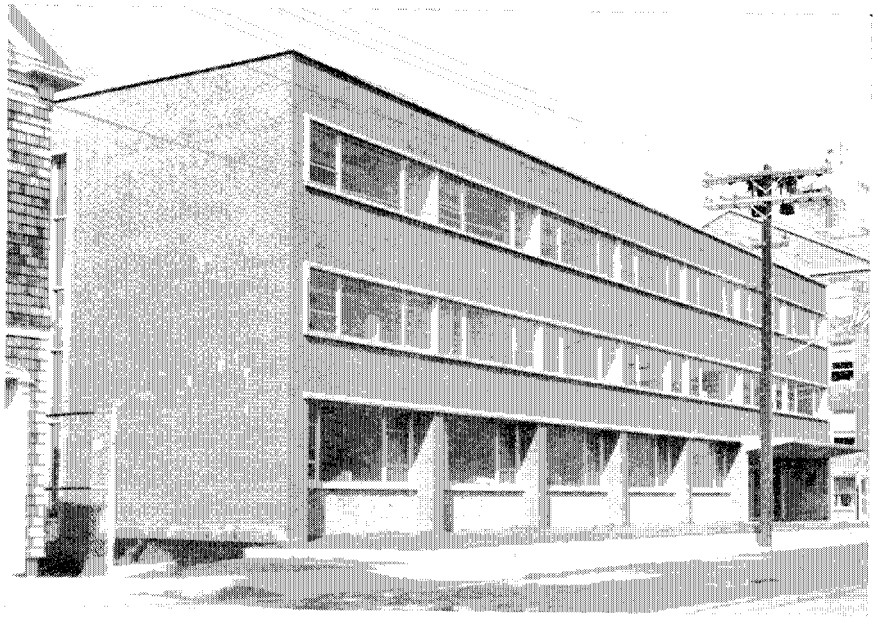
THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1954

1955



LABORATORY OF OCEANOGRAPHY OF THE OFFICE OF NAVAL RESEARCH

WOODS HOLE, MASSACHUSETTS

The Laboratory of Oceanography stands on the water-front at Woods Hole, adjacent to the Woods Hole Oceanographic Institution. This facility is operated by the Institution under contract with the Office of Naval Research. The building was dedicated by high ranking officers of the U. S. Navy on June 21, 1954.

TABLE OF CONTENTS

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PER L. SCHOLANDER, Physiologist.

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

MARY SEARS, Planktonologist.

HENRY C. STETSON, Research Oceanographer and Alexander Agassiz Fellow in Oceanography, Museum of Comparative Zoology, Harvard University; Submarine Geologist.

HENRY M. STOMMEL, Physical Oceanographer.

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PARKER D. TRASK, Research Engineer, University of California; Associate in Submarine Geology.

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IV. DIRECTOR'S REPORT

Introduction

THERE are so many interesting and varied features pertaining to research in the field of oceanography, that when one sits down to prepare a report of the year's activities of an Institution such as this one, a careful sense of evaluation has to be exercised. Speaking with the experience of only a few years at Woods Hole, but having been intimately associated with it for many, I have noted that the emphasis in research moves about. At one time, for example, the central point of interest focuses on problems dealing with the circulation of the surface layers of the ocean and efforts to derive a predication formula. Another time it is the interface between the air and sea with its processes of exchange that beckons. And so on.

The past year has witnessed more than normal interest and effort directed towards problems associated with the over-turn and renewal of the deeper water-masses of the ocean. A recurring question has been, what is the rate of exchange between the surface and the depths? Due to the inaccessability of abyssal waters, and the creeping rate of motion which has been assumed for these masses, little or no quantitative data have been obtainable. This is not a problem inherent to Woods Hole alone — it faces oceanographers throughout the world. Obviously too, this problem of the little known deeper circulation is one which will be with us for many years to come. It has such great implications, moreover, that it challenges one of oceanography's major research-engineering efforts.

One of the new investigations related to the above question is in the field of radio activity, which an atomic age has accelerated. A form which this inquiry has already taken is the gathering of information on the feasibility of using the depths of the ocean as a safe disposal dump for atomic wastes.

As in other fields of research, instrumentation plays an important role in the work both in the laboratory and in the ships at sea. During the past few years, it seems as if more than the ordinary effort has been made to advance the mechanical techniques. For example, we can point to two devices developed and being tested, one an improved method of determining seawater salinity by means of an electrical resistance bridge, the other an experimental instrument recovery buoy. A vigorous development program of oceanographic equipment and techniques paralleling the research, especially as these new tools assist to reduce or replace ship-time at sea, is an avowed policy of the Institution.

Among the firsts, therefore, this year we list:

(*a*) Field observations and statistical studies of the secular decrease of oxygen over the whole western North Atlantic at depths greater than 2500 meters.

(*b*) The summer's Labrador Expedition of the Institution's physiological group.

(*c*) The cooperative meteorological expedition to the Hawaiian Islands to investigate the processes which produce rain from warm marine clouds.

(*d*) Evaluation of the oxygen and the C^{14} methods, respectively, of determining photosynthetic activity in the ocean.

(*e*) The establishment of a laboratory of radio-isotope techniques as applied to oceanographic problems.

The Institution's sources of income this year have stemmed not only from its own endowment fund, but also, as in previous years, from the more substantial source of contracts with agencies of the Department of Defense, the National Science Foundation, and others. This year, furthermore, marked the establishment of Corporation Membership in the Associates of the Woods Hole Oceanographic Institution, and what appears to be the inauguration of a significant financial support of our oceanographic research. More extended remarks on the activities of the Associates and their cooperation are contained in a subsequent section.

The largest gift to the Institution since its establishment twenty-four years ago was that of a sizable lot of water-front property in East Boston, Massachusetts, made possible through the generosity of the General Foods Corporation of New York.

The report of the year's work of the Research Staff follows from the Senior Scientists.

Research

So far as the circulation problem is concerned there have been several developments during the last year. Mr. F. C. Fuglister spent the spring months at La Jolla examining some of the extensive temperature surveys of Pacific Ocean areas. Not only did he bring to the Scripps Institution of Oceanography a new point of view based on our experience with the Gulf Stream, but also he was able to show in a very effective manner that the Pacific data could be so analyzed as to support his multiple current hypothesis. This was true not only of the Japanese temperature surveys in the western Pacific, but also of the many detailed surveys of the very contrasting area off the coast of California.

Mr. L. V. Worthington became interested in deep observations of dissolved oxygen after helping to secure such data last winter from the Brownson Deep. Acoustic transmission measurements in this area had indicated that there might be a rather sharp gradient of temperature and salinity at the contact between bottom water of South Atlantic origin which fills the bottom of the trench and the less dense North Atlantic deep water.

In comparing recent deep oxygen determinations with some secured about thirty years ago he discovered that below a depth of about 2,500 meters over the whole western North Atlantic basin new observations showed about 0.3 cc per liter less oxygen than was found by the early expeditions. Since the oxygen-depth curves are in close agreement above 2,500 meters there is little chance that the chemical analyses are at fault.

Mr. Worthington came to the conclusion that there had been no, or very little, production of sufficiently dense water in high latitudes of recent years to sink below 2,500 meters in the North Atlantic. Using the indicated rate of consumption of oxygen, namely, 0.3 cc per liter in thirty years, he then calculated the length of time since the deep water was saturated with oxygen. This turned out to be approximately 140 years, an age very different from that indicated by the published C^{14} determinations; namely, about 1,500 years. From the standpoint of those who have been studying ocean circulation the lower figure is very much more acceptable. Furthermore, the climatological record shows that during several years centering around 1810 abnormally cold winters and even cold summers prevailed. Thus the supposition is that only during a cold climatic maximum does surface water become sufficiently dense to sink in large enough quantity to influence widely conditions deep down in the ocean.

During May Mr. Worthington made a long cruise on the CARYN to secure additional deep oxygen observations to compare with the old surveys. During the autumn he also made a cruise to the Caribbean on the ATLANTIS. These newest data continue to support his belief that oxygen is being consumed faster than it is being replaced by sinking of surface water in high latitudes. It is interesting to note that, if his estimate of the rate of consumption is correct, it will only require about 1,000 years before all the oxygen below a depth of 2,500 meters is used up. If, indeed, the ocean only overturns completely during exceptionally cold periods, there are many other important implications. However, the whole concept is too new to warrant further speculation here.

Mr. Henry Stommel returned from Bermuda in April having secured a large number of days of successful measurements of wind drift from his free-floating, radio telemetering buoys. Since then he and Mr. Robert Walden through more careful antenna design have succeeded in greatly increasing the assured radio range. Mr. Harlow Farmer has been making some design studies of the buoy-case with the objective of gaining a more stable and more seaworthy platform. An important by-product of his prospective design is that there would be much less danger of a buoy damaging the propeller of a passing vessel. After these and other engineering studies have been completed we will be in good position to assess the capabilities of free-floating buoys in oceanographic research.

During the autumn Mr. Stommel, assisted by Mr. Sloat Hodgson, set out a cable off Bermuda with thermal elements at three depths, the objective being to record internal waves. Arrangements were also made with the Bermuda Biological Station to secure bi-monthly deep hydrographic stations in the vicinity of the cable's sensing elements. The installation has continued to function well.

Considerable progress has also been made in the design of a reliable release for submerged buoys. Mr. David Frantz has successfully recovered his buoy on a number of occasions and we are gaining considerable confidence in his system. Essentially the device, which consists of an airtight chamber containing automatic recording instruments and a radio transmitter, is anchored at any desired subsurface depth. Recovery is achieved at the end of the desired observational period by exploding from the collecting ship, a charge which frees the buoy to the sea surface where it sends out radio signals. The reception of these transmissions by a direction finder leads to recovery of the buoy and its record. Homing on the buoy after it has surfaced has been accomplished each time with ease. The next step is to extend considerably the effective life of the release which is only about six weeks. It seems probable that this can be done by using transistors and such work is now in progress.

In short, in the circulation problem we seem to be at last approaching the point where our vessels will have the help of a variety of different kinds of buoys capable of gaining continuous information over extended periods of time.

While studying at M. I. T. last winter Mr. W. S. von Arx was able to consult with a number of interested experts concerning his plans for larger model studies which will now become possible in the new hydraulics laboratory. He has received much encouragement that his 24-foot diameter flat basin will perform as planned, and during this summer a graduate student from M. I. T. has been making some tests of a 7-foot flat basin preparatory to the design of the large one, the base and container for which is located in the new hydrodynamics building. Means of heating the water in low latitudes, and cooling it in high latitudes, have been provided, so at least in a qualitative way we will soon gain some insight as to what happens in a rotating model when heating and cooling are combined with a wind-driven circulation.

