THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

REPORT FOR THE YEAR 1957

1958

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IV. DIRECTOR'S REPORT

Introduction

DURING the past year we have had some notable scientific successes, as I will try to explain below, but we have also been going through some very rough weather financially. As the year progressed funds available through the military services for the support of basic research steadily declined. Were it not for the extra appropriations for the International Geophysical Year we would have had to curtail drastically much of our field work. As it turned out we just managed to finish out the year with a small deficit, but I do not remember a year when the budget involved so much worry and uncertainty. Inflation in the costs of carrying on oceanography has, of course, been increasingly severe.

The future would look most uncertain indeed were it not for the establishment of a new Committee on Oceanography by the National Academy of Sciences-National Research Council. This group, under the chairmanship of Professor Harrison Brown, is charged with studying the national needs in oceanography and with making recommendations as to how these can best be met. Financial support of these studies has been made available by the Office of Naval Research, by the U. S. Fish and Wildlife Service and by the Atomic Energy Commission. It has become more generally realized in Washington, D. C., that research cannot be carried on effectively under a system that results in widely fluctuating annual budgets.

The other important development of the past year is the enthusiasm which has continued to mount for the oceanographic program of the International Geophysical Year. In fact, we have already carried out a good deal more than the originally agreed program of deep observations and even more ambitious plans are in the making.

Studies of Oceanic Circulation both on a Large Scale and on a Small Scale

Nearly half the work going on at the laboratory and at sea falls under this general heading and excellent progress has been made during recent months. The basic material which we work with consists of measurements of temperature, salinity, and dissolved oxygen. A good deal of skill is required to obtain such observations from depths greater than about 3,000 meters, yet more than half the water in the ocean lies at depths greater than this.

In February, as part of our contribution to the International Geophysical Year, Mr. Frederick C. Fuglister set out on the CRAWFORD with a

relatively green crew of observers to obtain four complete east-west trans-Atlantic profiles. The expedition was away from Woods Hole for four months and steamed about 18,500 miles. They occupied a total of 114 stations, nearly all of which extended down to within a few meters of the bottom. When you consider that he was using a vessel displacing less than 300 tons when fully loaded it was a remarkable job indeed.

The primary objective was to re-occupy two of the METEOR profiles across the tropical South Atlantic that were made about 30 years ago. Until very recent years these were the best data for large-scale circulation problems that had ever been obtained. Using a ship only a fifth the size, Mr. Fuglister and his assistants obtained about twice as many points of observation as the METEOR on each crossing, including a great many close to the bottom. When these data are combined with the additional sections expected to be obtained during the remainder of I.G.Y., the basic information for Atlantic large-scale circulation problems will have been improved by a whole order of magnitude. Especially this is true for salinity, thanks to the new conductivity bridges developed by Mr. Alvin L. Bradshaw and Mr. Karl E. Schleicher.

Meanwhile, the ATLANTIS and the British research vessel DISCOVERY II had also "jumped the gun" for I.G.Y. They met at Bermuda in March and proceeded to make a very critical and successful series of observations in the waters over the outer limits of the Blake Plateau off Charleston.

Of recent years, as our ability to measure temperature close to the bottom improved, we have found that very deep crosscurrent density gradients exist under the Gulf Stream System. If one assumes that the Gulf Stream extends down to only 1,500 or 2,000 meters, theoretical considerations demand that the waters below this level are flowing in the opposite direction. Thus the problem was to locate the layer of minimum motion below the Gulf Stream System and to learn whether or not a countercurrent exists below this level.

Off Charleston, because of the presence of the Blake Plateau, the situation was particularly favorable for the success of such measurements, for the deep flow (whatever its direction) is not under the swift Florida Current, but lies well east of it. Thus at this point in the system the ships would not be handicapped by strong near-surface currents.

In spite of some bad weather the results were clear-cut. At about 2,000 meters there is, indeed, a layer of minimum motion and at 2,800 meters the water is moving toward the south at a rate of about 8 miles per day.

This is the first time we have traded scientific parties and techniques with our British friends and the exchange was highly successful for both groups. We gained first-hand experience in handling Dr. John C. Swallow's

new neutrally buoyant floats and the British profited by observing our techniques of measuring the very deep density gradients. Now that the ice has been broken it should be easier to arrange for continuing international cooperation in oceanography.

On the voyage back to England, Mr. L. Valentine Worthington and Mr. William G. Metcalf aboard the DISCOVERY had the opportunity of securing a very complete profile from the eastern edge of the Grand Banks to the approaches to the English Channel. None of our vessels could have worked this section successfully except in summer.

In short, between the DISCOVERY and the CRAWFORD five complete trans-Atlantic profiles were secured last winter. During October and November each vessel secured two more, and it is planned that in February the ATLANTIS will make a crossing at about Latitude 35°S.

It will be very exciting indeed to put all these new data together within a consistent framework. This will be the first time that it has been possible to treat the North and the South Atlantic Oceans as a single unit in a more or less synoptic manner.

There are many by-products of the long east-west profiles. In the first place, the improvements in the recording echo sounders, for which Mr. Sidney T. Knott is chiefly responsible, are producing much useful detail about the bottom topography. In addition, we have by no means neglected to collect samples of water for chemical analysis.

In September at Toronto an ambitious international symposium was held on problems of deep circulation. Our new data were presented there and it is hoped that what we have been accomplishing in the Atlantic during recent years will stimulate others to obtain similar data from other areas.

Dr. Richard G. Leahy, who joined our staff last winter, has been organizing and coordinating our I.G.Y. effort. In addition to the field work already mentioned which the CRAWFORD and the ATLANTIS are carrying out, he has supplied the Arctic ice flow camps with two oceanographic observers who have been studying the currents under the ice and he has stimulated several of Professor Birch's graduate students at Harvard to build equipment to measure the heat flow through the bottom sediments in the Arctic basin. This is a particularly favorable situation for such measurements because the probe can probably be left in the bottom for considerable periods of time, so slow are the ice movements. Dr. Leahy has also been testing our new CO_2 analyzer and developing, with the help of others, suitable plumbing so that it can be operated in our new airplane. While the major effort during I.G.Y. will be to gain a census of the CO_2 in the atmosphere, several of our staff have designs on this very exact instrument for studying the CO_2 cycle in the sea.

While improvement in the quality of the observations at sea has seemed to me the outstanding development of recent months, other groups have not been idle. We now have a particularly strong team attacking circulation problems by means of mathematical models. These are becoming increasingly elaborate and at the same time more convincing.

All during the winter our people met every two weeks with the corresponding team at the Massachusetts Institute of Technology. Not only were many formal papers given, but in the evenings at dinner and afterwards there was much stimulating discussion. The theoretical approach, both in meteorology and in oceanography, is now in very competent hands and it would be surprising indeed if some major break-throughs did not occur before long. I will mention only one of the lines of reasoning that seems profitable. Last winter Mr. Fuglister called attention to a peculiarity of the North Atlantic. Both because of geographical reasons and because of the wind system there is a net northward movement of the near-surface waters. Sea level must be higher in the northern North Atlantic than in any other ocean area. Estimates of the northward transport of surface water range as high as $20 \times 10^6/m^3 sec^{-1}$. The theoreticians then began to think about the character of the return flow in view of the rotation of the earth. As usual Mr. Henry Stommel came up with a very intriguing mathematical model which seems to explain not only the countercurrent under the Gulf Stream but also the relative weakness of the Brazil Current which is its counterpart in the South Atlantic.

It has recently been possible for Mr. Alan J. Faller to check experimentally some of the basic new ideas concerning such forced circulations. Incidentally, Mr. Faller has been invited to join the experimental group at the University of Chicago during the winter of 1957–58 and I am certain this added experience will be of great help to his future work here.

For the time being, at least, Dr. William S. von Arx has lost some of his enthusiasm for hydraulic models and has turned his main attention to other matters, notably the new navigating systems which are coming into being. In most of these the ocean enters into the picture in rather subtle ways and by studying the disagreement of the various systems it is possible to find out some things about the ocean. The U.S.S. COMPASS ISLAND, which is the ship being used for research by the Navy in precise navigation, is in effect a powerful tool for oceanography and Dr. von Arx has stimulated the very able officers on this ship to take the ocean into account in the course of using a huge array of very precise and complicated navigational instruments.

