward intensification developed waves which apparently remained nearly fixed in longitude but increased in amplitude as time passed. The motions of and within these waves are so slow that special experiments will be necessary to determine their exact behavior and identity, (for example, are they Rossby waves?).

During the autumn work began on preparing the large tank for studies of the circulation of the southern hemisphere oceans. Since during the International Geophysical Year for the first time many vessels will be operating south of the equator, these tank experiments could become an important aid in the analysis of the field observations.

The initial atmospheric experiments have largely been directed toward

evaluation of the symmetric heating and cooling mechanisms, their calibrations, and qualitative results. Of particular significance is the determination that the heating by radiation is independent of the temperature of the water and of the circulation. This is because the net radiative transfer is governed principally by the temperature of the spot lamps and at normal temperatures a variation of the temperature of the copper plate produces an insignificant variation of the back radiation. However, the correction for conduction to the air cannot be neglected.

Another preliminary result of significance is that the two methods of cooling by the flush cold source and by evaporation lead to fundamentally different patterns of circulation. The former produces a stratification with relatively strong zonal winds resembling a wintertime circulation, and the latter results in a less stable vertical profile with weak meridional temperature gradients and a correspondingly weak zonal circulation.

Although the resistance wire temperature elements have proven satisfactory for gross measurements of the zonally averaged temperature distribution, the maximum sensitivity of the elements has not been utilized because of apparent changes of calibration during the course of an experiment. The cause of this difficulty is as yet undetermined but is being systematically investigated. An accuracy of better than 0.1 °C should be possible.

A program of investigation will be systematically carried out to study the following:

(*a*) The response of the model atmosphere to varied distributions of zonally symmetric heating and cooling.

(*b*) The response of the model to slowly and rapidly varying heat sources and sinks resembling seasonal variation.

(*c*) Particular attention will be paid to the presence or absence of index cycle phenomena and the response of the system to small changes in the applied energy distribution.

(*d*) Comparisons will be made between the atmosphere and the model to point out regions of similarity and essential differences in the physical make-up of the two systems, in the application of the energy sources and sinks, and in the resulting circulations.

In addition to the principal efforts mentioned above there are two by-products. First, in connection with his course work at the Massachusetts Institute of Technology, Mr. Faller conducted an experimental study of the heights of surface wavelets determined through an analysis of the absorption of light in a dyed liquid illuminated from below. The method seems capable of high precision provided the efforts of refraction and the added path length due to the obliquity of marginal rays can be kept small. Sec-

ondly, it seemed expedient to assist the hurricane reconnaissance program to be undertaken by the CRAWFORD by applying the wide-field photographic techniques to the problems of cloud development photography and apparatus for automatic weather registration from shipboard. The optical system of the latter permits a camera to photograph through a zenith angle of 120° thereby recording the appearance of the whole sky and of the sea surface to a level 30° below the horizon and at the same time to include in the field of view a clock, aneroid barometer, compass, wet and dry bulb thermometers, and a wind speed indicator. The apparatus is turned on and off each day by the rising and setting of the sun and the record of one week's daytime weather is recorded on about 100 feet of 16 mm. film.

The development of atomic energy has raised new problems for the oceanographer. These problems include the present effects of weapons testing programs, and the possible future effects of the accidental or intentional discharge of atomic wastes into the oceans. Dr. B. H. Ketchum and Mr. Allyn C. Vine served as members of a committee of the National Academy of Sciences to consider the effects of atomic radiations on oceanography and fisheries. Among the conclusions of the committee was that studies of the biological and geochemical processes which would affect the distribution of radioisotopes are imperative; that studies of the age, degree of isolation and rate of exchange of water masses, especially in the deeper regions of the sea, should be accelerated; and that the use of radioisotopes to study problems of mixing and exchange, the biological productivity and transfer of materials in the sea should be encouraged. Several members of our staff are conducting research which will provide the basic information essential to the solution of these problems.