Theoretical studies of the circulation problem also for the first time are beginning to include the idea that thermohaline factors can combine with wind effects to produce currents. Mr. Henry Stommel and Dr. Willem V. R. Malkus have been developing a mathematical model of the Gulf Stream which permits the current to call upon energy available to it in the Sargasso

Sea as the result of deep winter wind stirring. As a consequence of the recent series of lectures by Dr. Jule G. Charney there has been much fruitful discussion concerning the possibilities of achieving a substantial advance in theories that apply both to large-scale meteorological and oceanographic phenomena.

During spring and summer, Dr. Malkus also carried out successful Gulf Stream cruises in the CARYN using novel methods. Starting near Cape Hatteras he drifted downstream along the axis of the current observing the changes in the velocity-depth distribution as a function of time. As usual the Gulf Stream each time did the unexpected. After moving rapidly for about 500 miles the water mass which the CARYN was observing slowed down and came virtually to a stop. There seemed to be the end of one filament of the Gulf Stream after passing through several more or less developed meanders. The relatively short endurance of the CARYN then became critical, for they were not able to establish with certainty the manner in which the isotherms marking the inshore edge of the swift current which they had been following linked up with another filament of current that each time was located about 50 miles inshore. Thus we have one more piece of evidence that the Gulf Stream System, near the surface at least, is somewhat discontinuous in nature. The filaments of swift flow appear to overlap more or less like the shingles on a roof.

During August the ATLANTIS made two geological cruises. An exceptionally large number of graduate students in geology worked here this summer and these cruises were in part planned to give them as much experience as possible in different aspects of submarine geology. On the first cruise they explored the canyons on the Nova Scotian continental shelf, and on the second one they examined and sampled the new sea mounts south of Georges Bank and then headed south to the red clay area northeast of Bermuda with the hope of obtaining some long cores. However, as so often happens in summer the plans were largely thwarted by the need of dodging two hurricanes.

Mr. H. C. Stetson's studies of the changes in underwater topography off exposed beaches are continuing. Through the enthusiasm and ingenuity of a friend of his, a pressure recording device has been constructed. By dragging this along the bottom, underwater profiles can be obtained across the surf zone more quickly and more safely than when the soundings have to be taken from a dory.

Opportunity for some very practical work in the geology of the continental shelf has occurred recently. As a part of the design study for some offshore, permanent structures we were asked to examine a number of proposed sites. Dr. John M. Zeigler enthusiastically undertook responsibility for this work. By aqua-lung swimming it was quickly shown that

Cashes Ledge is a solid mass of granite. On the other hand, the shoal part of Browns Bank as seen by underwater photography is covered by a mixture of sand, gravel, and boulders of all sizes. Two areas on each of Georges Bank and Nantucket Shoals were sounded in detail. Here, nothing but sand was encountered on the surface of the bottom. Two difficult questions were then posed to us by the foundation engineers: How deep are the sands and how much do the shoals shift in position? To answer the first of these questions, corings have been made from a DeLong barge. At one site the sands were more than 120 feet thick. At each site that has been drilled, a 5-inch diameter pipe was left standing in the core hole and extending about 15 feet above the bottom to serve as a permanent marker. Buoys have been set out and therefore it will be possible during the months ahead to observe in detail the changes in the sand ridges.

Wave research has also been contributing much to this project and in turn will gain from it. During the times when the barge was jacked up out of the water, it served as a fixed platform for the calibration of our free-floating wave recorders. A year or more from now when the permanent towers are erected they can serve in many ways as oceanographic observatories.

The development phase of floating wave recorders has about been completed. The instruments now work well in moderate seas, but are not large enough to withstand storm conditions. We have worked out a promising design for a ship-borne wave recorder which we feel is superior for scientific purposes to a similar British instrument.

During early October arrangements were made by the Office of Naval Research to obtain the services of two planes equipped with excellent cameras. Under the leadership of Mr. Wilbur Marks many pairs of photographs of the sea surface were secured. The ATLANTIS served as the scale for the photogrammetric analysis. The contouring of the best pair of photographs showing seas up to about 12 feet in height has been carried out at the Hydrographic Office. About one-half square mile of the sea surface has thus been frozen for the analysis of wave spectra.

The increasing interest in ocean wave phenomena stems partly from the many new applications of wave prediction methods, partly from the increasing concern of ship designers in wave phenomena, and partly from the very great advances in wave theory that have taken place at New York University. Wave research is the one outstanding case in oceanography where theory has outstripped our observational abilities and we can take pride in the fact that in the months before his death Dr. H. R. Seiwell provided the foundations for these developments.

Mr. Marks has also been hard at work computing the energy spectra

of small waves observed in Narragansett Bay last winter. The technique he is using continues to show great promise. If it turns out, as we believe it will, that small waves in a limited fetch resemble storm waves in their statistical characteristics, then many possibilities open up for interesting model studies.

During most of the winter the BEAR and the ATLANTIS were engaged in making acoustical and geophysical observations on a cruise to Puerto Rico. On the way south and also when returning, the vessels shot a refraction profile along the middle part of the continental shelf. Fifteen determinations of the depth to the basement were obtained. This is the first time that such observations have been made south of Cape Hatteras. It is clear from the measurements that the rock structure on which Cape Fear rests extends across the continental shelf underneath the sand deposits.

Dr. Charles B. Officer returned in April from a six month's visit to New Zealand under a Fulbright Fellowship. Using the available earthquake records, he made a highly successful study of the crustal structure of the southwest Pacific. While this is a rather complex region, he was able to distinguish between areas having an oceanic crust and those of a continental type. He was also able to show that a number of the islands, including New Zealand, have been built up with succeeding geologic time on an oceanic crust. They are not part of an extensive continent.

Dr. Officer received the prize for the best paper published in *Geophysics* in 1953, the title of which was "The Refraction Arrival in Water Covered Areas." He was also invited by the American Society of Exploration Geophysicists to give a series of lectures during the late autumn.

Following a suggestion of Mr. A. C. Vine, an examination was made of some "scattering layer" records secured by the BEAR south of Woods Hole. Dr. J. B. Hersey and Dr. R. H. Backus were able to show that the peak frequencies from the several different layers not only were different, but also that they increased in frequency as the layers descended in a manner roughly proportional to the first power of the depth. Since so sensitive a variation with depth suggests a highly compressible scatterer such as a gas bubble, on the basis of gas bubble theory they computed the diameter and volume of the corresponding gas bubbles at one atmosphere for the three most prominent frequency peaks. The range of sizes falls within those given for the swim bladders of common bathypelagic fishes. In the case of lantern fishes, known to be numerous in the area in question, particularly good agreement was found between the bubble size as computed from the acoustical measurements and actual measurements of the swim bladders themselves. While these results are a strong indication that most of the sound scattering in this area comes from the swim bladders of fish, this is by no means the only source of back scattering.

Steady improvement has been made in our ability to gain reliable measurements of the transport of heat, momentum, and water vapor in the turbulent layer of air over the ocean from the PBY plane. Encouraging confirmation of the accuracy of our instrumentation was received recently when the Johns Hopkins group distributed a report of their values of the shearing stress obtained during a joint operation but by a completely different method. Also in another joint operation when the plane was flown upwind past the meteorological tower at the Brookhaven National Laboratories there was again opportunity to compare data taken from a fixed platform with the measurements gained by the plane. The PBY appears to be the only type of plane with a sufficiently rigid wing structure to give adequate response to small-scale turbulence. Thus, this particular plane has become a carefully calibrated meteorological instrument and, as far as we know, it is unique.

Mr. Andrew Bunker is presently at work reducing the data on the above phenomena that he obtained last winter on flights over the Gulf of Mexico.

Dr. Joanne S. Malkus has been working on the 1953 cloud data from the Caribbean. With the help of Mr. Claude Ronne and Dr. William S. Richardson some laboratory experiments have been in progress in which Schlieren photography is being used to observe convective bubbles formed in air and in water over a uniformly heated metal plate.

Dr. Malkus and her husband left for England in September to spend the winter at the Imperial College of London. Dr. Willem Malkus has also been spending several days each week at the National Institute of Oceanography.

During July Dr. Herbert Riehl of the University of Chicago was at Woods Hole in order to discuss the role of cumulus convection in the maintenance of the basic circulation of the trade winds.

Mr. Alfred H. Woodcock organized and lead a major cooperative expedition to the Hawaiian Islands during the fall months in order to study the processes that produce rain from warm clouds. He arranged for the collaboration of Australian, Swedish, and American experts on various phases of cloud physics. The aim was to make a grand assault on the problems of warm clouds, taking advantage of the very favorable situations and facilities existing at Hawaii.

Mr. Duncan Blanchard has been studying in the laboratory the electrical charge on the minute droplets which are thrown into the air when air bubbles of various sizes break through a salt-water surface.

All of these various projects and others that have not been mentioned are considerably more intimately related than is likely to be made clear by such a summary as has been given above. The exchange of energy

between the sea surface and the atmosphere is a central theme which is being studied in many different ways, yet each investigator is well aware of the results and plans of his colleagues. In the same way the work on the circulation problem is being well integrated. The laboratory has not become so large that people with common interests cannot frequently consult so as to pool skills and techniques. The most difficult part of the program to merge with the others is the work in underwater acoustics. Dr. Richard Backus is trying to make acoustical techniques more readily available to biologists. The geologists through Dr. John Zeigler are no longer mystified by what goes on inside a recording echo sounder. However, the fact that so much of the literature of underwater acoustics is classified makes it a field to which physical oceanographers are somewhat reluctant to contribute much time. At the same time those having an appropriate background in physics or electrical engineering find it difficult to take the time to learn oceanography. It is hoped that through the new laboratory a better merging of acoustics and physical oceanography will gradually result.

The most comprehensive problem in oceanography is to determine the relationships on which the distribution and abundance of life in the sea depend. This problem requires a knowledge not only of the distribution of the many kinds of animals and plants in the sea and of their physiological and biochemical activities and requirements, but also an understanding of the circulation of the water and its chemistry, since these determine the quality of the environment in which marine organisms live. Marine ecology consequently is a synthesis of physical, chemical, geological, and biological information aimed at giving an intelligible picture of the sea as a system productive of living matter.

The great advantage which the biologists of the Institution enjoy is close association with experts in the physical fields which contribute to this problem. The complexity of the question has made it useful to use relatively confined bodies of water as "test tubes" in which general relations can be worked out under some control. Since the hydrography of such bays and estuaries is undeveloped, it has been necessary for the biologist to turn hydrographer and develop the physical information basic to his more general problem.

Since all animal life produced in the sea depends upon the microscopic plants which transform solar energy into the chemical energy required for growth, the program of the microbiology and chemistry group includes studies of the interrelationships between: (1) growth and photosynthesis of the phytoplankton, (2) the oxygen and carbon dioxide exchanges associated with photosynthesis, (3) the chemical nutrients (nitrogen, phosphorus, silica, etc.) in the water required for growth, and (4) the bacterial processes

which ultimately decompose the organic matter formed and return the chemicals to solution to be used again in the cycle. In the field studies, the hydrography must always be considered, since different parts of the cycle may be widely separated if the currents carry the surface water, where photosynthesis takes place, in a different direction or speed from the deeper waters, where much of the decomposition must occur. Some aspects of the problem are more readily studied in the laboratory; others in local confined areas which can be revisited frequently.