This is but one sample of his many activities. During the first half of last winter Dr. von Arx gave a successful course in oceanography at Massachusetts Institute of Technology and has recently been appointed an Associate

Professor there. The other half of the course was given jointly by Dr. Joanne S. Malkus and Dr. J. Bracket Hersey.

As far as coastal currents are concerned, Mr. Dean F. Bumpus, assisted by Mr. C. Godfrey Day and Mr. Joseph Chase, has continued to compile temperature and salinity data along the whole coast so as to study seasonal and longer term fluctuations from the fisheries standpoint. Our contract with the U. S. Fish and Wildlife Service has been continued for two more years, but on a somewhat reduced basis.

Mr. Day has made a rather thorough study of the modern drift bottle results and this has served as background for the setting out of a number of our new radio telemetering buoys, both in the Bay of Fundy and on Georges Bank. As experience with these free-floating buoys accumulates it is evident that they could be useful for many different sorts of problems, both physical and biological. Last year they survived November and December weather in the Bay of Fundy. In March four buoys were set adrift on Georges Bank in the area where haddock spawn. The movements of the water due to the local wind were studied intensively during about a six-week period, using the ALBATROSS III rather than our plane for locating the buoys at frequent intervals. After a storm two buoys failed to answer and were given up for lost. More than two months later one of these buoys suddenly began to be heard again and was located off New York. Its southwesterly progress has been at the rate of about four miles per day.

Mr. David H. Frantz and Mr. Robert G. Walden are engaged in improving the amount of information the buoys are able to report. In other words, the early ones when interrogated gave only a signal that could be homed-on or located by triangulation. Now this signal is being coded to transmit additional data that have been stored in the buoy since the last transmission.

Two more aspects of the buoy development work seem to deserve mention. The testing of the various components of Mr. Frantz' submerged buoy, known as the "pop-up," has just about been completed. This has turned out to be a long, slow job because the buoy and its sensing elements were designed to have a useful life of nearly a year. While the original buoy made here functioned as it was supposed to, there were a number of defects in the ten supposedly improved copies that were made commercially in the hope of making this type of device available to the other laboratories.

Mr. Gordon H. Volkmann, after spending nearly three years at Scripps, has recently returned to Woods Hole and is devoting full time to the development of our version of the Swallow-type, submerged, free-floating buoy.

Dr. William S. Richardson, Mr. Allyn C. Vine and Dr. J. B. Hersey have continued their program of employing vertically spaced arrays of

thermistors to study shallow temperature distributions. The earlier tests made from our own ships ATLANTIS and BEAR in the Cayman Sea in 1956 clearly indicated that the thermistor array could be much more effectively towed from a larger ship and with more fully designed towing gear. Accordingly Mr. Roy L. Rather, an associate of the Institution, through his company, The Commercial Engineering Company, Inc., designed and constructed a chain, in which the thermistors and connecting wires could be mounted, and a diesel-powered winch for towing and handling the chain. In the spring of 1957 this winch assembly was mounted on the stern of the Coast Guard Ship YAMACRAW, which was made available to the Institution for this purpose through the Office of Naval Research. An enormous quantity of new type temperature data was recorded in the following months in the Sargasso Sea and along the east coast from Nova Scotia to Charleston, S. C.

The chain was 600 feet long and had 23 thermistors mounted on it at 25-foot intervals. Each thermistor was connected to a self-balancing bridge and digitizer, which in turn fed into an electric typewriter. The whole instrument was calibrated and programmed so that the temperature in degrees centigrade at each thermistor is typed on a long strip of paper in a pattern corresponding to the vertical arrangement of thermistors in the water. Thus water temperatures at 23 different depths could be measured repeatedly at two-minute intervals while the ship is underway, providing a much more detailed temperature section than has hitherto been possible. Individual temperatures are accurate to $\pm 0.01°C$, a considerable increase in accuracy over the bathythermograph. Obviously the depth pattern of the measurements varies with the towing speed, to almost the full 600 feet at slow speeds and to about 400 feet at full speed (12 knots). Two depth meters mounted on the chain provide repeated depth checks. Thus far water structures between the east coast and Bermuda have been studied revealing in great detail the complicated surface structures between the coast and the Gulf Stream, those at the edge of the Stream, and the more constant structures in the western part of the Sargasso Sea. As I reported last year from the earlier observations in the Cayman Sea, this more sensitive instrument reveals considerable complexity even in the wind-mixed surface layers. Our acousticians are studying the significance of these findings to sound transmission, and it is quite obvious that these data will be very useful to students of mixing processes and energy exchange between the atmosphere and the ocean.

The YAMACRAW has provided many of our staff with an opportunity to work with a larger ship, and to be able to work and transit in rougher weather than we can in our smaller ships. All members of the Institution staff who

have had the pleasure of working with the Coast Guard crew of YAMACRAW have been impressed with the fine spirit of cooperation with which they have undertaken their assignment throughout.

Geophysics and Underwater Acoustics

For several years Dr. Hersey, Mr. Knott and others of the staff have been developing a high-definition seismic reflection apparatus for exploring shallow sediment structures in water-covered areas. It operates somewhat as an echo sounder, but differs by employing a broad spectrum sound pulse so that sound reflected from the bottom and rock layers below the bottom can be filtered to develop and emphasize subbottom reflections. Thus, it can be used to measure the thickness and sound velocity of sediments up to several hundreds of feet thick. In the late winter of 1957 the apparatus was used in Narragansett Bay to determine the depth to bedrock so as to aid the Navy in estimating the cost of deepening a channel there, and we are at this writing about to send ASTERIAS back to Narragansett Bay for a similar investigation for the Corps of Engineers in connection with their study of hurricane protection construction for that area. Mr. Don R. Fink and Miss Elizabeth T. Bunce are conducting the survey.

These engineering studies have the considerable advantage that bottom corings have been made which can be compared directly with reflection observations accurately placed at the core locations.

In addition, Dr. Earl E. Hays and Mr. J. Rietzel have used the reflection apparatus in a preliminary study of shifting sand bars in Vineyard Sound and Mr. Fink has started a detailed study of Buzzards Bay. We have also shared our instrument design with the Lamont Geological Observatory. Lamont staff members have employed the apparatus with considerable success in Long Island Sound and Chesapeake Bay.

Dr. Hersey and Miss Bunce have completed an intensive study of seismic data taken over the ocean area comprising the continental shelf, the Blake Plateau and adjacent deep water between the latitudes of Cape Henry, Va., and Jacksonville, Fla. The observations at sea were made on various cruises in 1954, 1955, and 1956, as I reported in 1956. These permit reasonable speculation about the geologic history and structure of the area which suggests that the Blake Plateau was formerly much shoaler, with an aspect similar to the modern Bahamas, and that a string of reefs or volcanic islands once stood along a southeasterly trend from Cape Fear about four hundred miles out to sea.

Dr. Charles B. Officer, Jr. (of the Rice Institute) and Mr. John Ewing (of Lamont Geological Observatory) have completed the analysis of seismic

data from their two expeditions on our vessels to the Caribbean and have published two of a projected series of papers. Their results are a fundamental contribution to understanding the tectonics of this region and other island arc structures.

The YAMACRAW was the means of getting many people to sea during the summer months. Among the observational programs carried out were a series of tests in three photographic projects in which different members of our staff have collaborated with Professor Harold E. Edgerton of the Massachusetts Institute of Technology. Professor Edgerton has developed a series of underwater cameras using his high-intensity electronic flash. Mr. Lloyd D. Hoadley of the Institution staff has worked with Professor Edgerton in the camera design, and Mr. David M. Owen has used the cameras at sea for a variety of observations during the past several years. Dr. Richard H. Backus, Mr. Henry R. Johnson, and others have used Edgerton cameras in conjunction with a suspended echo sounder for photographing individual sound scatterers in the deep scattering layers.

In addition Dr. Charles J. Hubbard carried out a program of measurements of the spectral distribution of sunlight under water. He used a deck recording spectrophotometer which scanned the optical spectrum from 400 to 650 μ at depths to 1500 feet. This type of data is basic to the problem of proper design of underwater television and other underwater optical equipment.

Professor Edgerton had also constructed a camera especially designed to take repeated photographs of the bottom when suspended on a long wire cable or line from a drifting ship. He uses no electrical leads in the suspending cable. The camera is coupled with a repeating electronic flash and a sound projector which sends out a series of short, intense pulses of sound. The research ship receives and measures the time interval between these pulses and their reflections from the bottom as an indication of the distance of the camera from the bottom. The distance can be adjusted by changing the wire out. This camera system was tested by Professor Edgerton, Dr. Backus and Dr. Hersey at three locations from the YAMACRAW. They obtained several hundred photographs on each lowering of the camera, indicating that such an approach to bottom photography can be used for detailed exploration in deep water.