Drs. B. H. Ketchum and V. T. Bowen have received a grant from the Atomic Energy Commission to study the biology and chemistry of coastal plankton populations. The program will permit the coordination of interests in the coastal circulation, in the productivity and development of the planktonic populations, in the biochemical cycles of nutrients, and in the chemical exchanges between the water and the bottom deposits. Drs. Sears, Ryther, and Richards will participate in the investigation. Mr. Vaccaro and Mr. Yentsch who are working under National Science Foundation grants will have increased opportunities to conduct their work at sea.

From data published by the Atomic Energy Commission one can estimate for several long-lived radioisotopes the amounts delivered to unit areas of sea surface as fallout following the various atomic tests. It is established that the strontium and cesium fallout are in soluble form and it seems most probable that this is also true for antimony. Thus there are radioactive tracers whose distributions in the sea can give invaluable information on the

vertical movements of surface waters. Since differences in the rates of movement of the tracers can be produced only by differences in the sea-water chemistry of the pertinent elements, comparisons of their vertical distributions would also give information on their chemistry. Dr. Bowen and Dr. Sugihara have been developing methods for the determination of these long-lived radioactive fission products in the sea. Determinations of strontium 90 in several surface water samples have been made; a method for the measurement of cesium 137 is being developed; and work will shortly start on cerium 144 and on antimony 125.

The physiology of marine plants is being actively studied, aided in great part by the use of radioactive tracers. Dr. John H. Ryther has continued his investigations on the discrepancy between the rates of photosynthesis obtained by measuring oxygen production and C^{14} assimilation. He has discovered the physiological basis for this difference and has shown that the C^{14} method alone cannot be used to determine the productivity of sea water.

These technical advances have enabled Dr. Ryther to define more exactly than heretofore the relation between light intensity and photosynthesis for a number of marine phytoplankton species. In collaboration with Mr. Charles S. Yentsch, Dr. Ryther has also made a study of the relationship between photosynthesis and the chlorophyll content of the phytoplankton. From the interrelationships of chlorophyll, light, and photosynthesis, a practical and reliable method has been developed for estimating productivity of the open sea.

Dr. Joyce C. Lewin is studying the physiology of silica deposition in the diatom skeleton. With Dr. Bowen, she is investigating further the organic phosphorus produced by marine algae.

The study of the distribution of deuterium in the ocean, in which the Institution has been collaborating for several years with Dr. Irving Friedman of the U. S. Geological Survey, is now bearing fruit. This heavy isotope of hydrogen promises to provide a tracer for the movement of water in its worldwide cycle. It has been found that the deep water of the Atlantic, from the Arctic Basin to the Antarctic Continent, is practically uniform in deuterium content, which is apparently determined by equilibrium with atmospheric moisture at the sites of deep-water formation in high latitudes. The surface waters of the Atlantic in mid-latitude are enriched in deuterium as the result of the excess evaporation in these regions; while in the Arctic Basin and along the coasts the deuterium concentration is reduced by the dilution of sea water with runoff from the land, which is characteristically of low deuterium content.

These findings appear to explain in a reasonable way the general distribution of deuterium in the ocean. Two discoveries are, however, of special

interest. The first is that the melt-water of sea ice is high in deuterium compared to that from atmospheric precipitation. It is thus possible in polar regions to determine whether the sea water is being diluted by melting ice or the products of atmospheric precipitation. The second is that the deep water of the Caribbean Sea and the Gulf of Mexico contains less deuterium than the supposed source waters from the Atlantic. This observation may have critical value in connection with the origin of the Caribbean water, concerning which Mr. Worthington has recently raised some provocative questions.

Dr. Francis A. Richards and Mr. Ralph Vaccaro have published an account of the preliminary study of the water in the Cariaco Trench. This is a deep basin on the continental shelf of northern Venezuela, in which the deep water appears to be isolated from the surface and from the surrounding deeps for at least 100 years. Their paper extends our knowledge of the biochemistry of the deep sea, especially as it is affected by the decomposition of organic matter sinking from the surface. Perhaps more important are the problems which remain to be examined in this isolated basin. These relate to rate of circulation of deep water, the determination of heat flux in the deeper layers of the continental sea bottom, and the chemistry of sediments laid down in deep anerobic waters. The latter problem is already under attack by Dr. Mary Alys Plunkett.