Each member of the group has his own specialty, but all are contributing towards the basic understanding of this broad problem. During 1954 the following investigations have been made.

Professor E. Steemann Nielsen of the Royal Farmaceutiske Hojskole, Copenhagen, Denmark, visited the Institution for a period of six months. During his visit he continued his studies of photosynthesis under laboratory conditions. His visit was very stimulating to our group which is using his Carbon-14 method for evaluating the productivity of the phytoplankton in the sea.

The Carbon-14 method of Steeman Nielsen for determining productivity has produced an estimate, for areas such as the Sargasso Sea, which is much less than the estimate derived from the oxygen method, used extensively by Dr. Riley of our staff. During his visit Steemann Nielsen performed experiments which indicate that the bacterial respiration may be inhibited by an antibiotic produced in the light as a by-product of photosynthesis. This would yield unusually high results by the oxygen method, but would not affect the Carbon-14 method.

In a carefully controlled laboratory experiment, Dr. Ryther has shown that the difference between Riley's and Steemann Nielsen's results may be related to the deficiency of nutrients (phosphorus and nitrogen) in such areas as the Sargasso Sea, and may reflect the physiological condition of the phytoplankton which grow there. This explanation suggests that the respiration of the nutrient deficient plants themselves may be nearly equal to their photosynthesis so that all of the organic matter formed is immediately respired. The oxygen method measures both the respired material as well as that remaining in the cell as new growth, whereas the Carbon-14 method measures only the latter, and assumes that a small proportion is respired. Further work is necessary and is planned to resolve the contradiction in these two valuable methods.

Dr. Ketchum prepared a review of the "Nutrition of Phytoplankton" which has appeared in (the 1954 issue of) *Annual Reviews of Plant Physiology*. The results of ecological studies and of laboratory studies were considered in order to show how each field could profit by a closer under-

standing of the problems in the other. Dr. Richards has written a review of the distribution of oxygen in the oceans which will appear as a chapter in the "Treatise on Marine Ecology and Paleoecology" to be published by the Ecology Sub-Committee of the Division of Geology and Geography of the National Research Council.

Dr. Richards and Dr. Redfield have completed an analysis of the distribution of oxygen in the Gulf Stream system. It was found that part of the Gulf Stream water, which apparently originates in the Caribbean, contains much lower concentrations of oxygen than water of the same density in the Sargasso Sea. This difference provides a method of tracing and differentiating the source of some of the water of the Gulf Stream.

In a paper published in 1937 Redfield, Smith and Ketchum showed that analysis of the total phosphorus content of seawater, supplemented by the conventional measurement of inorganic phosphate, could be used to untangle the essential features of the phosphorus cycle. The technical difficulties in the determination of total phosphorus have been largely eliminated, and a large number of samples can now be analyzed in a routine way. The samples can be obtained on any hydrographic cruise without the necessity of a chemist on board. The perfection of this technique should make it possible to increase greatly our knowledge of the distribution of phosphorus. A start has been made in obtaining data on the distribution of total phosphorus in the western North Atlantic. Samples have been analyzed for the International Ice Patrol in the belief that phosphorus may aid in characterizing different water masses. Samples have also been collected on several cruises to other parts of the North Atlantic.

The analysis of the distribution of nutrients in the tropical Atlantic is being continued on data obtained during the "Trade Winds" cruise of 1952. The determination of total phosphorus for about 3000 samples collected during this cruise has been completed. About 95% of the surface waters of the Equatorial Atlantic contain appreciable quantities of organic phosphorus most of which is present as dissolved organic compounds. A small fraction of the total phosphorus is found in the bodies of plants and animals. The deeper waters, however, contain an insignificant amount of the organic phosphorus. These observations emphasize the fact that most of the biological cycle is completed in the upper 1000 meters and that little of the organic matter formed in the surface waters can be expected to reach the bottom at greater depths.

Mr. Vaccaro has examined the distribution of oxidized forms of nitrogen in the samples collected on the Trade Winds cruise, and has correlated their distribution with the oxygen content of the water. Mr. Vacarro was aboard ATLANTIS during the first part of cruise 196, when he conducted studies of

productivity and collected samples for the analysis of the concentration of nutrients in the waters of the continental shelf south of Cape Hatteras. Mr. Foster conducted similar investigations on CARYN cruise 72 and ATLANTIS cruise 208.

Papers on the hydrography, phosphorus cycle, zooplankton and phytoplankton of Great Pond, a small estuary near Falmouth, have been prepared by Dr. John Barlow and Mr. E. M. Hulburt. A further study of the seasonal changes in the biological population and in the distribution of nutrients and oxygen in this estuary are being conducted by Conover, Foster, and Creitz. Great Pond is becoming a very useful "Test Tube" for testing principles, which grows in value as its ecology becomes better understood. Such studies, on small bodies of water which can be revisited frequently, increase our knowledge of the interrelationships among the various factors which influence and control the basic productivity of the oceans.

Another case in point is Lake Maracaibo in Venezuela to which a party from the Institution made a second visit in March, under contract with the Creole Petroleum Corporation. This is reputed to be one of the most productive bodies of water in the world, and has provided a wonderful opportunity for studying the hydrographic and climatological factors on which organic production depends. The Climatological Laboratory of Johns Hopkins University is collaborating in this study.

As an outgrowth of interest in Lake Maracaibo, the ATLANTIS made a hydrographic and biochemical survey of the Gulf of Venezuela in December. On the way there a hydrographic station was occupied in the Cariaco Trench, a deep depression in the continental shelf off the Venezuelan coast. The water in this great hole was found to be devoid of oxygen, and loaded with hydrogen sulfide from depths of 400 meters to the bottom at 1200 meters. The conditions are similar to those found in the Black Sea, and in many poorly circulated fjords. It is the first case where such conditions have been found to exist in a depression in the bottom of the open ocean. Further chemical studies of the water in the trench will be made during the next visit of the ATLANTIS to the Caribbean.

A follow-up survey of Great South Bay and Moriches Bay, Long Island, was made in July at the request of the Towns of Islip and Brookhaven. This provided opportunity to extend the studies made in previous years on the effects of the opening and closing of Moriches Inlet on the conditions in these polluted embayments.

One of the benefits of having the new Oceanographic Laboratory is that it enables the Institution to undertake new ventures for which recently there has been no room in its building. The first of these ventures is the establishment of a laboratory equipped for the application of radioactive

isotype techniques to oceanographic problems, such as the use of Carbon-14 by Dr. Ryther for measuring the assimilation of carbon by phytoplankton. Now a properly equipped laboratory is being installed for Dr. Vaughan T. Bowen, who comes to the Institution from the Brookhaven National Laboratory, as geochemist.

Dr. Bowen's objectives are two-fold; first to study the distribution in present day Atlantic seawater of as many of the long-lived fission products as can be detected, and second to apply radiochemical techniques to problems in the biogeochemistry of substances present in such small amounts that they cannot be dealt with effectively by other methods of analysis.

Dr. Thomas Sugihara of Clarke University spent the summer with Dr. Bowen attempting to develop methods for measuring the presence of Strontium-90, by way of its radioactive daughter, Yttrium-90. Dr. Sugihara has continued this study since returning to Clarke University and will return to Woods Hole next summer. Dr. Bowen is examining the chemistry and biological activity of the rare earths in the ocean. Progress in this problem awaits the development of effective methods of extracting the materials and concentrating them in measurable quantities.

Mr. Thomas Goreau of the University College of the West Indies was associated with Dr. Bowen during the early winter, learning radioactive techniques, and has returned to Jamaica to apply the use of radioactive calcium to the deposition of calcium in coral reefs.

During the first week of August a conference was held in Woods Hole between representatives of the principal agencies concerned with the disposal of radioactive wastes, as produced in large quantities in the industrial use of atomic energy, to consider problems which would arise from disposal of large quantities of waste at sea, and to determine what research should be done in this connection.

A related development is the study of the distribution of deuterium, an isotope in hydrogen, in the sea. This has grown out of an association with the U. S. Geological Survey formed two years ago through Dr. Daniel R. Norton. Dr. Irving Friedman, an associate of Norton's in the Survey, has developed methods for the estimation of the deuterium in natural waters. The Institution has supplied him with seawater samples for his preliminary studies and is undertaking to secure material for a world-wide coverage of the oceans. This is a study which has great promise, since the deuterium determinations enable one to trace the movements of water itself in its cycle of evaporation from the sea surface, its movement through the atmosphere, and its return to the sea as runoff from the land.

Dr. Scholander has made excellent progress in his studies of the remarkable mechanism by which fish are able to secrete gas into their swim bladders

against the great pressures existing in the deep sea. An examination of the equilibrium between oxygen and the blood of deep sea fish has pretty thoroughly disposed of the hypothesis generally held that this activity can be explained by the effects of acidity upon the properties of hemoglobin (the Bohr and Root effects) and indicate that some unknown biochemical or physical mechanism working within the swim bladder gland is forcing oxygen into the bladder. These studies have also demonstrated the remarkable fact that the swim bladder gland can secrete the inert gas argon and nitrogen with the same facility with which it handles the more active oxygen molecule.

Dr. Kanwisher has commenced a study of the ability of marine organisms to withstand being frozen. He finds that a number of species which live between tide lines recover even after a large part of their water has been converted into ice. This seems to be an adaptation developed particularly in the intertidal species and is a matter of interest because of the increasing use of freezing techniques in surgery.

The physiological group took a leading part in an expedition to Labrador during the summer. The expedition was sponsored by the Arctic Institute of North America and was led by Commander D. C. Nutt of Dartmouth College. A portable laboratory was established on Hebron Fjord where Dr. Scholander was able to continue studies made in Baffin Land in 1953 on the ability of fish to live at temperatures so low that their blood might be expected to freeze. Dr. Kanwisher extended his investigation of the ability of marine animals and plants to survive freezing to organisms naturally exposed to much more severe conditions than are found at Woods Hole. Dr. Scholander also brought back the first analyses of the gases entrapped in iceberg ice, which he believes may provide a record of the composition of the atmosphere in past ages.

In addition to the physiological contingent from Woods Hole scientists from Rutgers, Michigan, Chicago, Yale, McGill, and Dartmouth conducted studies on the microbiology, marine algae, plankton, lichens and fish of the region while Commander Nutt continued his hydrographic studies of the Hebron Fjord and Nain areas.

Mr. William C. Schroeder made two cruises during the summer to explore the fish fauna of the continental slope. These expeditions bring to completion the present phase of these studies and he is now preparing a report on his findings. Commercial fishermen are now exploiting profitably the concentration of lobsters which he discovered in deep waters, being able to catch up to 5,000 pounds of lobsters in the course of two day's fishing. A commercial enterprise is now investigating the possibility of canning the large crabs found in this area.