For the past several years Dr. Backus, Mr. Johnson and others have been developing a technique for photographing individual sound scatterers in deep scattering layers. This technique has been emphasized because it appears to be the most promising means of identifying the organisms which scatter the sound received as "scattering layers" on ship-mounted echo sounders. This method consists of lowering an echo sounding system

mounted with a camera into the scattering layer under study. The echo sounder and camera are electrically connected to the research ship so that an observer watching the sound recording can determine exactly when to actuate the camera to photograph an object scattering sound.

Dr. Harold Barnes of the Marine Station, Millport, U. K., collaborated with Dr. Backus and others in various investigations with the British underwater television apparatus which was so kindly loaned to the Institution upon his recommendation by the Scottish Home Department. The television equipment was combined with the suspended echo sounder for studying open ocean sound scatterers in the fall of 1956. These studies served to confirm previous observations made with the echo sounder and underwater camera discussed above, but unfortunately the cruises were plagued by bad weather, so that their studies did not progress further. In shallow water they made a number of interesting observations of the bottom which were combined with detailed, short pulse echo sounder recordings. This work has encouraged them to regard this combination of techniques as promising for study of acoustical properties of the bottom.

Geology

Arrangements have been made recently for Professor Raymond Siever, who came to Harvard University in the autumn on a permanent basis, to take over general supervision of our sedimentary research. In effect he will be taking over Mr. Henry C. Stetson's duties. His interests, however, run along somewhat more chemical lines. This is also the area in which Dr. Leahy has specialized so it is expected that in the future the chemistry of marine sediments will receive rather more attention here than has been the case in the past.

Meanwhile Dr. Parker D. Trask, Professor Bernhard Kummel, and Dr. E-an Zen are hard at work analyzing the sediment cores which Mr. Stetson secured during his last expedition to the waters off the coast of Peru.

Dr. John M. Zeigler and his several assistants have continued to study beach dynamics vigorously. He and Mr. William D. Athearn have also become interested in the long cores supplied by the Raymond Concrete Pile Company from the radar tower sites. The borings off New York are especially provocative, for they reached down to some well-dated Long Island clay. These very long cores indicate that the rate of deposition of sand across the continental shelf has been remarkably rapid (about 90 feet) since glacial times. It is planned to follow up this clue and to renew studies of the transportation of the offshore sands.

Marine Meteorology

Field work in meteorology has been more or less at a standstill during recent months due to the fact that we have been in the process of changing over from the PBY-type plane to a DC3. Since over the years the PBY had become a well-calibrated meteorological instrument, much effort has been required to bring the new plane up to these standards. The first flights gathering meteorological data took place during July, but for other purposes the plane has been flying since early spring. The chief advantages of the DC3 are more working space in the cabin, which also has acoustical insulation; the top speed is considerably greater than the PBY, but it can also fly slowly; and it can fly safely on one engine which the older plane could not do for any considerable distance.

Meanwhile, good use of the time has been made in the laboratory to improve the instrumentation and to complete papers based on the accumulated data.

A recent visit of Dr. Joanne S. Malkus to Stockholm was particularly fruitful. Dr. C.-G. Rossby had arranged before he died for her to use the Swedish computer to work out the events following the arrival of a bubble of warm air at cloud base.

Dr. Raymond Wexler, Mr. Alfred H. Woodcock, and Dr. Malkus each have produced a paper on hurricanes during recent months. Although financial support on the part of the Weather Bureau for hurricane research has been shrinking steadily, there is no lack of interest on the part of the people here. Mr. Michael Garstang, a keen student of tropical meteorology, has joined our staff recently and spent much of August and September at sea on the CRAWFORD in order to test some of the ideas which he formed about the early stages of a hurricane when he was stationed at Trinidad.

We have yet to solve the problem of observing wind direction and velocity aloft from a small vessel in fairly rough seas, but our electronics people have by no means run out of ideas and it is hoped by next season we will have a reliable system for measuring the vertical wind profile. Such observations are critical to the various models which have been devised in an effort to explain the early stages of a hurricane.

Wave Studies

The David Taylor Model Basin allowed Mr. Wilbur Marks to return to Woods Hole for two months last summer in order to finish up the analysis of the motions of the launch RISK which were made several years ago. This

should become a classical paper in the literature of naval architecture for it is one of the first to apply modern theory to the response of a model ship to an irregular, natural sea. Mr. Richard G. Barakat and Mr. Charles E. Carver are planning to extend such studies to the CRAWFORD and to a self-propelled model of the CRAWFORD. The newly-constructed wave tower, which will be planted soon in Buzzards Bay, is the first step in this new attack on wave-measuring techniques.

Last winter a long visit by the German wave expert, Dr. Hans Walden, did much to stimulate the various members of our staff interested in wave problems.

The very considerable labor of deriving the power spectrum from wave records has been a serious bottleneck in wave research. A new and very versatile electronics computer has recently been developed for wave investigations at the Sperry Gyroscope Company and this should greatly accelerate not only the program here but also the studies of other interested groups.

Biology and Chemistry

The following section of this report was prepared by Dr. Bostwick H. Ketchum and consequently fails to indicate the important part he is playing in leading and organizing our expanding program in marine biology.

We have initiated an intensive study of the plankton populations in the waters over the continental shelf. This program is supported jointly by Institution funds and by a grant from the Atomic Energy Commission under the supervision of Dr. Ketchum and Dr. Vaughan T. Bowen. Dr. Mary Sears and Dr. John H. Ryther are cooperating in the investigation. The program has also increased the opportunities for observations at sea for Mr. Ralph F. Vaccaro and Mr. Charles S. Yentsch, both of whom are supported by research grants from the National Science Foundation.

Periodic observations of the plankton populations and of the chemistry of the water are being made and the plan is to continue such observations for a period of at least three years in an effort to understand more completely the ecological conditions which determine the size, productivity, and succession of plankton populations in a coastal area.

The cruises have been planned to provide two cross sections of the continental shelf with stations in water ranging in depth from 30 meters to 2,000 meters. Thus a comparison between the ecology of inshore coastal populations and of offshore populations is provided. Six replicate cruises to the area were completed in 1957. A preliminary survey of the results of the program was presented at the meeting of the American Society of Limnology and Oceanography held in Woods Hole in September. Dr.

Ketchum and Dr. Ryther participated in a Symposium on Oceanic Productivity held in Bergen, Norway, at the end of September.

A relatively cold, low salinity body of water was found from about 30 meters to the bottom in the section south of Montauk Point in September. This water was isolated from surface water by an intense temperature gradient and from the offshore waters by an intense salinity gradient. No water of these characteristics was present in the section running seaward from Barnegat Lightship off the coast of New Jersey, though water of intermediate characteristics was found in the area of the Hudson Canyon. This suggests that the Hudson Canyon has a profound influence on the mixing of waters in this area. In July of this year this cold water was again present in the same locality, and an effort was made to track it eastward and northward into the Gulf of Maine, where similar water is found in the summertime. No continuity between the cold water on the continental shelf south of Cape Cod and the cold water in the Gulf of Maine was found. It, therefore, appears that this body of water is formed during the wintertime on the continental shelf and remains isolated from adjacent bodies of water throughout the summer. This isolated body of water may make it possible to follow biological changes in the water more easily than would be the case where mixing and circulation is more vigorous. It also seems clear that sea disposal of wastes or radioactive materials should be planned to avoid this body of water, where considerable accumulations could develop.

On these cruises Dr. Ryther and Mr. Yentsch have continued their studies of productivity in relationship to chlorophyll and light intensity. Quantitatively, the rates of photosynthesis observed in this area are comparable to those which have been observed in other coastal regions. It is, however, becoming increasingly apparent that the respiration of phytoplankton populations fluctuates widely. At some times virtually all of the new organic material produced by photosynthesis is utilized directly by the phytoplankton in their respiration; at other times large amounts of organic material in excess of respiratory needs are produced and this excess is available for the zooplankton and other members of the aquatic community. This empirical observation emphasizes the necessity of understanding the physiological state of the phytoplankton population in order to evaluate measurements of photosynthesis or of productivity.