Dr. Richards has recently prepared several interesting reviews of aspects of chemical oceanography which are not adequately covered by recent publications. One of these serves to emphasize the totally inadequate knowledge which exists of the minor elements in truly representative ocean water. A second is a re-examination of the saturation of the ocean surface with oxygen, required by new determination of the solubility of oxygen in sea water. With Mr. Ralph Vaccaro, Dr. Richards is developing a much needed improvement on the methods for the determination of the nitrogen in sea water.

Perhaps the most striking accomplishment in marine zoology has been the development by Dr. George L. Clarke of a supersensitive instrument for measuring light in the deep sea. This bathyphotometer is capable of measuring and recording light intensities as small as 1/1,000,000,000,000 of full sunlight. The instrument is so sensitive that it has been advantageous to work at night in order to reach depths where no surface light can be detected. During the past year an improved model has been perfected, with the assistance of Mr. Charles J. Hubbard, which can be lowered to very great depths. On a recent cruise of the CARYN it was used successfully to depths of more than a mile. Even at these depths there is a detectable illumination attributed to the luminescence of animals. Against this background frequent brighter flashes are recorded as individual animals light up when close to the photometer.

A very active group interested in the fauna of the sea bottom has been working more or less in association with the shellfish project being conducted by Mr. Harry J. Turner for the Commonwealth of Massachusetts. In addition to a number of men working on summer fellowships these included Mr. Joseph Connell, who came to us a year ago from the Millport Laboratory in Scotland and who left in the Fall to take an Assistant Professorship at Santa Barbara College, and Dr. Howard L. Sanders.

Mr. Connell has been examining the spatial distribution of a number of sedentary animals which live between tide lines to determine whether they distribute themselves at random in areas suitable to them, or whether some biological factor causes them to be aggregated or to be spaced more evenly than chance would dictate. Examples of all three were discovered, soft-shell clams being distributed at random, several other mollusks appeared to be aggregated, while the burrows of fiddler crabs were uniformly spaced owing to the behavior of these animals in keeping other crabs away from the territory around their homes.

Dr. Sanders is making a very detailed survey of the fauna which inhabits the sediments at the bottom of Buzzards Bay. The objective is to discover how each species obtains its food and to understand the competition between the different species for sources of nourishment and, finally, to compute the quantities of organic matter produced by each kind of animal. The bottom fauna is a very important part of the marine environment which is difficult to study and Dr. Sanders' investigations should add much to our knowledge of its economy. In the course of this work he has discovered a small crustacean, *Hutchinsoniella macracantha*, which represents an entirely new subclass intermediate in character between other modern crustaceans and the ancient Trilobites. It is thus a missing link in the evolution of the crustacea.

One of the greatest difficulties in the propagation of shellfish is in obtaining an adequate supply of "seed" for cultivation. Small stages of mollusks must be found in natural situations from which they are moved to places suitable for their subsequent growth. Dr. Loosanoff of the U. S. Fish and Wildlife Service had shown that the common quahog, *Venus mercenaria*, may be induced to spawn in the laboratory and reared until the adult stage is reached. Mr. Turner is now attempting to determine whether seed quahogs can be reared in sufficient numbers to provide a practical source of "seed" for quahog farming. This work requires the detailed study of many aspects of the physiology of these mollusks during their early stage which, in themselves, will be of value to zoology quite apart from the practical objective.

Dr. John W. Kanwisher has been engaged in an investigation of the effects of freezing on marine organisms under a contract with the Arctic Institute of North America. He has recently completed papers on the ability of the

seaweeds of Labrador to survive being frozen into the ice during the arctic winter and on the oxygen consumption of marine algae in the frozen state. He has found that more than three-quarters of the water in a frozen organism separates to form ice. This leads to a great concentration of salt in the remaining tissue fluids. The effects of freezing consequently closely resemble those of desiccation.