Under the joint authorship of Henry B. Bigelow and William C. Schroeder there appeared during the year two notable contributions to our knowledge of fish. These are a paper on "Deepwater Elasmobranchs and Chimaeroids from the Northwestern Atlantic Slope," published by the Museum of Comparative Zoology at Harvard and a monograph describing the skates, rays, and chimaeras which forms Part II of a series of memoirs on "Fishes of the Western North Atlantic" being issued by the Sears Foundation for Marine Research at Yale.

The migrations of the large pelagic fish, such as tuna, are a mystery of interest to scientists and sportsmen alike. Some success has been had recently in tagging relatively small tuna which can be taken alive into a boat, but marking really big tuna without injury to man and fish is another matter. Mr. Frank J. Mather III has recently devised a miniature harpoon which may be used to plant a tag in a large fish when it has been brought alongside, after which the fish may be released in the hope it will be caught again at some distant point. Mr. Mather attended a recent tuna-fishing tournament at Bimini, where this device attracted the attention of sport-fishermen who have volunteered to help in his investigation.

The Institution continues to enjoy a contract with the Commonwealth of Massachusetts for research on shellfish. This year Mr. Harry J. Turner's report to the State contains a very valuable review of the extensive studies on shellfish which have been made by state and federal agencies during the last ten years.

Mr. Turner has conducted a tagging experiment in connection with the rock crab fishery in Boston Harbor which indicates that at least 22 percent of the crab population is caught each season. He is now investigating the factors which may effect the growth of the quahaug, *Venus mercenaria*, in salt water ponds, to see if it is practical to raise these clams in controlled enclosures.

Dr. Mary Sears published this year an account of the ecology of Pisco Bay, Peru, a region of interest in connection with the occurrence of El Niño and its effect on the guano industry. Dr. Sears is now serving as the American Editor of *Deep-Sea Research* a recently established international journal of oceanography. Her skillful editorship is helping to provide an outlet of the highest quality for the publication of oceanographic papers.

Dr. George L. Clarke, who pioneered during the pre-war period on measurements of the penetration of light into the sea and on studies of the related diurnal migrations of zooplankton has developed an extra sensitive submarine photometer. It is believed that this instrument will measure the very low light intensity present at the depths occupied by the scattering layer and will thus contribute to understanding the vertical migration of

the organisms believed to be responsible for this phenomenon, which is of such great interest to physical oceanographers and biologists alike. We welcome Dr. Clarke's return to the investigation of a subject to which he has contributed so successfully in the past. Dr. Clarke published during the year a text book "Elements of Ecology" which will be influential in the education of the next generation of marine biologists.

Publications

Sixty scientific papers bearing contribution numbers have been published in 1954.

	Contr. No.
VON ARX, W. S. The circulation systems of Bikini and Rongelap Lagoons. Bikini and nearby atolls. Pt. Oceanography (Physical). *Geol. Survey Prof. Pap.* No. 260-B:265–273. Figs. 85–90. (Same paper as published earlier in *Trans. Amer. Geophys. Union*)	421
BIGELOW, H. B., and W. C. SCHROEDER. Fishes of the Western North Atlantic. Sawfishes, Guitarfishes, Skates and Rays. *Mem. Sears Found. Mar. Res.*, No. 1(2), Ch. 1:1–514, 117 text figs. (dated 1953)	570
BIGELOW, H. B., and W. C. SCHROEDER. Fishes of the Western North Atlantic. Chimaeroids. *Mem. Sears Found. Mar. Res.*, No. 1(2), Ch. 2:563–588, 11 text figs. (dated 1953)	571
KETCHUM, B. H. Relation between circulation and planktonic populations in estuaries. *Ecology*, 35(2):191–200, 7 text figs.	598
FELSENFELD, G. The binding of copper by hemocyanin. *J. Cell. Comp. Physiol.*, 43(1):23–38, 2 text figs.	614
MALKUS, W. V. R. The heat transport and spectrum of thermal turbulence. *Proc. R. Soc., London*, A, 225(1161):196–212, 2 text figs.	620
ARONS, A. B., and C. F. KIENTZLER. Vapor pressure of sea-salt solutions. *Trans. Amer. Geophys. Union*, 35(5):722–728, 5 text figs.	635
SOULE, F. M. Physical oceanography of the Grand Banks Region and the Labrador Sea in 1952. U.S. Coast Guard Bull. No. 38:31–100 (dated 1953)	637
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CHASE, J. A comparison of certain North Atlantic wind, tide-gauge and current data. *J. Mar. Res.*, 13(1):22–31.	652
LAWRENCE, BARBARA, and W. E. SCHEVILL. *Tursiops* as an experimental subject. *J. Mammal.*, 35(2):225–232.	653
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BIGELOW, H. B., and W. C. SCHROEDER. A new family, a new genus and two new species of batoid fishes from the Gulf of Mexico. *Breviora*, No. 24:16 pp., 4 text figs.	657

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VON ARX, W. S. Measurements of the oceanic circulation in temperate and tropical latitudes. In: Oceanographic Instrumentation. *Nat. Res. Counc. Publ.* No. 309:13–35. 689

LONGUET-HIGGINS, M. S., M. E. STERN and H. STOMMEL. The electrical field induced by ocean currents and waves, with applications to the method of towed electrodes. *Pap. Phys. Oceanogr. Meteorol.*, 13(1):1–37, 28 text figs. 690

KIENTZLER, C. F., A. B. ARONS, D. C. BLANCHARD, and A. H. WOODCOCK. Photographic investigation of the projection of droplets by bubbles bursting at a water surface. *Tellus*, 6(1):1–7, 3 text figs. 691

BIGELOW, H. B., and W. C. SCHROEDER. Deepwater elasmobranchs and chimaeroids from the northwestern Atlantic slope. *Bull. Mus. Comp. Zool., Harvard Coll.*, 112(2):37–87, 7 text figs. 692

STOMMEL, H. Exploratory measurements of electrical potential differences between widely spaced points in the North Atlantic Ocean. *Arch. Meteorol., Geophys. u. Bioklim.*, A, 7:292–304, 2 text figs. 693

WORTHINGTON, L. V. Three detailed cross-sections of the Gulf Stream. *Tellus*, 6(2):116–123, 11 text figs. 694

RICHARDS, F. A., and A. C. REDFIELD. A correlation between the oxygen content of seawater and the organic content of marine sediments. *Deep-Sea Res.*, 1(4):279–281, 2 text figs. 695

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ARONS, A. B. Underwater explosion shock wave parameters at large distances from the charge. *J. Acoust. Soc. Amer.*, 26(3):343–346, 3 text figs. 698

SCHOLANDER, P. F., and L. VAN DAM. Secretion of gases against high pressures in the swimbladder of deep sea fishes. 1. Oxygen dissociation in blood. *Biol. Bull.*, 107(2):247–259, 4 text figs. 699

SCHOLANDER, P. F. Secretion of gases against high pressures in the swimbladder of deep sea fishes. II. The rete mirabile. *Biol. Bull.*, 107(2):260–277, 5 text figs. 700

MONTGOMERY, R. B. Convection of heat. *Arch. Meteorol., Geophys. u. Bioklim.*, A, 7:125–132. 701

MATHER, F. J., III. Northerly occurrences of warm water fishes in the western Atlantic. *Copeia*, 1954(4):292–293. 702

NEWTON, C. W. Analysis and data problems in relation to numerical prediction. *Bull. Amer. Meteorol. Soc.*, 35(7):287–294, 5 text figs. 703

CLARKE, G. L. Elements of ecology, John Wiley & Sons, Inc., 534 pp. 704

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SPILHAUS, A. F. Sea and air resources. *Geogr.. Rev.*, 44(3):346–351. 707

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BLANCHARD, D. C. A simple method for the production of homogeneous water drops down to 1 micron radius. *J. Colloid Sci.*, 9(4):321–328, 3 text figs....	711
STOMMEL, H. Serial observations of drift currents in the central North Atlantic Ocean. *Tellus*, 6(3):203–214, 6 text figs.	713
TURNER, H. J. JR., and J. A. POSGAY. Sixth report on investigations of the Shellfisheries of Massachusetts. Comm. Mass., Dept. Nat. Resources, Div. Mar. Fish., 74 pp. (dated 1953)	715
MALKUS, J. S., and C. RONNE. On the structure of some cumulonimbus clouds which penetrated the high tropical trophosphere. *Tellus*, 6(4):351–366, 9 text figs.	716
WORTHINGTON, L. V. A preliminary note on the time scale in North Atlantic circulation. *Deep-Sea Res.*, 1(4):244–251, 5 text figs.	717
CLARKE, A. H., JR. Some mollusks from the continental slope of northeastern North America. *Breviora*, No. 40:11 pp.	722
NEWTON, C. W. Frontogenesis and frontolysis as a three-dimensional process. *J. Meteorol.*, 11(6):449–461, 14 text figs.	723
SMITH, P. E. Further measurements of the sound scattering properties of several marine organisms. *Deep-Sea Res.*, 2(1):71–79, 12 text figs.	728
RYTHER, J. H. Inhibitory effects of phytoplankton upon the feeding of *Daphnia magna* with reference to growth, reproduction and survival. *Ecology*, 35(4):522–533	730
BLANCHARD, D. C. Bursting of bubbles at an air-water interface. *Nature*, 173:1048	734

In addition to the strictly scientific and technical papers which have appeared during the year by members of the Research Staff, there have been a few semi-popular scientific articles on oceanographic subjects contributed to periodicals as follows:

Malkus, Joanne S., Trade Wind Clouds — *Scientific American*, Nov. 1953, Vol. 189, No. 5, pp. 31–35, figs. in text, 6.

The Institution published three issues of a pamphlet called OCEANUS for the benefit of the Associates of the Woods Hole Oceanographic Institution. This modest little magazine contains an assortment of news and reports on oceanography and the main developments of the Institution's research.

Other publications of the Institution in 1954 include two illustrated brochures, one entitled, "Your Stake in the Last Frontier," and the other, "Perpetuating Your Love for the Sea." The purpose of the former is to interest industrial corporations in extending support to the basic oceanographic research of the Institution, and the latter is a step toward increasing the capital endowment of the Institution.

Vessels and Airplanes

The Institution's fleet of research vessels and airplanes kept active in 1954.

Ship operations for the year began in mid-January with the departure of ATLANTIS and BEAR for an extended southern cruise which lasted until the first of April. In spite of rather heavy weather, the southbound leg witnessed a full hydrographic schedule under the chief scientiest, Mr. Bumpus. The research operations in Puerto Rican waters and return to Woods Hole, was under Dr. Hersey's supervision. Sound transmission observations in company with the Hudson Laboratory's Ship ALLEGHENY, and a submarine, provided a full program.

ATLANTIS parted company with BEAR at Woods Hole to proceed to Munroe's Yard, Boston, for a six weeks overhaul, the major items being a complete engine refit and the replacement of a fractured tail shaft. Again it was apparent that age makes for more extensive yard work than with a younger ship.