Dr. Ryther and Mr. Yentsch have developed a method of calculating the rate of organic production in the ocean from measurements of the chlorophyll content of the plankton, of the daily radiation incident to the sea surface, and of the transparency of the water. By using this method, productivity values may be obtained quickly and easily at sea with a minimum of interference with other activities, and without the services of a

specialist in the field. This method has proved satisfactory in comparison with other more complex methods such as the measurement of the rate of assimilation of carbon-14 in bottles suspended at various depths for one half to one day periods.

Measurements of primary production were made on all IGY cruises during 1957 using this new method. They have been made on eight sections at a total of approximately 160 stations, representing about a ten-fold increase in the existing productivity data for the open Atlantic.

A study of the plankton ecology and related chemistry and hydrography of the Sargasso Sea was initiated in cooperation with the Bermuda Biological Station under contract with the AEC by Dr. Ryther and Dr. David Menzel. This study is being conducted with the Station's Research Vessel PANULIRUS. Observations are made in conjunction with the regular hydrographic station which has been occupied at regular intervals throughout the past several years under the direction of Mr. Stommel, and include biweekly measurements of primary production, phytoplankton, zooplankton, and plant nutrients.

A survey was conducted in June of Great South Bay and Moriches Bay, Long Island at the request of the Townships of Islip and Brookhaven by Dr. Ryther, Dr. Edward M. Hulburt, Mr. Vaccaro and Mr. Yentsch. Similar studies of this area have been made annually since 1950 and provide a continuing record of the ecology of these embayments in relation to their pollution and unique hydrographic features. A supplementary study of the dynamics of a diatom bloom was made at the same time in a tributary of Moriches Bay and has since been submitted for publication.

Doctors Ryther and Clarke were Institution delegates to the 9th Pacific Science Congress held in Bangkok, November 1–17, 1957. Both read papers at the Oceanography Section. En route to Bangkok they visited laboratories and gave lectures at Hawaii, Japan, and Hong Kong, and following the Bangkok meetings they made a brief lecture tour of India under the sponsorship of UNESCO.

Mr. Guy C. McLeod, working with Dr. Ryther under a grant from the National Science Foundation, has constructed an ultra-violet submarine filter photometer with which he has studied the penetration of ultra-violet radiation in coastal and offshore waters. He has also made laboratory studies of the effects of ultra-violet on photosynthesis by marine phytoplankton, and visited the Oak Ridge National Laboratories where, with Dr. W. J. Arnold, he measured the action spectrum of photosynthesis throughout the visible and ultra-violet spectrum in several species of marine algae.

The cycle of nutrients in the coastal area have been followed by Mr. Vaccaro and Mr. Nathaniel Corwin. In the inshore waters inorganic

phosphate is always present even when inorganic nitrogen compounds are exhausted, indicating that available nitrogen probably limits the growth of the phytoplankton. Further analysis of these data should give an independent estimate of the productivity of this region, and it is hoped that it will also help to explain the variations in the physiological conditions of the plankton which lead to the variations in respiration and in the net production of organic matter mentioned above.

The regeneration of plant nutrients in the sea has been studied particularly in relation to microbial nitrification (i.e., oxidation of ammonia to nitrite and nitrate) by Dr. Stanley W. Watson and Mr. Vaccaro. While in a preliminary phase, these investigations permit some definite conclusions concerning the role of these organisms in the sediments of the continental shelf. Nitrifiers are present in the shallow sediments but absent from the sediments underlying water deeper than 100 meters. It appears that much of the process of nitrification in shallow waters occurs in the sediments but at deeper offshore locations most of the nitrification must occur in the water column. Attempts to isolate nitrifying bacteria from the water have been unsuccessful, but are being continued.

The species composition of the phytoplankton populations is being studied by Dr. Hulburt. Dramatic changes in the character of the population are commonly observed over the edge of the continental shelf where abrupt changes from characteristically coastal water to characteristically oceanic water are also observed. So far the biologists can give no definite answer to the question "What ecological property of the water determines the type of organism which is able to thrive in it?" It is hoped that our observations of both the population and various aspects of the water character and chemistry will help to solve this problem. However, it seems probable that no definite answer will be possible until we learn to culture some of these oceanic species in the laboratory and are able to evaluate their response to changes in environmental conditions.

The zooplankton populations are being studied by Dr. Sears and Miss Constance Chadwick. Nearly twenty years have passed since Dr. Bigelow and Dr. Sears completed their previous study of the zooplankton of the continental shelf. Unfortunately none of the Institution vessels can be run at a slow and uniform speed as could be done when ATLANTIS had the variable pitch propeller. The variation in speed during the two makes it difficult to obtain quantitative samples from known depths. Nevertheless, it is hoped that these samples will provide a better understanding of the ecological relationships of the zooplankton which will supplement the productivity estimates made at the same time.

Studies of zooplankton populations were also conducted during the past

winter by Mrs. Angeles Alvariño de Leira, Instituto Español de Oceanografia, Madrid. During her visit she analyzed the zooplankton obtained in the Gulf of Maine by the U. S. Fish and Wildlife Service in 1956. The distribution of arrow worms in this area afforded contrasts and comparisons with similar distributions she had observed at Plymouth, England, and off the coast of Spain.

Dr. T. S. Satyanarayana Rao of Andhra University, India, has studied the seasonal variation of the zooplankton population in the Woods Hole area. Dr. William H. Sutcliffe, Jr., Director of the Bermuda Biological Laboratory, spent two months in Woods Hole analyzing the copepods in the plankton tows obtained during the "Trade Wind" cruise by the ATLANTIS in 1952.

Studies of the silica metabolism of diatoms have been conducted by Dr. Joyce C. Lewin. The silicate skeletons of marine diatoms are resistant to solution in sea water, and Dr. Lewin has shown that this depends upon the formation of an insoluble linkage with a trivalent cation. Iron and aluminum have been shown to be effective, and studies of other cations are planned.

Dr. Vaughan T. Bowen and Dr. Thomas T. Sugihara have continued their studies of the concentration of long-lived radioisotopes contributed by fall-out to the sea. The concentration of strontium-90 in surface water samples was higher than would be estimated from the published terrestrial measurements in this latitude. Although these analyses were performed on surface water, which could be assumed to reach horizontal homogeneity during the several years that strontium-90 has been accumulating, the analyses reveal a five-fold variation in concentration. This result indicates that mixing cannot have reached, in either the vertical or horizontal directions, the uniformity which is indicated by the analysis of other chemical properties of the water. Methods for the determination of other long-lived fission products in sea water have been devised and the analyses will include determinations of cerium-144, cesium-137, promethium-147 and antimony-125 in the studies of the fission-product distribution and concentration in the sea.

The cruises planned for the International Geophysical Year have afforded an opportunity to obtain samples of water at various depths for studies of the distribution of natural radioisotopes. Samples for this purpose were obtained at six stations during CRAWFORD Cruise 10 to the South Atlantic and at four stations on CRAWFORD Cruise 16. The CO_2 was extracted from these samples on shipboard and the isotope ratios of C^{12}, C^{13}, and C^{14} will be determined on these samples. After the extraction of CO_2, thirty gallons of the water were returned to Woods Hole in plastic drums. These samples

will be analyzed for the fission-product radioactivities, for tritium, and for the rare-earth elements.

Dr. Bowen and Dr. Leahy, as a part of the Institution's IGY program, have been investigating the CO_2 content of the atmosphere. An infra-red absorption CO_2-analyzer has been obtained and modified both physically and electronically to permit its use on the Institution's airplane. Dr. Leahy has made several flights in conjunction with studies being carried out by Mr. Andrew Bunker. Although the program for production of standard $CO_2.N_2$ mixtures has not developed on the anticipated national cooperative basis, some comparative data has been obtained. Whereas some, but not all, vertical soundings over warm water have shown more CO_2 at 500 feet than at 1000 to 10,000 feet, none of these made over cold water have shown this pattern. In the Trade Winds area, even above the inversion layer, considerable fluctuation of CO_2 content was found, appearing to coincide with the passage of different air masses. This program is being continued and, with the help of Dr. John W. Kanwisher, being expanded.

Professor Edward W. Moore, from the Department of Sanitary Engineering at Harvard University, has been working during the past year in collaboration with Dr. Bowen developing methods for the determination of strontium-90 in marine sediments. Samples of various muds in the neighborhood of Woods Hole have been processed and the analyses will be completed in the near future.