During the summer Dr. Laurence Irving of the U. S. Public Health Service and Dr. J. L. Hart of the University of Toronto were at the laboratory engaged in a study of the physiological mechanisms which enable seals to conserve body heat when in cold water or air and to dissipate heat when it is warm. Six seals spent what for them was apparently a comfortable summer in a pen constructed in the boat basin while awaiting experimentation. The newly-installed cold room, in which temperatures of −40 °C. can be maintained, found its first use in this work.

Mr. William C. Schroeder now has in preparation a paper on the offshore lobster population and the fishery which has developed as the result of his exploratory cruises, which have been described in previous reports. He now has in prospect further exploration aimed particularly at seeking information on the spawning place of the bluefish and the early stages in the development of this important species—a matter on which there is complete ignorance.

Mr. Frank J. Mather III, who has been developing studies of the pelagic fish of interest to sport fishermen, is now on leave of absence in the Virgin Islands where he is looking into fishery possibilities for the government. Dr. Robert H. Gibbs, Jr., has joined the staff and is carrying on with the work in which Mr. Mather was formerly engaged in association with Mr. Schroeder.

Dr. Henry B. Bigelow and Mr. Schroeder have completed a paper on the sharks of the suborder Squaloidea, based in part on material collected by the Institution's vessels, while Dr. Richard H. Backus has recorded a number of interesting observations on the distribution of various fish picked up in the course of our explorations.

Publications

During 1956, 56 papers bearing contribution numbers were published:

	Contr. No.
WORTHINGTON, L. V., 1956. The temperature increase in Caribbean deep water since 1933. *Deep-Sea Res.*, 3(3): 234–235	666
VON ARX, W.S., 1956. Some techniques for laboratory study of the primary ocean circulation. *Fluid Models in Geophysics, Proc. First Symposium on Use of Models in Geophysical Fluid Dynamics, Johns Hopkins Univ.*, Sept. 1–4, 1953: 89–99	681
BUNKER, A. F., 1956. Measurements of counter-gradient heat flows in the atmosphere. *Australian J. Physics*, 9(1): 133–143	682

SCHELL, I. I., 1956. Interrelationship of Arctic ice with the atmosphere and the ocean in the North Atlantic-Arctic and adjacent areas. *J. Meteorol.*, 13(1): 46–58 ..... Contr. No. 745

FALLER, ALAN J., 1956. A demonstration of fronts and frontal waves in atmospheric models. *J. Meteorol*, 13(1): 1–4 754

HULBURT, E. M., 1956. The phytoplankton of Great Pond, Massachusetts. *Biol. Bull.*, 110(2): 157–168 764

AYERS, J. C., 1956. Population dynamics of the marine clam, *Mya arenaria*. *Limnol. and Oceanogr.*, 1(1): 26–34 766

BULLIS, H. R., JR. and F. J. MATHER, 1956. Tunas of the genus *Thunnus* of the northern Caribbean. *Amer. Mus. Novitates*, No. 1765: 12 pp. 774

LAWRENCE, BARBARA and W. E. SCHEVILL, 1956. The functional anatomy of the delphinid nose. *Bull. Mus. Comp. Zool., Harvard Coll.*, 114(4): 103–151 793

SCHELL, I. I., 1956. Further evidence of dynamic persistance and of its application to foreshadowing. *J. Meteorol.*, 13(5): 471–481 797

FAIRBANK, N. G., 1956. Methods and preliminary results in a study of minerals from the eastern Gulf of Mexico. *J. Sed. Petr.*, 26(3): 268–275 798

STOMMEL, HENRY, A. B. ARONS and D. C. BLANCHARD, 1956. An oceanographical curiosity: the perpetual salt fountain. Ltr. to the Editors. *Deep-Sea Res.*, 3(2): 152–153 799