ATLANTIS engaged in an extremely busy summer schedule consisting of trips to the Gulf Stream and the Nova Scotian Shelf, while later she journeyed to Bermuda and carried out a bathymetrical survey of Kelvin Bank. The year-end witnessed ATLANTIS' return from a voyage to mid-Atlantic, to Barbados, and the Caribbean, under chief scientist Worthington. During the year she put in 213 days at sea.

CARYN was recommissioned in mid-May from which date until late fall she was kept pretty much underway. Several of the Staff used her for their particular projects, the largest one being a six weeks hydrographic cruise, three hundred miles southeast of Bermuda to St. Thomas and return. Mr. Worthington, chief scientist, reported an efficiently operating ship which confirmed the belief of several at the Institution that CARYN, for certain kinds of oceanographic field work, is quite useful. She operates at approximately one-third less cost than ATLANTIS.

BEAR, following its winter cruise with ATLANTIS plied on a weekly program out of Woods Hole for Dr. Hersey and Mr. Vine testing experimental equipment and conducting acoustical operations south of Martha's Vineyard. The installation of a Sperry gyroscopic compass was a feature, which after considerable adjustments, is now believed to be a reliable instrument. The latter part of the year witnessed a rather extensive overhaul and general refit which the BEAR had not had for a long time.

ASTERIAS, our smaller 40-foot craft was employed throughout the year for harbor and coastwise trips ranging from Jamestown, Rhode Island to Gloucester, Mass.

This year marked the second one in which an airplane on loan from the

Navy was operated for oceanographic research. The PBY-6A-46683 made several over-water flights on missions which included cloud physics and turbulence studies for the meteorological group; charting of the inner edge of the Gulf Stream off the Atlantic seaboard for the hydrographic group, and photographing the changing shore line in the beach study work. A cooperative mission of the Institution, and the U. S. Coast Guard's Ice Patrol, took the airplane to Argentia, Newfoundland.

To find an airplane which fits the needs of both the oceanographers and the meteorologists is difficult, the former desiring a relatively slow-speed craft, the latter needing a rather fast airplane with large fuel capacity to cover expansive sea areas.

A Stinson Voyager airplane was received in February from the Civil Aeronautics Authority via the Navy, it having been declared surplus equipment and offered to the Institution for whatever research purposes we might find it useful. While not as adaptable to most of the oceanographic work as the larger airplane, it has become employed in limited meteorological work and for occasional utility purposes.

As all of those who were living in coastal New England August 31 and September 9, 1954 vividly recall, visitations by hurricanes caused great damage to marine property. Fortunately the ATLANTIS was in Bermuda during the passage of Hurricane Carol, and the CARYN successfully rode it out moored to the Institution's pier at Woods Hole. None of the smaller craft of the Institution was damaged. On two other occasions, however, the two larger vessels had to seek a more protected harbor being dispatched from Woods Hole to Boston, thus causing considerable disruption in research operations and consequent loss of valuable time.

The desirability of reproducing the older units of our fleet, particularly the ATLANTIS, with ships designed for modern oceanographic operations, is a task which continues to engage our attention.

A detailed summary of the year's operations of the Institution's fleet is to be found in the Appendix.

Plant

The physical holdings of the Institution received an unusual increment during March through a donation by the General Foods Corporation of 361,000 square feet of land and four buildings located at New Street, East Boston, Mass., and assessed for tax purposes in the sum of $276,000. This figure was considered excessive due to the present state of disrepair of the buildings and the abandonment and non-use of the property since the General Foods Corporation had removed its activities to another site a year or more ago.

Although the Institution had no practical use of the property itself in

the immediate future, acceptance was based upon subsequent lease or sale, if the interests of the Institution could be best served by such action. At the close of the year an appeal to the City of Boston tax authorities had been filed, and the property appraised and reparceled for sale or lease. It is hoped that financial benefits will eventually be realized on this real estate holding.

Mention has already been made of the hurricanes of 1954. The Institution's pier witnessed the water level rising at the height of Hurricane Carol on August 31 to a person's waist, with waves rolling even higher. The fact that the maximum intensity of the storm coincided with the time of high water combined to wreak more damage than otherwise. Another foot in the rise would have permitted the camel to ride over the top of the fender piles, causing more extensive damage to the pier. However, the platform of the pier was lifted off its foundation, and then on the recession of the waters was left resting insecurely on a washout in the wall foundation.

Seawater to a depth of a foot or more entered the basement of the laboratory building causing damage to equipment and fixtures. One window was blown out, and the corner of the building used as a carpenter shop was slightly undermined.

The Institution-owned property, across the street from our main building was badly flooded with salt water which on the main street attained a height of two feet. The electric wiring in the buildings was condemned by the Falmouth building inspector, and this, considered with the dilapidated condition of one of the buildings previously rented as an apartment, was sufficient grounds for vacating it for this purpose. This building is now used as a storage of Institution equipment. The other building on the lot, a bungalow, has been renovated and continues as rental property.

The land on Nonamessett Island, across Woods Hole Great Harbor, which we lease for the storage of explosives, suffered from the inflow of the sea during Hurricane Carol. The several small buildings used as magazines were skewed on their foundations, and the small pier over which the explosives were landed and loaded was entirely swept away. This latter represents a sizeable restoration cost as does the repair on our main pier at Woods Hole.

A more detailed report of the hurricane damage is filed in the Institution's records along with the report of the hurricane of the year 1938.

The village property of the Institution consisting of Challenger House, Meteor House, Fram Cottage, l'Hirondelle, and the Barn (now renovated into three summer apartments and bachelors quarters) all are maintained in good condition. No major outlays have been necessary during the year. The Challenger Mess was operated throughout the summer but the patron-

age continued to dwindle which raises the question as to whether it should not be suspended until more use is indicated.

June 21 witnessed the dedication of the Office of Naval Research's new Laboratory of Oceanography, and following the acceptance by the Chief of Naval Research, delivery of the keys was made to this Institution for operation.

The legislation that provided for the Laboratory of Oceanography stipulated that it should be operated for the Navy by private interests. Accordingly, a contract called a facilities agreement has been executed between the Office of Naval Research and the Institution, providing for the use of the facilities for government contract research and for such other purposes as shall be approved. The running expenses are borne by the research contracts.

The benefits which are realized by the new laboratory is first the security which has been previously mentioned as a desirable attribute of the new arrangements. Further benefit lies in enabling the Institution to undertake new ventures in oceanographic research for which in recent years there has been little opportunity due to the excessively crowded condition and lack of laboratory space.

Personnel

The Research Staff in 1954 numbered 229.

As of July 1, 1954, the persons associated with the Institution were tabulated as follows:

	1953		*1954*	
RESEARCH STAFF				
Full time:				
Scientists and Technicians:				
At Woods Hole	79		94	
Off Campus	29		21	
Secretaries and Clerks	8		7	
Part time:				
At Woods Hole	43		44	
Off Campus	17		37	
Fellowship Holders	10		20	
Visiting Investigators	4	190	6	229*
SUPPORTING PERSONNEL				
Administrative:				
Department Heads and Assistants	12		10	
Secretaries and Clerks	19		12	
General Maintenance and Service Personnel	59		63	
Crews of Vessels	51	141	47	132
Grand Total		331		361

* Includes 82 Staff Appointees

It will be noted from the above listing of Institution personnel that while the Research Staff recorded an increase of approximately 17 per cent as of July 1, 1954, no increase occurred in supporting personnel. In fact a small reduction was effected in the latter.

It is with pleasure that we record the following additions to the Research Staff:

Appointment from July 1, 1954 to September 1, 1957:

Dr. Vaughn T. Bowen	Geochemist

Appointments for a period of one year from September 1:

Earl W. Barrett	Research Associate in Meteorology
L. A. Earlston Doe	Associate in Physical Oceanography
Robert A. Lufburrow	Research Associate in Physics
Jerome Namias	Associate in Meteorology
David M. Owen	Research Associate in Underwater Photography
F. Claude Ronne	Research Associate in Photography
George T. Scott	Associate in Physiology
Allard T. Spencer	Research Associate in Engineering
Thomas T. Sugihara	Associate in Geochemistry
Gunther K. Wertheim	Associate in Physical Oceanography
Geoffrey G. Whitney, Jr.	Research Associate in Physical Oceanography

Appointments for the period from December 16, 1954 to August 31, 1955:

John G. Bruce, Jr.	Research Associate in Physics
Herbert Small	Research Associate in Electronics
Ralph F. Vaccaro	Research Associate in Microbiology

Reappointments of Staff Members, whose terms expired in September, were made in all cases with the exception of Dr. William S. Butcher whose new appointment, that of Associate in Geology is due to his resignation as a full-time member which was accepted last year. Other appointment changes were effected in the cases of both Dr. Bostwick H. Ketchum and Dr. Alfred C. Redfield, namely from Senior Biologist to Senior Oceanographer respectively.

It is with regret that we accepted the resignations of Dr. Frank T. Dietz, Dr. George W. Wheeler and Mr. Kenneth G. McCasland.

The Institution lost through death, the services of Mr. Nathaniel R. Wing, Janitor, who passed away September 24, 1954 after more than twelve years of faithful and efficient service.

Several of the Staff visited Europe during the year either to attend international scientific meetings or to remain for more prolonged study. The list includes Dr. Edward H. Smith, the Director, who as the Reporter for Oceanography on the U. S. National Committee for the International

Geophysical Year attended the Special Committee's meetings at Rome, September 28–October 4. Following their adjournment, Dr. Smith visited for a day or less, oceanographic laboratories at Hamburg, Germany, Bergen, Norway, and Wormley, England. Visits were also made to the Meteorological Institute at Stockholm and the Department of Meteorology at Imperial College, London.

Mr. William S. von Arx attended the meetings of the International Union of Geodesy and Geophysics in Rome in September. He took part in the symposium on Current Measurements of the Association Internationale d'Océanographie Physique. Mr. von Arx also visited the Laboratoire National d'Hydraulique in Chaton, France, and gave a seminar on rotating models of the ocean circulation. In England, he visited Cambridge University, the Imperial College of Science and Technology and the newly established National Institute of Oceanography at Wormley. Mr. von Arx participated in the series of opening lectures at the Institute of Meteorology of the University of Stockholm.

Mr. Harry J. Turner attended the symposium on oyster and mussel culture of The International Council for the Exploration of the Sea at Paris, in October. Included in Mr. Turner's trip were visits to the Marine Zoological Station at Den Helder and the Government Fisheries Laboratory, Bergen-op-Zoom, Holland. He also visited several marine stations in Denmark, Sweden, and England.

Dr. Mary Sears attended meetings of the Joint Commission on Oceanography and the Union Géodesique et Géophysique Internationale at Rome, Italy in September. She then visited the Musée Océanographique in Monaco, the Zoologisch Museum in Amsterdam, the British Museum, and laboratories in Copenhagen, Oslo and Southampton.