Dr. Francis A. Richards has received a Guggenheim Fellowship and spent the winter at the University of Oslo, Norway. This has given him an opportunity to continue his studies of the chemistry of anaerobic waters in the fjords in Norway, and he also worked on the development of new methods for the determination of ammonia in sea water. After his return from Norway in September, he re-visited the Cariaco Trench on the ATLANTIS with the scientific party headed by Dr. Zeigler. A more accurate description of the sulfide distribution in the anaerobic water was obtained using plastic lined sampling bottles which do not react with the sulfide in the water as the all-metal Nansen bottles did. Other chemical variables were observed, in an attempt to relate the unique chemistry of the water column to that of the sediments.

Mr. Harry J. Turner has continued his studies of shellfish and other marine bottom populations for the Department of Conservation of the Commonwealth of Massachusetts. In collaboration with Dr. Nathan W. Riser he has been rearing larvae and young juvenile quahogs in the laboratory and has completed a study of the processes of fertilization and maturation of the quahog egg. A paper describing the chromosome number and the early development stages of this organism has been prepared for publication.

This work may be a milestone in shellfish culture since it lays the groundwork for possible genetic and breeding studies of this organism. It is hoped to extend the studies of the spawning and development of larvae of shellfish to other forms, and an investigation of the spawning behavior of the bay scallop has already been initiated. Mr. Turner has also undertaken a study of the hydrography and circulation of Nantucket Sound to determine if the extensive bed of large quahogs now under exploitation are likely to be the parent stocks of inshore populations along Cape Cod and the Island.

Mr. James E. Hanks has undertaken an investigation of the early life history of the clam drill, *Polinices*. He has demonstrated that egg-laying is stimulated by warm temperatures and an adequate food supply with little or no seasonal influence. The larvae of this species have been maintained as long as a month on a diet of phytoplankton.

A similar study of the larval development of the common mud snail, *Nassarius*, was conducted by Mr. Rudolf Sheltema on a summer fellowship, Mr. Sheltema demonstrated conclusively that metamorphosis of the larvae of this species is stimulated by the presence of certain kinds of substrata containing a heat labile substance.

Dr. Howard L. Sanders has continued his studies of both the bottom populations in Buzzards Bay and the significance to crustacean evolution of *Hutchinsoniella macracantha* which he discovered in Long Island Sound and has found in Buzzards Bay. This unusual crustacean has many characteristics which are intermediate between the long extinct Trilobites and various modern crustacea, and the study of these characteristics may give important clues to the ways in which crustacean evolution has taken place. His studies of the bottom populations have correlated the species present and the density of the population with the physical characteristics of the bottom and with the circulation of the water which determines the type of sediment found in various locations. Dr. Wolfgang Wieser, Universität Wien, Vienna, is extending these investigations this summer by studying smaller members of these communities.

Dr. Harold Barnes of the Marine Station, Millport, Scotland, received a fellowship as a visiting investigator at the Institution. During his visit he continued his studies of the biology of barnacle populations and conducted investigations of the usefulness of underwater television in studies of the scattering layer and of bottom populations.

Dr. George L. Clarke has continued his investigations of light conditions in the sea and of the control by light and other factors of the vertical distribution of pelagic organisms. These relations are of interest not only in the fundamental ecology of the deep sea but also in relation to the transport of radioactive materials, which may be concentrated in the bodies of

animals, from one level in the ocean to another. Improvement of the bathyphotometer made possible the measurement of total light at all levels to a depth of one mile. In addition an underwater spectroscope and a scattering meter have been built. In clear ocean water, during the middle of the day, light from the surface was measured to about 2,000 feet. From about 1,500 feet to 6,000 feet flashes of luminescent animals were detected in great profusion. Quantitative records of the frequency, duration, and intensity of these flashes revealed the presence of very different populations at various depths. A camera which will be activated by light flashes is now being coupled with the photometer in order to show photographically which types of luminescent animals are present at various levels at different times of day.

Direct studies of the migrations and reactions of animals are difficult but it is expected that further knowledge of the mechanisms involved may be obtained by the closer studies of the vertical movements of zooplankton possible in fresh-water ponds and of the behavior of animals brought into the laboratory. For this purpose an investigation of diurnal migration was undertaken in Flax Pond and in Duck Pond on Cape Cod. The latter is of particular interest because its transparency was found to be comparable to clear ocean water and far clearer than most ponds or lakes. Investigation has also been begun of improved methods for culturing oceanic zooplankton —a technique which has never been adequately developed. When healthy animals are maintained in the laboratory, not only may their reactions to light and other factors be studied but opportunity will be presented for testing directly their ability to concentrate radioactive materials.

Dr. John Kanwisher has continued his studies of shore plants and animals that were previously found to be frozen for long periods during the winter. Microscopic examination of the frozen specimens shows considerable internal disruption from the ice formation but gives no clue to survival. An automatic recording oxygen system has been developed and is being used to determine photosynthesis and respiration of macroscopic algae as a function of temperature and illumination. From such data and the size of the standing crop productivity can be estimated. Measurements were also made on live porpoises at Marineland to compare their body temperature regulating mechanisms with those of large whales previously studied. The smaller but structually similar animal must conserve heat more efficiently because of its much larger surface to volume ratio.

A report by Dr. H. B. Bigelow and Mr. William C. Schroeder on the relationship of the shark genera of the suborder Squaloidea was published in August 1957. A paper describing several new skates from the Gulf of Mexico and off the Bahamas together with further notes on recently de-

scribed species is in press. Dr. Bigelow and Mr. Schroeder are now working on the family Osmeridae, the capelin and smelts, to be included in Part 3 of Fishes of the Western North Atlantic. Mr. Schroeder is also preparing a report on the offshore lobster fishery which is becoming increasingly important commercially, and a section comprising the elasmobranchs of the western North Atlantic that will form part of a monograph on aquatic biology, sponsored by the National Research Council.

The research program dealing with the biology of the larger pelagic fishes, supported by a grant from the National Science Foundation, has made good progress under the direct supervision of Dr. Robert H. Gibbs, Jr. About 100 bluefin tuna, 100 yellowfin tuna and over 400 white marlin were tagged in an effort to learn more about their migratory habits and various data have been collected bearing on the biology of these and other species. Near the end of the year Mr. Frank J. Mather III returned from his leave of absence in the Virgin Islands and is continuing the program on pelagic fishes.

Dr. Backus has continued his studies of pelagic sharks. The crews of the Institution's research ships have contributed greatly to this end by keeping logs of their shark captures. These studies have been concerned chiefly with the great blue and white-tip sharks. Both of these animals are abundant and widespread on the high seas. The great blue shark is a known man-eater and the white-tip is probably such, and so these animals constitute to some extent a hazard to "survivors" at sea. In this connection Dr. Backus has been working with a Navy-and Air Force-supported group which is exploring the means by which a better shark repellent may be developed.

Dr. Backus has completed a paper on the fishes of Labrador which culminates three summers of observation made on BLUE DOLPHIN Labrador Expeditions. These expeditions were in part Institution-sponsored.

Mr. William E. Schevill has continued his studies of the natural history of whales and porpoises, particularly in connection with their sound production and its significance to the animal. The underwater sounds of the sperm and right whales have recently been recorded for the first time. After years of only occasional sightings, Institution vessels encountered sperm whales half a dozen times during the summer of 1957 in waters between Nova Scotia and Bermuda. Migrating right whales have called in Vineyard Sound during March and April of 1956 and 1957.

Mr. Schevill is also studying the systematics, distribution and natural history of the widely-distributed whale genus *Globicephala* (the pothead whales or blackfish). This study should lead to conclusions as to what factors

constitute the boundaries on the high seas between the ranges of closely-allied species of larger marine animals.

This rather complete account of the work in progress during 1957 has been prepared partly for the assistance of Dr. Paul M. Fye, who will take over from me as Director in June 1958, and also to indicate to other interested persons the very wide range of activity that is now in progress. Oceanography has indeed grown both in quantity and in quality during the life of this Institution, and it has been a great privilege to the present Director to witness the whole of this development and to know intimately the many people who have contributed to the total effort. We all look forward, and the present writer probably most of all, to the return to Woods Hole next spring of Dr. Fye. There is every expectation that under his leadership we can increasingly help the science of oceanography to mature.

Research Vessels

Major repairs to our vessels during 1957 include a thorough inspection and repair of the mainmast of ATLANTIS. A large area of dry rot about half way up the mast had been discovered last autumn and patched in a temporary manner. The BEAR also was found to be suffering from dry rot and was fitted with a new bow at considerable expense.