SOULE, F. M. and J. E. MURRAY, 1956. Physical oceanography of the Grand Banks and the Labrador Sea in 1955. *U. S. Coast Guard Bull.*, No. 41: 59–114 801

MALKUS, W. V. R., 1956. Outline of a theory of turbulent shear flow. *J. Fluid Mech.*, 1(6): 521–539 804

MACKIEWICZ, JOHN and R. H. BACKUS, 1956. Oceanic records of *Lasionycteris noctivagans* and *Lasiurus borealis*. *J. Mammal.*, 37(3): 442–443 805

SCHLEICHER, K. E. and A. BRADSHAW, 1956. A conductivity bridge for measurement of the salinity of sea water. *J. du Cons.*, 22(1): 9-20 810

MORGAN, G. W., 1956. On the wind-driven ocean circulation. *Tellus*, 8(3): 301–320 811

HOLMES, R. W., 1956. The annual cycle of phytoplankton in the Labrador Sea, 1950–51. *Bull. Bingham Ocean. Coll.*, 16(1): 1–74 813

BACKUS, R. H., STEWART SPRINGER and E. L. ARNOLD, JR., 1956. A contribution to the natural history of the white-tip shark, *Pterolamiops longimanus* (Poey). *Deep-Sea Res.*, 3(3): 178–188 814

SCHEVILL, W. E., 1956. *Lagenorhynchus acutus* off Cape Cod. *J. Mammal.*, 37(1): 128–129 815

SCHOLANDER, P. F., L. VAN DAM and T. ENNS, 1956. Nitrogen secretion in the swimbladder of whitefish. *Science* 123(3185): 59–60 816

SCHOLANDER, P. F., J. W. KANWISHER and D. C. NUTT, 1956. Gases in icebergs. *Science*, 123(3186): 104–105 818

Personnel

At their twenty-seventh Annual Meeting the Members of the Corporation elected the following Trustees to serve until 1960; namely,

DETLEV W. BRONK	DANIEL MERRIMAN	ALFRED C. REDFIELD
NOEL B. MCLEAN	EMANUEL R. PIORE	GERARD SWOPE, JR.

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

CARL-G. ROSSBY	EMANUEL R. PIORE

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

LINCOLN BAXTER II	Research Associate in Electronics
ROBERT H. GIBBS, JR.	Research Associate in Marine Biology
EDWARD M. HULBURT	Research Associate in Marine Biology
LAURENCE IRVING	Associate in Physiology.
BERNHARD KUMMEL	Associate in Submarine Geology
CHARLES E. RENN	Associate in Engineering
GEORGE VERONIS	Research Associate in Mathematics
RAYMOND WEXLER	Meteorologist

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.

The following Visiting Investigators spent considerable time at the laboratory during the past year:

ANGELES ALVARIÑO DE LEIRA	Spanish Institute of Oceanography (Navy Ministry), Spain
RICHARD FAY	U. S. Weather Bureau
MALCOLM S. GORDON	Yale University
ALISTER C. HARDY	University Museum, Oxford, England
LAURENCE IRVING	Arctic Health Research Center, Alaska
ALLEN MILNE	Pacific Naval Laboratory, British Columbia
EDWARD W. MOORE	Harvard University
T. S. SATYANARAYANA RAO	Andhra University, India
GEORGE SHOR	Scripps Institution of Oceanography
S. WENNERBERG	Research Institute of National Defence, Sweden