In September, Dr. Willem V. R. Malkus left for England to continue his research program in connection with accelerated oceanographic studies and instrumentation. He will conduct his research at the National Institute of Oceanography, Wormley, near Godalming, Surrey, England. During his stay abroad, Dr. Malkus will visit other oceanographic laboratories.

Dr. Joanne Malkus went on leave of absence from the Institution in September to continue her research program in cloud physics at the Imperial College, London, for a period of approximately one year. This program in London is supported by a fellowship from the Munitalp Foundation. Dr. Malkus is also a holder of a fellowship from the John Simon Guggenheim Foundation.

Dr. Jule G. Charney, Professor of Meteorology at the Institute of Advanced Study, Princeton, New Jersey, was the Woods Hole Oceanographic Associates' Lecturer for 1954. Dr. Charney gave a series of six lectures on "Scale and Stability in Planetary Fluid Motions."

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

Bermuda Biological Station for Research	Guillard, Robert R. L.	Nicholson, John R.
Bowen, E. G.	Hazen, William E.	Nielsen, E. Steemann
Charney, Jules G.	Leahy, Richard G.	Pierce, E. Lowe
Doe, L. A. Earlston	Miller, Richard S.	Plunkett, Mary A.
Faller, Alan J.	Moore, James R. III	Raymont, John E. G.
Gabriel, Vittali G.	Montgomery, Raymond B.	Riley, Gordon A.
	Moulton, James M.	

It is desired to record in this section the action of the Members of the Corporation at their annual meeting at Woods Hole, August 12 in re-electing for another four-year period the following trustees whose terms expired in 1954:

Horace S. Ford	Arnaud C. Marts	Selman A. Waksman
Albert E. Parr	Athelstan F. Spilhaus	

In addition Charles Francis Adams, Jr., was elected to fill the vacancy on the Board occasioned by the death of his father.

It is with deep regret that the passing of Mr. Charles Francis Adams is recorded. He was one of our earliest trustees whose prudent advice and sound financial counsel measurably added to the stature of the Institution. The Chairman of the Board has contributed a moving tribute in the record to Mr. Adams,—a lifelong friend of loyal and upright character.

At the Trustee's annual meeting on August 12 the following persons were elected as Members of the Corporation:

Charles F. Adams, Jr.	Robert E. McConnell	John A. Gifford
Ferdinand Eberstadt	Frank Pace, Jr.	Noel B. McLean

The persons whose names are listed below were members of the Institution (additional to those otherwise listed) for a period of six months or more during the calendar year 1954.

RESEARCH ASSISTANTS, ENGINEERS, AND TECHNICIANS

Andersen, Nellie E.	Bradshaw, Alvin L.	Corwin, Nathaniel
Athearn, William D.	Cain, Henry A.	Creitz, Grace I.
Atwood, Barbara A.	Campbell, Sybil A.	Davis, Lee C.
Baldwin, Elizabeth E.	Cangiamila, Angelo	Davis, Priscilla K.
Barstow, Elmer M.	Carlson, Edgar	Day, C. Godfrey
Bennett, Paul E.	Carter, Alwyn L.	Dingwell, Paul E.
Bergstrom, Stanley W.	Chase, James F.	Duys, Gerritt, Jr.
Berry, Audrey W.	Chute, Edward H.	Edwards, Melville E.
Black, William A.	Chute, Nancy W.	Edwards, Richard S.
Bonini, William E.	Conover, John T.	Faller, Alan J.

RESEARCH ASSISTANTS, ENGINEERS, AND TECHNICIANS (CONTINUED)

FEE, FRANCES M.
FOSTER, DONALD B.
FRASER, JOHN G.
HAYES, CARLYLE R.
HOADLEY, LLOYD D.
HODGSON, SLOAT F.
KAHLER, YOLANDE A.
MCCASLAND, KENNETH
MOSS, WILLIAM M.
PASLEY, GALE G., JR.
PIERCE, PHEBE
PINGREE, FREDERICK DEW.
POOLE, STANLEY E.
PURINTON, CHARLES S.
RAICHE, SHIRLEY A.
ROSE, JOHN C.
RUTSTEIN, MILTON S.
SCHROEDER, ELIZABETH H.
SHEARER, BARBARA J.
SHULTZ, WILLIAM S.
SODERLAND, ELOISE M.
THAYER, LAWRENCE A.
THAYER, MARY C.
TORPHY, SHANNON R.
VOLKMANN, GORDON H.
VOLKMANN, SUZANNE B.
WALSH, MARTHA A.
WILKINS, CHARLES H.
WILKINS, EVANGELINE T.
WITZELL, WARREN E.

TECHNICAL CLERKS AND SECRETARIES

ALLEN, ETHEL B.
BEEHAN, ELIZABETH M.
BERGSTROM, EILEEN S.
BRADLEY, MABEL D.
BRAILEY, LEOLA R.
DOW, EVELYN
ENGLISH, JEAN
GLAESER, FLORENCE E.
MARSHALL, SONDRA L.
MELLOR, FLORENCE K.
ORTOLANI, MARY
OSTIGUY, BETTY P.
OWEN, HELEN T.
PERRY, BARBARA L.
PHILLIPS, HELEN F.
ROGERS, DOROTHY
SCHARFF, MARGARET
SMYTH, CLARA
SOUZA, CECELIA
SPOONER, JOANNE C.
STEWART, DORIS H.
THATCHER, BEVERLY J.
VEST, DOLORES E.
VEST, DOLORES R.
WILSON, ESTHER N.

ADMINISTRATIVE AND SECRETARIAL PERSONNEL

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

TECHNICAL SERVICES PERSONNEL

BAILEY, FRANK A.
BLAKE, FORREST W.
BODMAN, RALPH H.
BOWMAN, WARREN O.
BRIGHAM, ROBERT K.
CONDON, J. WILLIAM
DIMMOCK, RICHARD H.
DUNKLE, WILLIAM M., JR.
ELDRIDGE, STANLEY N.
FAIRCHILD, RICHARD G.
FELDMAN, JOEL
FISHER, STANLEY O.
GALLAGHER, GLORIA S.
GALLAGHER, WILLIAM F.
GASKELL, FRED
GIFFORD, JAMES E.
GRANT, CARLTON
HODGKINS, HARRY L.
HOWLAND, MYRON P., JR.
KAPLET, DOROTHY
MORRISON, KENNETH
NELSON, DONA E.
PENNIMAN, NORMAN
PERRY, ALLISON E.
PERRY, LEONARD S.
RENNIE, THOMAS D.
SPOONER, CHARLES E.
STIMPSON, JOHN W.
WEEKS, ROBERT G.
WING, CARLETON R.
WING, NATHANIEL (deceased)

MAINTENANCE, HOUSING AND CUSTODIAL PERSONNEL

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

OFFICERS AND CREWS OF VESSELS, BOATS, AND AIRCRAFT

ADAMS, MALCOLM H.
BACKUS, CYRIL
BAILEY, JAMES S.
BARROS, GEORGE M.
BISAILLON, RALPH
BLUTE, JOHN J.
BOYDEN, DEANE G.
BRADLEY, JOHN III
BRAY, W. SCOTT
CABRAL, JOHN V.
CASILES, DAVID F.
CAVANAUGH, JAMES J.
CLARKIN, JAMES J.
COLBURN, ARTHUR D., JR.
COOK, HANS
COPESTICK, LOUIS B.
CORNELL, THOMAS L.
COUGHLIN, BROOKS W.
DAY, JOSEPH V.
FOURNIER, RICHARD A.
GINGRASS, NORMAN
GRAFFAM, ROBERT
HARVEY, STANLEY A.
HAY, WILLIAM, JR.
HOWE, PAUL M.
HOWLAND, PAUL C.
KARLSON, ARVID
LAMBERT, JOSEPH L.
LYON, THOMAS
MACKEY, MALCOLM R.
MATTHEWS, FRANCIS S.
MCCANN, CLEMENT L., JR.
MOFFET, IVAN L.
MYSONA, EUGENE J.
NAILOR, DAVID A.
O'BRIEN, WARREN E., JR.
PALMER, WILLIAM E.
RODERICK, MILTON
ROSE, LAWRENCE
SEIBERT, HARRY H.
SHIELDS, WILLIAM J.
SMITH, JOHN J.
SPEIGHT, CARL W.
SUTHERLAND, PETER A.
VAN LOOY, FELIX J.
WAGNER, RICHARD M.
WILDE, DONALD F.

A new system of retirement benefits for the personnel was established during the year in place of the plan which had been in effect practically ever since the Institution was founded but had in recent years fallen into disuse. The plan as adopted by the Board, and put into effect as of July 1, 1954, offers a greater financial security to those permanently working at the Institution, and over the years it is anticipated that it will yield desirable profits in the form of soundly established internal relations and productive research.

The new retirement plan also has brought about a policy regarding the normal retirement age of Institution personnel which has been established as 65 years. In cases, however, of those individuals whose services are exceptionally valuable to the Institution, provision is made for their continuance on a year to year basis when so recommended by the Director and approved by proper authority.

Seven of our older employees not eligible under the new retirement plan on account of age, and having more than ten years of continuous service, will be kept on as long as practicable and their retirement worked out on as fair a basis as possible.

Acknowledgements

It is desired to record the support which the research program has received from the U. S. Navy Department's Office of Naval Research, the U. S. Bureau of Ships, the Bureau of Aeronautics, the Bureau of Ordnance, and the U. S. Air Force. The Commonwealth of Massachusetts, Division of Marine Fisheries, continued its support by furthering the shell-fish

investigations. The appreciation of the Institution is hereby expressed to the above Government departments and agencies.

Due acknowledgment is also extended to the following for their co-operation and support of oceanographic research, either in the form of grants or contracts:

National Science Foundation	Towns of Islip and Brookhaven
Rockefeller Foundation	Munitalp Foundation
Research Corporation	American Bureau of Shipping

Creole Petroleum Corporation

The gift of a sizeable lot of water front property by the General Foods Corporation together with a sum equal to the taxes for a period of one year, is gratefully recorded.

It is desired in this section to acknowledge with much appreciation the support which is growing stronger each year from the Woods Hole Oceanographic Associates. On February 26 the Associates held their annual dinner at the New York Yacht Club to some 150 members and guests following which Dr. Redfield spoke on the Institution's history and Captain Jaques-Yves Cousteau of the French Navy gave an illustrated lecture on his experiences in under-water diving by means of his invention, the aqua-lung. In April Mr. Noel B. McLean, President of the Edo Corporation, was elected Chairman of the corporate committee of the Associates. Earlier we have mentioned the Associates lectureship given in July. On August 7 the Associates held their annual cruise in Atlantis, when approximately 150 members and guests followed the start of the New York Yacht Club fleet race from Vineyard Haven to Nantucket. During the cruise, in perfect weather, oceanographic instruments were demonstrated and aqua-lung divers descended to the bottom of Vineyard Sound to bring up specimens.

"Oceanus," the modest little magazine which has been published at the Institution to keep the Associates currently informed on oceanographic events was stepped up to an issue of four times a year. At the end of the year the Associates numbered 124 individuals and 13 corporation members,—a growing organization of which we are justly proud.