When the CRAWFORD returned from the South Atlantic in June it was found that both engines required excessive maintenance. A study of the situation revealed that because of her increased displacement the screws had been overloading the engines and to correct the situation their pitch has been decreased. The engines now can turn up to their designed top speed and are able to operate easily at about 85% of full power, whereas before, especially after some fouling had occurred, they were laboring hard at cruising speed.

Since spring the CARYN has again been advertised as being for sale. We have removed all the Navy-owned equipment and have replaced the skylight over the main cabin, but as yet we have had no serious offer.

Publications

During 1957, 71 papers bearing contribution numbers were published:

	Contr. No.
RICHARDS, F. A., 1957. Oxygen in the ocean. Ch. 9 in: Treatise on Marine Ecology and Paleoecology, Vol. 1. *Mem., Geol. Soc. Amer.*, 67: 185–238	714
HULBURT, E. M., 1957. Distribution of phosphorus in Great Pond, Massachusetts. *J. Mar. Res.*, 15(3): 181–192	748
BARLOW, J. P., 1957. Effect of wind on salinity distribution in an estuary. *J. Mar. Res.*, 15(3): 193–204	752

MARKS, WILBUR, and JOSEPH CHASE, 1957. Observation of the growth and decay of a wave spectrum. Interaction of sea and atmosphere, a group of contributions. *Meteorol. Monogr.*, 2(10): 67–75 ..... Contr No. 769

GORDON, M. S., and R. H. BACKUS, 1957. New records of Labrador fishes with special reference to those of Hebron Fjord. *Copeia*, 1957(1): 17–20 800

BLANCHARD, D. C., 1957. The supercooling, freezing and melting of giant raindrops at terminal velocity in air. Conference on the Physics of Cloud Precipitation Particles, Woods Hole, Sept. 1955. In: Artificial Stimulation of Rainfall, Pergamon Press, Ltd., 233–249 809

BLANCHARD, D. C., 1957. Discussion of raindrop distributions made during Project SHOWER, Hawaii, 1954. Conference on the Physics of Cloud Precipitation Particles, Woods Hole, Mass., Sept. 1955. In: Artificial Stimulation of Rainfall, Pergamon Press, Ltd., 213–223 812

VON ARX, W. S., 1957. An experimental approach to problems in physical oceanography. In: Progress in Physics and Chemistry of the Earth, Pergamon Press, Ltd. 2: 1–29 820

REDFIELD, A. C., and A. R. MILLER, 1957. Water levels accompanying Atlantic coast hurricanes. Interaction of sea and atmosphere, a group of contributions. *Meteorol. Monogr.*, 2(10): 1–23 828

MILLER, A. R., 1957. The effects of steady winds on sea level at Atlantic City. Interaction of sea and atmosphere, a group of contributions. *Meteorol. Monogr.*, 2(10): 24–31 829

BUNKER, A. F., 1957. Turbulence measurements in a young cyclone over the ocean. *Bull., Amer. Meteorol. Soc.*, 38(1–1): 13–16 833

HULBURT, E. M., 1957. The taxonomy of unarmored Dinophyceae of shallow embayments of Cape Cod, Massachusetts. *Biol. Bull.*, 112(2): 196–219 838

OFFICER, C. B., J. I. EWING, R. S. EDWARDS and H. R. JOHNSON, 1957. Geophysical investigations in the eastern Caribbean, Antilles Island Arc and Puerto Rico Trench. *Bull., Geol. Soc., Amer.*, 68(3): 359–378 839

MALKUS, J. S., 1957. Trade cumulus cloud groups: some observations suggesting a mechanism of their origin. *Tellus*, 9(1): 33–44 843

RICHARDS, F. A., 1957. Some current aspects of chemical oceanography. In: Progress in Physics and Chemistry of the Earth, Pergamon Press, Ltd., 2: 77–128 844

STOMMEL, HENRY, 1957. Florida Straits transports, 1952–1956. *Bull. Mar. Sci., Gulf & Caribbean*, 7(3) 252–254 845

BIGELOW, H. B., and W. C. SCHROEDER, 1957. A study of the sharks of the suborder Squaloidea. *Bull. Mus. Comp. Zool.*, Harvard Coll., 117(1): 1–150 848

WALDEN, H., and H. G. FARMER, 1957. Auswertung von Seegangsregistrierungen des Forschungsschiffes ATLANTIS mit dem "ship-borne wave recorder" sowie Vergleich mit entsprechenden Seegangsberechnungen aus den Windverhältnissen (hindcasting). *Deutsche Hydrogr. Zeits.*, 10(4) 121–134 850

VINE, A. C., 1957. Some trends in oceanographic instrumentation. *Proc. UNESCO Symp., Phys. Ocean., Tokyo*, 1955: 49–52 851

	Contr. No.
VAN BERGEIJK, W. A., and EMIL WITSCHI, 1957. The basilar papilla of the anuran ear. *Acta Anatomica*, 30: 81–91	890
SCHOLANDER, P. F., L. VAN DAM, J. W. KANWISHER, H. T. HAMMEL and M. S. GORDON, 1957. Supercooling and osmoregulation in Arctic fish. *J. Cell. Comp. Physiol.*, 49(1): 5–24	891
SCHOLANDER, P. F., and L. VAN DAM, 1957. The concentration of hemoglobin in some cold water Arctic fishes. *J. Cell. Comp. Physiol.*, 49(1): 1–4	892
YENTSCH, C. S., and J. H. RYTHER, 1957. Short-term variations in phytoplankton chlorophyll and their significance. *Limnol. & Oceanogr.*, 2(2): 140–142	893
BACKUS, R. H., and H. BARNES, 1957. Television echo sounder observations of midwater sound scatterers. *Deep-Sea Res.*, 4(2): 116–119	894
WALDEN, R. G., D. D. KETCHUM and D. H. FRANTZ, JR., 1957. Buoy telemeters ocean temperature data. *Electronics*, 30(6): 164–167	895
BACKUS, R. H., 1957. The fishes of Labrador. *Bull., Amer. Mus. Nat. Hist.*, 113(4): 277–337	896
BARNES, H., 1957. The northern limits of *Balanus balanoides* (L.). *Oikos*, 8(1): 1–15	897
YENTSCH, C. S., 1957. A non-extractive method for the quantitative estimation of chlorophyll in algal cultures. *Nature*, 179: 1302–1304	898
STOMMEL, HENRY, and GEORGE VERONIS, 1957. Steady convective motion in a horizontal layer of fluid heated uniformly from above and cooled non-uniformly from below. *Tellus*, 9(3): 401–407	899
MATHER, F. J., III, and R. H. GIBBS, JR., 1957. Distribution records of fishes from waters off New England and the middle Atlantic states. *Copeia* 1957(3): 242–244	901
RYTHER, J. H., and C. S. YENTSCH, 1957. The estimation of phytoplankton production in the ocean from chlorophyll and light data. *Limnol. & Oceanogr.*, 2(3): 281–286	902
SUTCLIFFE, W. H., JR., 1957. An improved method for the determination of preserved plankton volumes. *Limnol. & Oceanogr.*, 2(3): 295–296	903
BUMPUS, D. F., 1957. Surface water temperatures along Atlantic and Gulf coasts of the United States. *U.S.F.W.S., Spec. Sci. Rept., Fish.*, No. 214: 153 pp.	904
ATHEARN, W. D., 1957. Comparison of clay from the continental shelf off Long Island with Gardiners clay. *J. Geol.*, 65(4): 448–449	905
BOWEN, V. T., and T. T. SUGIHARA, 1957. Strontium 90 in North Atlantic surface water. *Proc. Nat. Acad. Sci.*, 43(7): 576–580	907
WORTHINGTON, L. V., and W. E. SCHEVILL, 1957. Underwater sounds heard from sperm whales. *Nature* 180 (4580): 291	908
HAHN, JAN, 1957. Oceanus goes to the bottom of the sea. *Oceanus* 5(1–2): 20–31	909
SWALLOW, J. C., and L. V. WORTHINGTON, 1957. Measurement of deep currents in the western North Atlantic. *Nature* 179: 1183–1184	910
MCLEOD, G. C., 1957. The effect of circularly polarized light on the photosynthesis and chlorophyll *a* synthesis of certain marine algae. *Limnol. & Oceanogr.*, 2(4) 360–362	911