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

SPENCER APPOLONIO	Bowdoin College
HAROLD BARNES	Marine Station, Millport, Scotland
DUNCAN C. BLANCHARD	Woods Hole Oceanographic Institution
HUBERT CASPERS	Zoologisches Staatsinstitut, Germany
JOHN CHRONIC	University of Colorado
R. F. CLIPPINGER	Datomatic Corporation
GEORGE M. CRESSWELL	Harvard University
R. M. CUNNINGHAM	Air Force Cambridge Research Center
HERBERT CURL, JR.	A & M College of Texas
GEORGE E. R. DEACON	National Institute of Oceanography, England
ROBERTA C. EIKE	Harvard University
HELEN B. FINK	Harvard University
EL SAYED MOHAMED HASSAN	New York University
GERALD J. HOLTON	Harvard University
W. W. HOWELLS	Harvard University
BORJE KULLENBERG	Oceanographic Institute, Sweden
J. B. LUCKE	University of Connecticut
ROBERT L. MILLER	University of Chicago
YASUO MIYAKE	Meteorological Research Institute, Japan
JAMES M. MOULTON	Bowdoin College
LEONARD K. NASH	Harvard University
ERIK PALMÉN	Academy of Finland
RODERIC B. PARK	California Institute of Technology
JACQUES PICCARD	Paris, France
W. H. PINSON	Massachusetts Institute of Technology
MARY ALYS PLUNKETT	Vassar College
E. G. PRINGSHEIM	Pflanzenphysiologisches Institut, Germany
ARTHUR G. RANDALL	Marine Station, Millport, Scotland
HERBERT RIEHL	University of Chicago
GORDON A. RILEY	Yale University
W. RODHE	University of Uppsala, Sweden
HARTLEY ROGERS, JR.	Harvard University
ALFRED S. ROMER	Harvard University
RUDOLF S. SCHELTEMA	Harvard University
HARLOW SHAPLEY	Harvard University
B. K. SKINNER	Harvard Observatory
PARMATMA SRIVASTAVA	New York University
EDWARD D. STROUP	University of Hawaii
KEN SUGAWARA	Nagoya University, Japan
PARKER D. TRASK	University of California
P. L. R. S. WELANDER	University of Stockholm, Sweden
GEORGE C. WILLIAMS	Michigan State University
D. P. WILSON	Marine Biological Laboratory, England
GEORG WÜST	Institut fur Meereskunde der Universitat, Germany
E-AN ZEN	Harvard University
STETSON MEMORIAL FUND	

V. TREASURER'S REPORT

THE accounts for the year 1956 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds, at December 31, 1956 was $3,238,878, of which $818,357 represents accumulated net gains from sales of investments, and $2,420,521 the original value of endowment funds. The market value of endowment assets on the same date was $4,550,357. Endowment fund investments and income received therefrom are summarized in Schedule D. The first addition to endowment funds, since the original Rockefeller grants, came in December of this year in the form of a gift by a member of The Associates of 10 shares of Amerada Petroleum Corp. at a valuation of $1,101.

Income received on endowment assets, including interest charged on the advance to current funds, was $167,380 for the year ended December 31, 1956, compared with $158,743 the previous year. This income represents a return on endowment fund assets of 3.7% at year-end market quotations, 5.2% on the book amount, and 6.9% on the original amount of the endowment fund.

Endowment income was allocated for 1956 operating expenses at the rate of 5.3% of the book amount of original endowment funds, or $128,229; the rate was the same as that of the previous year. The balance of endowment income, $39,151, was transferred to the income and salary stabilization reserve.

The advance to current funds from endowment funds was paid off during the year.

Deferred charges amounting to $247,272 represent expenditures for the benefit of future years. The deferred portion of the costs of reconditioning the Crawford amounting to $228,969 comprise the major part of such charges at December 31, 1956. 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 $73,189, from which were made expenditures and allocations to specific projects of $33,936. The balance, amounting to $39,253, added to the balance on hand December 31, 1955, totals the $71,549 shown on the balance sheet. The above total of Associates' income for the year was made up of $54,700 corporate and individual dues, $8,000 of life memberships, and $10,489 of miscellaneous contributions by Associates.

The Institution's 1956 contribution to the Woods Hole Oceanographic

Institution Employees Retirement Trust amounted to $60,750. The Trust is administered by three trustees. The balance remaining in the old retirement fund, which is in the custody of the Treasurer, amounted to $62,893 as at December 31, 1956.