During the year a positive force and policy was set in motion to add capital to the endowment fund of the Institution in the form of a brochure entitled, "Perpetuating Your Love for the Sea." Captain Marion Eppley accepted the Chairmanship of an Endowment Committee, by whose efforts and the distribution of the brochure, it is hoped through the years, that the capital endowment of the Institution will grow.

V. TREASURER'S REPORT

THE accounts for the year 1954 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of Endowment Funds at December 31, 1954 was $3,023,151, of which $603,731 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 $4,246,844, including cash and advance to Current Funds. 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 $149,255 for the year ended December 31, 1954, compared with $151,862 for the calendar year 1953. This income represents a return on the Endowment investments of 3.5% on the year-end market value, 4.9% on the book value, and 6.2% on the original value of the Endowment.

The Executive Committee, upon the recommendation of the Finance Committee, voted to allocate for 1954 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, $21,026, was transferred to the Income and Salary Stabilization Reserve. The rate was the same as voted in 1953.

On March 17, 1954 the General Foods Corporation made a generous gift to the Institution of its former marine base at New Street, East Boston. In addition to the property, they made a cash gift of $15,000 at the same time. These gifts were made without restriction. As the Institution, after careful consideration, feels it cannot use the property, it has been offered for sale. The value of the property is not included in the balance sheet, but the net proceeds will be added to Current Fund Assets when it is sold, for such disposition as may hereafter be determined.

The note payable to the New England Trust Company of $295,000 was paid off during the year, and replaced by an advance from the Endowment Funds to Current Funds. This advance was $175,000 on December 31, 1954. Interest on this advance at 2¼% is credited to Endowment income out of our Current Expenses in place of the interest formerly paid to the bank. The 2¼% rate is approximately the rate of interest received on the Government bonds sold to provide the cash for the advance. The net result of the above transaction was to save $5,132 in annual interest charges over the amount of interest paid in 1953.

Deferred Charges amounting to $71,033, as shown at the bottom of the balance sheet, 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 allocated to Research are shown in Schedule C, and the balance, representing contributions of the Woods Hole Oceanographic Associates as yet not specifically allocated, amounts to $35,957.

During the year contributions to the old Retirement Plan were ended by vote of the Trustees, and the new Woods Hole Oceanographic Institution Employees' Retirement Plan and Trust was voted and went into effect as of July 1st. The first contribution to this Trust, amounting to $26,810, was made early in January, 1955, and appears on the balance sheet as a Current Liability as of December 31, 1954. The amount was charged to Indirect Costs and a large proportion was recovered through the operation of the Overhead Recovery provisions in our Governmental contracts. The balance remaining in the old Retirement Fund, which is in the custody of the Treasurer as Trustee, amounted to $59,307 as at December 31, 1954. This amount represents balances held in separate savings bank accounts for ten individuals. We will continue to hold these amounts in this way until they become payable to the participants or their estates under the provisions of the original Retirement Plan.

At the suggestion of the new auditors, the Treasurer's Report and financial statements are being presented in a different form than in the past. The Income Statement this year includes all income of the Institution. In prior years Receipts under Contracts have not been included. Schedules A and B show details of Direct Costs of Research Activity, General and Administration Expenses, and Expenses of Plant Operation. It is interesting to note that for each dollar received, 74 cents were spent for Direct Costs of Research Activity, 19 cents for General and Administration Expenses and 7 cents for Plant Operation and Miscellaneous.

BALANCE SHEET

As at December 31, 1954

ASSETS

ENDOWMENT FUND ASSETS:		
Investment securities (Schedule D):		
Bonds (market quotations $1,635,198)		$1,611,987
Stocks (market quotations $2,415,052)		1,214,570
		$2,826,557
Cash		21,594
Advance to current funds		175,000
		$3,023,151
PLANT ASSETS (note A):		
Laboratory plant and equipment		$ 512,152
Vessels and equipment		364,983
Other property		161,541
		$1,038,676
CURRENT FUND ASSETS:		
Cash		$ 72,626
Accounts receivable:		
U. S. Government	$ 52,368	
Other	5,120	57,488
Unbilled costs on research contracts:		
U. S. Government	$283,461	
Other	7,302	290,763
Supply inventories		25,287
Deferred charges (note B)		71,033
		$ 517,197
		$4,579,024

LIABILITIES

ENDOWMENT FUNDS:		
Unrestricted		$2,000,000
For upkeep of plant		419,420
Accumulated net gain on sale of investments		603,731
		$3,023,151
FUNDS INVESTED IN PLANT		$1,038,676
CURRENT LIABILITIES AND FUNDS:		
Accounts payable and accrued expenses		$ 40,632
Contribution payable to employees' retirement plan and trust		26,810
Advance from endowment funds		175,000
Unexpended balances of gifts and grants:		
For research (Schedule C)		30,866
Oceanographic Associates		35,957
General fund:		
General plant and equipment reserve	$150,024	
Income and salary stabilization reserve	44,659	
Unappropriated	13,249	207,932
		517,197
		$4,579,024

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 25% 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, 1954 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 $9,400 net expenses in connection with this property.

STATEMENT OF INCOME, OPERATING EXPENSES AND UNAPPROPRIATED GENERAL FUND

For the Year Ended December 31, 1954

INCOME:		
Reimbursement of sponsored research activity:		
For direct costs		$1,288,026
For indirect costs		429,069
		1,717,095
Endowment income after amortization of bond premiums (Schedule D)	$149,255	
Less amount added to income and salary stabilization reserve	21,026	128,229
Miscellaneous		1,405
Total income availed of		1,846,729
OPERATING EXPENSES:		
Direct costs of research activity (Schedule A):		
Salaries and wages		696,227
Vessel operations		382,360
Materials and services		225,275
Travel		68,687
		1,372,549
Indirect costs:		
General and administration (Schedule B)	350,857	
Plant operation (Schedule B)	116,622	
Miscellaneous (including $4,000 reserved for replacement of equipment)	11,432	478,911
Total operating expenses		1,851,460
EXCESS OF OPERATING EXPENSES		4,731
UNAPPROPRIATED GENERAL FUND, JANUARY 1, 1954		17,980
UNAPPROPRIATED GENERAL FUND, DECEMBER 31, 1954		$ 13,249

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1954

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. GOVERNMENT CONTRACTS	$596,127	$367,104	$213,584	$59,062	$1,235,877
OTHER SPONSORED RESEARCH	39,636	1,782	5,561	5,170	52,149
Total direct costs of sponsored research	635,763	368,886	219,145	64,232	1,288,026
INSTITUTION RESEARCH	60,464	13,474	6,130	4,455	84,523
Total direct costs of research	$696,227	$382,360	$225,275	$68,687	$1,372,549

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1954

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:		
Staff benefits:		
Contributions to retirement plan effective July 1, 1954 and to retirement fund discontinued at that date		$27,969
Social security taxes		17,048
		45,017
Grants and fellowships		18,893
Purchase of books and equipment		26,674
Shop services		55,233
Housing and mess, net		6,331
Publications		8,893
ADMINISTRATION EXPENSES:		
Salaries and wages	$137,968	
Insurance, travel, supplies and other	59,507	197,475
		358,516
Less equipment charged to general plant and equipment reserve		7,659
		$350,857

PLANT OPERATION

SALARIES AND WAGES		$47,820
PROVISION FOR DEPRECIATION (credited to general plant and equipment reserve)		23,516
OTHER REPAIR COSTS	$20,311	
HEAT, LIGHT AND POWER	15,494	
OTHER	9,481	45,286
		$116,622

SCHEDULE C

SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH

Year Ended December 31, 1954

	Unexpended Balance January 1, 1954	Received	Expended Direct Costs	Expended Indirect Costs	Other Charges or (Credits)	Unexpended Balance December 31, 1954
American Society of Limnology and Oceanography		$915	$769	$146		
Arctic Institute	$635	1,407	1,498	544		
Barataria Bay Model	455		325			$130
Blue Dolphin		313	211	102		
Boat Lemming		342	342			
Columbia University			(34)		$34 [1]	
Commonwealth of Massachusetts	4,795	20,000	10,696	4,988		9,111
Creole Petroleum Corporation		5,349	4,221	1,128		
Great South Bay Project		2,000	2,358	1,353	(1,711) [1]	
Manufacture, sale and calibration of instruments			1,972	2,991	(4,963) [2]	
Munitalp Foundation		10,000			4,200 [3]	5,800
National Science Foundation:						
Biological productivity		2,760	2,400	360		
Buoyancy control in fish		5,373	4,818	555		
Penetration of light		6,200	4,450	667		1,083
Properties of chlorophyll		4,700	1,925	289		2,486
Oceanographic Associates		5,000	584	58		4,358
Research Corporation	438		339	63	(1,370) [2]	1,406
Rockefeller Foundation:						
Marine physiology	19,686	12,000	12,625		13,611 [4]	5,450
Meteorological research		2,500	1,458			1,042
Underwater swimming manual		2	1	1		
U.S. Coast Guard Oceanographic Unit		1,676	1,191	306	179 [1]	
	$26,009	$80,537	$52,149	$13,551	$9,980	$30,866

[1] Credited or (charged) to Institution operating expenses.
[2] Receipts from sales or services.
[3] Payments to designated award recipients.
[4] Returned to donor.