GIBBS, R. H., JR., 1957. A taxonomic study of *Myctophum affine* and *M. nitidulum*, two lantern-fishes previously synonymized, in the western North Atlantic. *Deep-Sea Res.*, 4(4): 230–237 ..... Contr. No. 912

ZEN, E-AN, 1957. Preliminary report on the mineralogy and petrology of some marine bottom samples off the coast of Peru and Chile. *Amer. Mineralog.* 42: 889–903 913

MOULTON, J. R., 1957. Sound production in the spiny lobster, *Panulirus argus* (Latreille). *Biol. Bull.*, 113(2): 286–295 914

WHITNEY, G. G., JR., 1957. Factors affecting the accuracy of thermometric depth determinations. *J. du Cons.*, 22(2): 167–173 916

STOMMEL, HENRY, 1957. A survey of ocean current theory. *Deep-Sea Res.*, 4(3): 149–184 917

BUMPUS, D. F., 1957. Oceanographic observations, 1956, east coast of the United States. *U.S.F.W.S. Spec. Sci. Rept., Fish.*, No. 233: 132 pp. 918

ZEIGLER, J. M., W. D. ATHEARN and HERBERT SMALL, 1957. Profiles across the Peru-Chile Trench. *Deep-Sea Res.*, 4(4): 238–249 919

SCHOLANDER, P. F., 1957. Oxygen dissociation curves in fish blood. *Acta Physiol. Scandinavica* 41(4): 340–344 921

GIBBS, R. H., JR., 1957. Preliminary analysis of the distribution of white marlin, *Makaira albida* (Poey) in the Gulf of Mexico. *Bull. Mar. Sci., Gulf & Caribbean*, 7(4): 360–369 922

PLUNKETT, M. A., 1957. The quantitative determination of some organic compounds in marine sediments. *Deep-Sea Res.*, 4(4): 259–262 924

BUMPUS, D. F., JOSEPH CHASE, C. G. DAY, D. H. FRANTZ, JR., D. D. KETCHUM, and R. G. WALDEN, 1957. A new technique for studying non-tidal drift with results of experiments off Gay Head, Mass., and in the Bay of Fundy. *J. Fish. Res. Bd, Canada*, 16(6): 931–944 926

FOLSOM, T. R., and A. C. VINE, 1957. On the tagging of water masses for the study of physical processes in the oceans. In: The effects of atomic radiation on oceanography and fisheries. *Nat. Acad. Sci.-Nat. Res. Counc., Publ.*, 551: 121–132 929

BUMPUS, D. F., and C. G. DAY, 1957. Drift bottle records for the Gulf of Maine and Georges Bank, 1931–1956. *U.S.F.W.S. Spec. Sci. Rept., Fish.*, No. 242: 61 pp. 941

Personnel

Two members of our staff who had a long association with this laboratory died during the year. Dr. Carl-Gustaf Rossby had visited Woods Hole many times since the first year of the Institution's existence. He was a member of the Board of Trustees and one of the most distinguished members of the staff. As Director of the Institute of Meteorology in Stockholm he was the universally acknowledged leader of the theoretical approach in both meteorology and oceanography. Several of our staff have recently worked there. Dr. Arnold B. Arons is at present enjoying a sabbatical leave at Dr.

Rossby's institute. Dr. Louis W. Hutchins also died suddenly. He had worked at Woods Hole during the war years on the ecology of fouling organisms and then went on to be the Director of the Bermuda Biological station. He was studying our collection of fouling organisms in Washington at the time of his death.

There were a very large number of visitors at Woods Hole during the past summer. Several committees, both national and international, held meetings at the laboratory. In addition, more than one hundred people worked here temporarily during the summer.

Among the visiting investigators who worked at the laboratory for considerable periods of time during the past year were the following:

Angeles Alvariño de Leira	Spanish Institute of Oceanography (Navy Ministry), Spain
Harold Barnes	Marine Station, Millport, Scotland
Thanom Charernlarb	Royal Thai Navy, Thailand
Robert Conover	University of Rhode Island
Richard Fay	United States Weather Bureau
Takashi Ichiye	Central Meteorological Office, Tokyo University, Japan
Jack McLachlan	Oregon State College
Allen Milne	Pacific Naval Laboratory, British Columbia
E. G. Pringsheim	Pflanzenphysiologisches Institut, Germany
T. S. Satyanarayana Rao	Andhra University, India
Carl-G. Rossby	Institute of Meteorology, University of Stockholm, Sweden
William H. Sutcliffe, Jr.	Bermuda Biological Station, Bermuda
John B. Tait	Marine Laboratory, Scottish Home Department, Aberdeen, Scotland
Hans Walden	Deutscher Wetterdienst, Germany
Georg Wüst	Institut für Meereskunde der Universität, Germany

The following persons were awarded grants, honoraria or fellowships during 1957:

Angeles Alvariño de Leira	Spanish Institute of Oceanography (Navy Ministry), Spain
Thomas S. Austin	Pacific Oceanic Fisheries Investigations, Hawaii
Harold Barnes	Marine Station, Millport, Scotland
Duncan C. Blanchard	Massachusetts Institute of Technology
K. F. Bowden	University of Liverpool, England
Norman A. Chamberlain	Johns Hopkins University
Leon S. Ciereszko	University of Oklahoma
Waller MacN. Conard	Putney School

GUNTHER DIETRICH	Deutsches Hydrographisches Institut, Germany
EL SAYED MOHAMED HASSAN	New York University
ALAN HAUGHT	Amherst College
BERNHARD HAURWITZ	New York University
LOUIS W. HUTCHINS	Washington, D. C.
JAMES M. MOULTON	Bowdoin College
RODERIC B. PARK	California Institute of Technology
MARY A. PLUNKETT	Vassar College
C. H. B. PRIESTLY	Commonwealth Scientific & Industrial Research Organization, Australia
CAROL REICHERT	Antioch College
GORDON A. RILEY	Yale University
ALLAN R. ROBINSON	Harvard University
RUDOLF S. SCHELTEMA	University of North Carolina
THEODORE J. SMAYDA	University of Oslo, Norway
EDITH L. STETSON	Smith College
RAYMOND G. STROSS	University of Wisconsin
EDWARD D. STROUP	Johns Hopkins University
WILLIAM H. SUTCLIFFE, JR.	Bermuda Biological Station
JOHN B. TAIT	Marine Laboratory, Scottish Home Department, Aberdeen, Scotland
OLIVE TATTERSALL	London University, England
JOHN E. TYLER	Scripps Institution of Oceanography
B. VOLCANI	Biochemical Laboratories, Massachusetts General Hospital
HANS WALDEN	Deutscher Wetterdienst, Germany
WOLFGANG WIESER	Zoological Institute, University of Vienna, Austria
E-AN ZEN	Harvard University

V. TREASURER'S REPORT

THE accounts for the year 1957 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds at December 31, 1957 was $3,268,095, of which $836,574 represented accumulated net gains from sales of investments. The market value of endowment assets on the same date, including real estate at book amount, was $4,346,208. Endowment fund investments and income received therefrom are summarized in Schedule D.

Income received on endowment assets, including interest charged on the advance to current funds, was $180,593 for the year ended December 31, 1957, compared with $167,380 the previous year. This income represented a return on endowment fund assets of 4.2% at year-end market quotation, 5.5% on the book amount and 7.4% on the contributed amount of the endowment fund.

Endowment income was allocated for 1957 operating expenses at the rate of 5.3% of the book amount of original endowment funds, or $128,328; the rate was the same as that of the previous year. The balance of endowment income, $52,265, was transferred to the income and salary stabilization reserve. Advances were made from endowment funds to current funds during portions of the year, but all such advances were paid off prior to the end of the year.

Deferred charges amounting to $248,320 (see balance sheet for breakdown) represented expenditures for the benefit of future years. A proportionate part of these charges will be added to current costs, or other appropriate accounts, as the benefits accrue.

The details of unexpended balances of gifts and receipts for research, other than government, are shown in Schedule C. The income from Woods Hole Oceanographic Associates for the year amounted to $76,907. Expenditures and allocations to specific projects of $77,841, plus $11,000 of life memberships transferred to endowment assets reduced the balance on hand of $71,549 at December 31, 1956 to $59,615 on December 31, 1957.

The Institution's 1957 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to $68,898. The trust is administered by three trustees. The balance of the old Retirement Fund, administered by the Treasurer, amounted to $65,973 as at December 31, 1957. This balance consisted of amounts on deposit in sixteen savings bank accounts held in trust for ten members of the plan. No contributions to the old plan were made in 1957. Interest totalling $2,079 was credited to the savings accounts during the year.