In the financial statements that follow it is interesting to note that for each dollar spent 79.5 cents were spent for direct costs of research activity, 15.6 cents for general and administration expenses and 4.9 cents for plant operation and miscellaneous. Total administrative salaries amounted to only 6.3 cents of each dollar of total expense.

BALANCE SHEET

As at December 31, 1956

ASSETS

Endowment Fund Assets:		
Investment securities (Schedule D):		
Bonds (market quotations $1,863,083)		$1,975,696
Stocks (market quotations $2,642,334)		1,218,242
		3,193,938
Cash		44,940
		3,238,878
Plant Assets (note):		
Laboratory plant and equipment		552,145
Vessels and equipment		364,983
Other property		161,541
		1,078,669
Current Fund Assets:		
Cash		35,793
Accounts receivable:		
U. S. Government	$364,462	
Other	15,176	379,638
Unbilled costs on research contracts:		
U. S. Government	269,596	
Other	5,267	274,863
Supply inventories		23,199
Deferred charges:		
Reconditioning boat Crawford	228,969	
Other	18,303	247,272
		960,765
		$5,278,312

LIABILITIES

Endowment Funds:		
Unrestricted		$2,001,101
For upkeep of plant		419,420
Accumulated net gain on sale of investments		818,357
		3,238,878
Funds Invested in Plant		1,078,669
Current Liabilities and Funds:		
Accounts payable and accrued expenses		150,022
Contribution payable to employees' retirement plan and trust		60,750
Unexpended balances of gifts and grants:		
For research:		
Government	$332,579	
Other (Schedule C)	21,707	354,286
Oceanographic Associates		71,549
General Fund:		
General plant and equipment reserve	183,574	
Income and salary stabilization reserve	114,324	
Unappropriated	26,260	324,158
		960,765
		$5,278,312

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, 1956

INCOME:		
Reimbursement of sponsored research activity:		
For direct costs		$1,641,986
For indirect costs		512,204
		2,154,190
Endowment income after amortization of bond premiums (Schedule D)	$167,380	
Less amount added to income and salary stabilization reserve	39,151	128,229
Miscellaneous		337
Total income availed of		2,282,756
OPERATING EXPENSES:		
Direct costs of research activity (Schedule A):		
Salaries and wages		807,336
Vessel operations		498,648
Materials and services		380,537
Travel		74,649
		1,761,170
Indirect costs:		
General and administration (Schedule B)	346,831	
Plant operation (Schedule B)	104,118	
Miscellaneous	4,500	455,449
Total operating expenses		2,216,619
EXCESS OF INCOME		66,137
Additions to plant from current funds— books and equipment purchased		31,053
		35,084
DEFICIT IN UNAPPROPRIATED GENERAL FUND, JANUARY 1, 1956		8,824
UNAPPROPRIATED GENERAL FUND, DECEMBER 31, 1956		$26,260

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1956

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. GOVERNMENT CONTRACTS	$707,310	$471,212	$299,232	$63,799	$1,541,553
OTHER SPONSORED RESEARCH	37,056	13,590	43,669	6,118	100,433
Total direct costs of sponsored research ...	744,366	484,802	342,901	69,917	1,641,986
INSTITUTION RESEARCH.....	62,970	13,846	37,636	4,732	119,184
Total direct costs of research.....	$807,336	$498,648	$380,537*	$74,649	$1,761,170

* Includes grants and fellowships:

Other sponsored research	$11,250
Institution research	13,785
	$25,035

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1956

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:		
Staff benefits:		
Contributions to retirement plan.....		$60,750
Social security taxes.....		20,952
Group insurance.....		2,137
		83,839
Shop services.....		69,005
Housing, net.....		2,571
ADMINISTRATION EXPENSES:		
Salaries and wages.....	$140,285	
Insurance, travel, supplies and other.....	51,131	191,416
		$346,831

PLANT OPERATION

SALARIES AND WAGES.....		$41,754
PROVISION FOR DEPRECIATION (credited to general plant and equipment reserve)		24,377
OTHER REPAIR COSTS.....	$13,408	
HEAT, LIGHT AND POWER.....	17,978	
OTHER.....	6,601	37,987
		$104,118