SCHEDULE D

SUMMARY OF INVESTMENTS

As at December 31, 1954

	Book Amount	% of Total	Market Quotation	% of Total	Income
BONDS:					
U.S. Government	$527,518	18.66	$525,230	12.97	$11,723
Railroad	419,371	14.84	437,206	10.79	10,392
Public utility	228,582	8.09	228,657	5.65	3,769
Industrial	231,468	8.19	238,705	5.89	4,037
Financial and investment	205,048	7.25	205,400	5.07	(780)
Total bonds	$1,611,987	57.03	$1,635,198	40.37	$29,141
STOCKS:					
Preferred	$368,023	13.02	$405,313	10.01	$19,936
Common:					
Public utility	$275,412	9.74	$410,901	10.15	$22,435
Industrial	429,976	15.22	1,310,430	32.35	61,344
Miscellaneous	141,159	4.99	288,408	7.12	12,208
Total common stocks	$846,547	29.95	$2,009,739	49.62	$95,987
Total stocks	$1,214,570	42.97	$2,415,052	59.63	$115,923
Total Investments	$2,826,557	100.00	$4,050,250	100.00	$145,064
INTEREST ON ADVANCE TO CURRENT FUNDS CHARGED TO MISCELLANEOUS OPERATING EXPENSE					4,191
TOTAL ENDOWMENT FUND INCOME					$149,255

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1954 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, 1954 and the results of its operations for the year then ended.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts
May 16, 1955

APPENDIX

ATLANTIS

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist—Remarks
196	18 Jan.	1 Feb.	Woods Hole	Miami	15	H. Johnson
	6 Feb.	19 Feb.	Miami	St. Thomas	14	H. Johnson
	22 Feb.	27 Feb.	St. Thomas	San Juan	6	H. Johnson
	1 Mar.	5 Mar.	San Juan	San Juan	5	H. Johnson
	8 Mar.	9 Mar.	San Juan	San Juan	2	H. Johnson
	15 Mar.	23 Mar.	San Juan	Nassau	9	H. Johnson
	24 Mar.	2 Apr.	Nassau	Woods Hole	10	H. Johnson
	7 Apr.	7 Apr.	Woods Hole	Boston	1	To Boston for annual
	19 May	19 May	Boston	Woods Hole	1	drydocking
197	24 May	28 May	Woods Hole	Woods Hole	5	H. Johnson
198	7 June	17 June	Woods Hole	Woods Hole	11	W. Malkus
199	24 June	30 June	Woods Hole	Woods Hole	7	W. Schroeder
200	6 July	9 July	Woods Hole	Woods Hole	4	D. Frantz
201	14 July	17 July	Woods Hole	Woods Hole	4	H. Johnson
202	21 July	24 July	Woods Hole	Woods Hole	4	H. Johnson
203	26 July	5 Aug.	Woods Hole	Woods Hole	11	H. Stetson
204	7 Aug.	7 Aug.	Woods Hole	Woods Hole	1	Associates Cruise
205	9 Aug.	21 Aug.	Woods Hole	Woods Hole	13	H. Johnson
206	26 Aug.	30 Aug.	Woods Hole	Bermuda	5	J. Zeigler
	4 Sept.	10 Sept.	Bermuda	Woods Hole	7	J. Zeigler
207	10 Sept.	10 Sept.	Woods Hole	Boston	1	Hurricane precaution
	12 Sept.	12 Sept.	Boston	Woods Hole	1	
208	17 Sept.	26 Sept.	Woods Hole	Bermuda	10	L. Worthington
	28 Sept.	1 Oct.	Bermuda	Woods Hole	4	L. Worthington
209	10 Oct.	14 Oct.	Woods Hole	Woods Hole	5	H. Johnson
210	15 Oct.	15 Oct.	Woods Hole	Boston	1	Hurricane precaution
	16 Oct.	16 Oct.	Boston	Woods Hole	1	
211	17 Oct.	27 Oct.	Woods Hole	Woods Hole	11	R. Walden
212	3 Nov.	8 Nov.	Woods Hole	Bermuda	6	L. Worthington
	9 Nov.	26 Nov.	Bermuda	Barbados	18	L. Worthington
	30 Nov.	30 Nov.	Barbados	Barbados	1	L. Worthington
	1 Dec.	1 Dec.	Barbados	Barbados	1	L. Worthington
	2 Dec.	2 Dec.	Barbados	Barbados	1	L. Worthington
	3 Dec.	19 Dec.	Barbados	Woods Hole	17	L. Worthington
			Total		213	

CARYN

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist—Remarks
71	17 May	21 May	Woods Hole	Woods Hole	5	J. Zeigler
72	28 May	1 June	Woods Hole	Bermuda	5	L. Worthington
	2 June	13 June	Bermuda	St. Thomas	12	L. Worthington
	17 June	24 June	St. Thomas	Bermuda	8	L. Worthington
	25 June	29 June	Bermuda	Woods Hole	5	L. Worthington
73	12 July	19 July	Woods Hole	Woods Hole	8	J. Zeigler
74	20 July	21 July	Woods Hole	Woods Hole	2	R. Edwards
75	22 July	24 July	Woods Hole	Woods Hole	3	D. Frantz
76	25 July	29 July	Woods Hole	Woods Hole	5	R. Edwards
77	3 Aug.	5 Aug.	Woods Hole	Woods Hole	3	G. Clarke
78	5 Aug.	15 Aug.	Woods Hole	Woods Hole	11	H. Johnson
79	19 Aug.	29 Aug.	Woods Hole	Woods Hole	11	F. Fuglister
80	2 Sept.	4 Sept.	Woods Hole	Woods Hole	3	D. Frantz
81	9 Sept.	9 Sept.	Woods Hole	Boston	1	Hurricane precaution
	12 Sept.	12 Sept.	Boston	Woods Hole	1	
82	15 Sept.	17 Sept.	Woods Hole	Woods Hole	3	D. Owen
83	15 Oct.	15 Oct.	Woods Hole	Boston	1	Hurricane precaution
	17 Oct.	17 Oct.	Boston	Woods Hole	1	
84	19 Oct.	22 Oct.	Woods Hole	Woods Hole	4	W. Moss
85	28 Oct.	2 Nov.	Woods Hole	Woods Hole	6	W. Athearn
86	30 Nov.	2 Dec.	Woods Hole	Woods Hole	4	R. Walden
87	9 Dec.	9 Dec.	Woods Hole	Woods Hole	1	R. Walden
88	17 Dec.	17 Dec.	Woods Hole	Boston	1	To Boston for annual
	30 Dec.	30 Dec.	Boston	Woods Hole	1	dry-docking
			Total		105	

BEAR

Cruise No.	Depart	Arrive	From	To	Days	Chief Scientist—Remarks
89	18 Jan.	23 Jan.	Woods Hole	Morehead City	6	F. Dietz
	26 Jan.	1 Feb.	Morehead City	Miami	7	F. Dietz
	7 Feb.	18 Feb.	Miami	St. Thomas	12	G. Wheeler
	23 Feb.	23 Feb.	St. Thomas	San Juan	1	G. Wheeler
	1 Mar.	5 Mar.	San Juan	San Juan	5	G. Wheeler
	11 Mar.	12 Mar.	San Juan	San Juan	2	G. Wheeler
	15 Mar.	23 Mar.	San Juan	Nassau	9	G. Wheeler
	24 Mar.	2 Apr.	Nassau	Woods Hole	10	G. Wheeler
90	18 May	18 May	Woods Hole	Woods Hole	1	A. Vine
91	19 May	19 May	Woods Hole	Woods Hole	1	A. Vine
92	25 May	28 May	Woods Hole	Woods Hole	4	J. Zeigler
93	1 June	6 June	Woods Hole	Woods Hole	6	W. Shultz
94	14 June	17 June	Woods Hole	Woods Hole	4	R. Edwards
95	25 June	25 June	Woods Hole	Woods Hole	1	R. Edwards
96	6 July	9 July	Woods Hole	Woods Hole	4	W. Athearn
97	14 July	14 July	Woods Hole	Woods Hole	1	W. Dow
98	21 July	24 July	Woods Hole	Woods Hole	4	J. Hersey
99	28 July	29 July	Woods Hole	Oyster Bay	2	Installation of equipment at Sperry Gyro Co.
	30 July	30 July	Oyster Bay	Woods Hole	1	
100	9 Aug.	20 Aug.	Woods Hole	Woods Hole	12	J. Hersey
101	24 Aug.	24 Aug.	Woods Hole	Woods Hole	1	C. Officer
102	25 Aug.	25 Aug.	Woods Hole	Woods Hole	1	C. Officer
103	27 Aug.	27 Aug.	Woods Hole	Woods Hole	1	G. Duys
104	9 Sept.	9 Sept.	Woods Hole	Woods Hole	1	C. Officer
105	10 Sept.	10 Sept.	Woods Hole	Boston	1	Hurricane precaution
	12 Sept.	12 Sept.	Boston	Woods Hole	1	
106	13 Sept.	17 Sept.	Woods Hole	Woods Hole	5	R. Backus
107	22 Sept.	22 Sept.	Woods Hole	Woods Hole	1	C. Officer
108	10 Sept.	14 Sept.	Woods Hole	Oyster Bay	5	J. Hersey
	15 Sept.	17 Sept.	Oyster Bay	Woods Hole	3	
109	3 Nov.	4 Nov.	Woods Hole	Woods Hole	2	H. Johnson
110	7 Nov.	9 Nov.	Woods Hole	Woods Hole	3	To Sperry Gyro Co. and return
111	10 Nov.	12 Nov.	Woods Hole	Woods Hole	3	H. Johnson
112	15 Nov.	15 Nov.	Woods Hole	Boston	1	To Boston for shipyard repairs
				Total	122	

PBY–6A

Flight No.	Date	Bases	Days	Chief Scientist—Remarks
	4 Jan.–5 Feb.	Local flights	11	
P-98	8 Feb.	Otis to Cherry Point		W. Richardson
	9 Feb.	Cherry Point to Miami, Fla.		
	10 Feb.	Miami to Charleston, S. C.		
	11 Feb.	Charleston to Otis	4	
	16 Feb.–23 Feb.	Local flights	4	
P-103	24 Feb.	Otis to Kindley, Bermuda		A. Bunker–W. Malkus
	26 Feb.	Kindley local		
	27 Feb.	Kindley local		
	28 Feb.	Kindley to Otis	4	
	4 Mar.–5 Mar.	Local flights	2	
	5 Mar.–29 Mar.	To Quonset for check and return	2	In for 720-hr check
P-108	31 Mar.	Otis to Argentia, Nfld.		W. Richardson
	6 Apr.	Argentia local		
	8 Apr.	Argentia local		
	9 Apr.	Argentia local		
	10 Apr.	Argentia local		
	11 Apr.	Argentia local		
	13 Apr.	Argentia local		
	14 Apr.	Argentia local		
	15 Apr.	Argentia local		
	17 Apr.	Argentia local		
	19 Apr.	Argentia local		
	20 Apr.	Argentia local		
	22 Apr.	Argentia to Otis	13	
	26 Apr.–29 Apr.	Local flights	2	
P-111	5 May	Otis to Cherry Point		A. Redfield
	6 May	Cherry Point to Daytona Beach		
	7 May	Daytona Beach to Cherry Point		
	8 May	Cherry Point to Atlantic City		
	9 May	Atlantic City to Otis	5	
	12 May–7 June	Local flights	10	
P-122	8 June	Otis to Elizabeth City		W. Richardson
	9 June	Elizabeth City to Otis	2	
	11 June–17 June	Local flights	3	
P-127	18 June	Otis to Quonset	1	Into check
P-128	2 July	Quonset to Otis	1	Out of check
	8 July–9 July	Local flights	2	
P-131	12 July	Otis to Kindley		W. Richardson
	14 July	Kindley local		
	15 July	Kindley local		
	16 July	Kindley to Otis	4	
	22 July–18 Nov.	Local flights	45	
P-176	21 Nov.	Otis to Elizabeth City		W. Richardson
	22 Nov.	Elizabeth City local		
	23 Nov.	Elizabeth City to Otis	3	
P-177	24 Nov.	Otis to Quonset	1	Maintenance
P-178	14–15 Dec.	Quonset to Pensacola, Fla.	1	Maintenance
	16–17 Dec.	Pensacola to Otis	1	Return flight
P-179	19 Dec.	Otis to Bermuda		W. Richardson
	21 Dec.	Bermuda to Otis	2	
	29 Dec.	Local flight	1	
		Total	124	