In the financial statements that follow it is interesting to note that for each dollar spent 79 cents was spent for direct costs of research activity, 15.5 cents for general and administration expenses and 5.5 cents for plant operation and miscellaneous. Administrative salaries amounted to only 6 cents of each dollar of total expense. Included in the 15.5 cents for general and administration expenses was 3.8 cents for staff benefits (group insurance, social security taxes, and contributions to retirement plan.)

BALANCE SHEET

As at December 31, 1957

ASSETS

Endowment Fund Assets:		
Investments (Schedule D):		
Bonds (market quotations $1,770,412)		$1,869,682
Stocks (market quotations $2,414,953)		1,237,570
Real estate		98,417
		3,205,669
Cash		62,426
		3,268,095
Plant Assets (note):		
Laboratory plant and equipment		578,401
Vessels and equipment		364,983
Other property		161,541
		1,104,925
Current Fund Assets:		
Cash		16,402
Accounts receivable:		
U. S. Government	$298,452	
Other	5,935	304,387
Unbilled costs on research contracts:		
U. S. Government	188,682	
Other	6,216	194,898
Supply inventories		31,687
Deferred charges:		
Reconditioning boat Crawford	200,881	
Electronic equipment	31,055	
Other	16,384	248,320
		795,694
		$5,168,714

LIABILITIES

Endowment Funds:		
Unrestricted		$2,012,101
For upkeep of plant		419,420
Accumulated net gain on sale of investments		836,574
		3,268,095
Funds Invested in Plant		1,104,925
Current Liabilities and Funds:		
Accounts payable and accrued expenses		157,687
Contribution payable to employees' retirement plan and trust		68,898
Unexpended balances of gifts and grants:		
For research:		
Government	$109,228	
Other (Schedule C)	9,942	119,170
Oceanographic Associates		59,615
General fund:		
General plant and equipment reserve	211,888	
Income and salary stabilization reserve	166,589	
Unappropriated	11,847	390,324
		795,694
		$5,168,714

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

STATEMENT OF INCOME, OPERATING EXPENSES AND UNAPPROPRIATED GENERAL FUND

For the Year Ended December 31, 1957

INCOME:		
Receipts for sponsored research:		
For direct costs		$1,857,053
For indirect costs		472,888
Fees for use of facilities		76,548
		2,406,489
Endowment income after amortization of bond premiums (Schedule D)	$180,593	
Less amount added to income and salary stabilization reserve	52,265	128,328
Miscellaneous		421
Total income availed of		2,535,238
OPERATING EXPENSES:		
Direct costs of research activity (Schedule A):		
Salaries and wages		938,678
Vessel operations		564,337
Materials and services		394,399
Travel		91,356
		1,988,770
Indirect costs:		
General and administration (Schedule B)	392,220	
Plant operation (Schedule B)	136,325	
Miscellaneous	3,795	532,340
Total operating expenses		2,521,110
EXCESS OF INCOME		14,128
Additions to plant from current funds — books and equipment purchased		28,541
		(14,413)
UNAPPROPRIATED GENERAL FUND, JANUARY 1, 1957		26,260
UNAPPROPRIATED GENERAL FUND, DECEMBER 31, 1957		$ 11,847

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1957

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. GOVERNMENT CONTRACTS	$814,514	$504,840	$321,098	$79,849	$1,720,301
OTHER SPONSORED RESEARCH	38,698	40,104	55,884	2,066	136,752
Total direct costs of sponsored research.	853,212	544,944	376,982	81,915	1,857,053
INSTITUTION RESEARCH.....	85,466	19,393	17,417	9,441	131,717
Total direct costs of research.....	$938,678	$564,337	$394,399*	$91,356	$1,988,770

*Includes grants and fellowships:

Other sponsored research.....	$21,491
Institution research.....	450
	$21,941

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1957

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:		
Staff benefits:		
Contributions to retirement plan.....		$68,898
Social security taxes.....		25,656
Group insurance.....		2,324
		96,878
Shop services.....		83,824
Housing, net.....		2,303
ADMINISTRATION EXPENSES:		
Salaries and wages.....	$152,662	
Insurance, travel, supplies and other.....	56,553	209,215
		$392,220

PLANT OPERATION

SALARIES AND WAGES.....		48,417
PROVISION FOR DEPRECIATION (credited to general plant and equipment reserve).....		27,566
OTHER REPAIR COSTS.....	10,018	
HEAT, LIGHT AND POWER.....	21,111	
CARYN LAY-UP COSTS.....	18,243	
OTHER.....	10,970	60,342
		$136,325

SCHEDULE C

SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH

Year Ended December 31, 1957

	Unexpended Balance January 1, 1957	Received	Expended Direct Costs	Expended Indirect Costs	Other Charges or (Credits)	Unexpended Balance December 31, 1957
American Society of Limnology and Oceanography		$ 856	$ 598	$ 258		
Arctic Institute of North America — freezing of living tissue		3,500	2,510	990		
Bermuda Biological Station for Research		253	244	9		
Commonwealth of Massachusetts — shellfish propagation	$ 5,100	20,000	14,435	8,882		$1,783
Esso Research and Engineering Company:						
Foraminifera cataloging		108	108			
Peruvian samples analysis	2,000		2,000			
Gordon project		85	72	8	$ 5 (a)	
Manufacture, sale, and calibration of instruments		2,173	20,372	5,060	(15,029)(b) (8,230)(c)	
Lou Marron science fund — pelagic fish studies		1,000	2,405		(1,659)(d)	254
Munitalp Foundation — meteorological research		6,500	4,500	300		1,700
National Academy of Sciences — project Nobska		41	41			
National Lead Company		2,532	2,303	229		
Oceanographic Associates:						
Deuterium studies		1,000	245	58		697
Peruvian core analysis	10,482		7,156	220		3,106
Crawford Meteorological expedition		38,247	38,247			
Other (including fellowships, lectureships, and portion of research costs)		37,245	34,904	682	1,659(d)	
Research Corporation — instrument fund	2,558		364	181	(389)(e)	2,402
Socony-Mobil Laboratories — Peruvian samples analysis	1,000		1,000			
Sundry work done for others		5,056	4,161	895		
Town of Islip, New York — Great South Bay survey	567	1,000	1,087	480		
	$21,707	$119,596	$136,752	$18,252	($23,643)	$9,942

(a) Credited to income. (b) Transferred to laboratory equipment. (c) Charged to other projects. (d) Transfers. (e) Sales.

SCHEDULE D

SUMMARY OF INVESTMENTS

As at December 31, 1957

	Book Amount	% of Total	Market Quotation	% of Total	Income
BONDS:					
U. S. Government	$ 326,070	10.17	$ 317,281	7.41	$ 11,691
Railroad	525,855	16.40	464,558	10.84	21,694
Public utility	397,039	12.39	389,970	9.10	11,373
Industrial	365,494	11.40	340,390	7.95	11,884
Financial and investment	255,224	7.96	258,213	6.03	10,181
Total bonds	1,869,682	58.32	1,770,412	41.33	66,823
STOCKS:					
Preferred	295,309	9.21	283,663	6.62	15,100
Common:					
Public utility	314,988	9.83	525,382	12.26	22,460
Industrial	449,257	14.02	1,316,525	30.73	57,018
Miscellaneous	178,016	5.55	289,383	6.76	13,472
Total common stocks	942,261	29.40	2,131,290	49.75	92,950
Total stocks	1,237,570	38.61	2,414,953	56.37	108,050
REAL ESTATE	98,417	3.07	98,417*	2.30	5,092
Total investments	$3,205,669	100.00	$4,283,782	100.00	179,965
INTEREST ON ADVANCE TO CURRENT FUNDS CHARGED TO MISCELLANEOUS OPERATING EXPENSE					628
TOTAL ENDOWMENT FUND INCOME					$180,593

*At book amount.

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASSACHUSETTS

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1957 and the related statement of income, operating expenses and unappropriated general fund for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances; however, it was not practicable to confirm receivables from United States Government departments, as to which we have satisfied ourselves by means of other auditing procedures.

In our opinion, the accompanying financial statements present fairly the position of Woods Hole Oceanographic Institution at December 31, 1957 and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

Boston, Massachusetts
May 12, 1958

LYBRAND, ROSS BROS. & MONTGOMERY