SCHEDULE C

SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH

Year Ended December 31, 1956

	Unexpended Balance January 1, 1956	Received	Expended Direct Costs	Expended Indirect Costs	Other Charges or (Credits)	Unexpended Balance December 31, 1956
American Bureau of Shipping — sea keeping hulls	$443		$270	$173		
American Society of Limnology and Oceanography		$600	410	190		
Arctic Institute of North America:						
Buoyancy control in fish		6	(11)	17		
Freezing of living tissue	2,392	2,500	3,605	1,287		
Barataria Bay model	45	60	105			
Bermuda Biological Station for Research		519	519			
Bigelow volume	2,748	45	2,793			
Blue Dolphin		1,497	1,468	29		
Commonwealth of Massachusetts—shellfish propogation	14,203	20,000	18,620	10,483		$5,100
Esso Research and Engineering Company:						
Foraminifera cataloging	2,213	5,300	4,794	2,719		
Peruvian samples analysis		5,000	3,000			2,000
Gordon project		137	126	11		
Hudson Laboratory		4,990	4,990			
Manufacture, sale, and calibration of instruments		2,001	4,012	2,188	($4,199) [2]	
Massachusetts Institute of Technology — pressure pump	35		31	4		
Munitalp Foundation — atmospheric chemistry		8,000	8,000			
National Academy of Sciences:						
Operation Piccard		4,514	4,514			
Project Nobska		1,180	761	419		
National Lead Company		2,944	2,591	353		
Oceanographic Associates:						
Deuterium studies	404	2,325	2,478	251		
Peruvian core analysis	5,478	10,500	6,169	827	(1,500) [3]	10,482
Other (including fellowships, lectureship, and pelagic fish studies)		20,018	19,140	878		
Outside work done for others		2,518	1,831	687		
Research Corporation — instrument fund	2,220	2,000	1,150	512		2,558
Rockefeller Brothers Fund Incorporated — motion picture on oceanography		6,141	6,141			
Socony-Mobil Laboratories — Peruvian expedition	2,500	2,500	2,500		1,500 [3]	1,000
Town of Islip, New York — Great South Bay Survey		1,000	333	100		567
U.S. Coast Guard Oceanographic unit		1,655	93	30	1,532 [4]	
	$32,681 [1]	$107,950	$100,433	$21,158	($2,667)	$21,707

[1] Omitting $7,681, National Science Foundation, classified as goverment in 1956.
[2] Charged to other projects. [3] Transfers. [4] Credited to income.

SCHEDULE D

SUMMARY OF INVESTMENTS

As at December 31, 1956

	Book Amount	% of Total	Market Quotation	% of Total	Income
BONDS:					
U.S. Government	$610,919	19.13	$598,854	13.29	$12,384
Railroad	546,904	17.12	508,227	11.28	21,759
Public utility	187,743	5.88	162,095	3.60	7,305
Industrial	293,037	9.17	263,776	5.85	10,232
Financial and investment	337,093	10.56	330,131	7.33	10,697
Total bonds	1,975,696	61.86	1,863,083	41.35	62,377
STOCKS:					
Preferred	305,349	9.56	307,443	6.82	15,980
Common:					
Public utility	293,218	9.18	478,216	10.61	20,392
Industrial	441,601	13.83	1,562,252	34.68	53,668
Miscellaneous	178,074	5.57	294,423	6.54	13,011
Total common stocks	912,893	28.58	2,334,891	51.83	87,071
Total stocks	1,218,242	38.14	2,642,334	58.65	103,051
Total investments	$3,193,938	100.00	$4,505,417	100.00	165,428
INTEREST ON ADVANCE TO CURRENT FUNDS CHARGED TO MISCELLANEOUS OPERATING EXPENSE					1,952
TOTAL ENDOWMENT FUND INCOME					$167,380

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1956 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, 1956 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
June 4, 1957