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left:

Part of a group attending the Course for Industry given by the Institution.

middle:

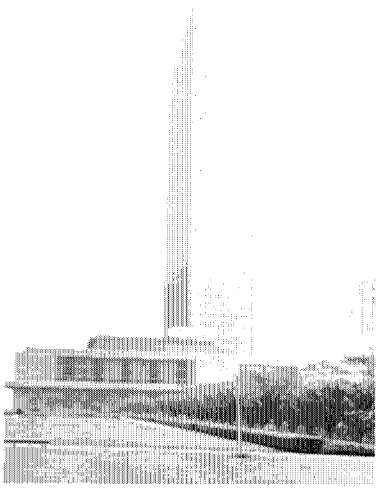
The first International Oceanographic Congress was held August and September at the United Nations, New York City.

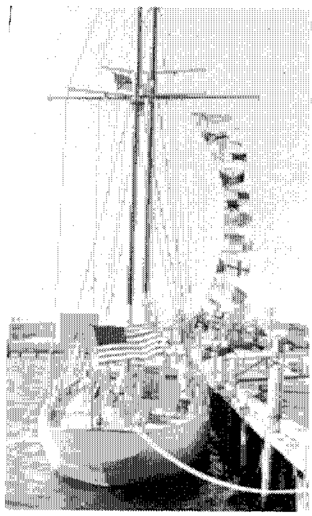
right:

The "Aries", recently acquired from Mr. R. J. Reynolds, after her arrival at the Institution.

below:

A special House Subcommittee on Oceanography, from Washington, hold a hearing in Woods Hole on the importance, support and future of the marine sciences.





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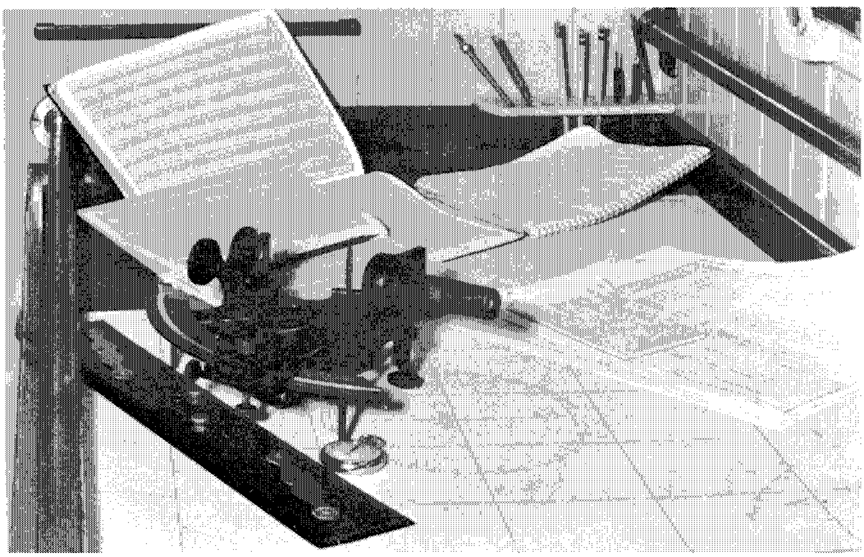

HIGHLIGHTS OF 1959

The multitude of technical problems presented by the oceans continues to stimulate and inspire scientists devoted to their solution. This has been a good year for oceanography in that the opportunities for oceanographers have expanded and the challenges of the ocean have been dramatically defined by a number of important events. As an introduction to the **"Annual Report"** of the Woods Hole Oceanographic Institution, a few of these important events are listed.

Two reports of national significance in oceanography were published early in the year. In January, Admiral Arleigh Burke officially approved the U. S. Navy's TENOC (Ten-Year Oceanographic) program. In February, the National Academy of Sciences released its report "Oceanography 1960-1970". National interest was aroused by these reports. A Special Subcommittee on Oceanography of the Committee of Merchant Marine and Fisheries of the House of Representatives started hearings in Washington where many oceanographers and Government representatives were heard. We were most pleased that the Subcommittee's Chairman, Representative George P. Miller (D.-Cal.), together with Congressmen James C. Oliver (D.-Me.), Gerald T. Flynn (D.-Wis.) and the representative for the 9th Massachusetts district, Hastings Keith (R.-Mass.), arranged to hold a hearing at Woods Hole in June. The Director and staff members presented statements followed by demonstrations and an inspection of facilities. The interest created by these reports and congressional hearings should develop sufficient support in oceanography so that we can realize many long-standing objectives and permit marine sciences to assume their proper role in technological development.

At the beginning of the year we received a fine gift from Mr. R. J. Reynolds in the form of his 93-foot ketch ARIES. The ship was brought to Woods Hole during some heavy March gales and was refitted with a minimum of damage to her yacht-like appearance to serve for a two-year period in the Bermuda area. It is worth noting that the ARIES has been used in a joint project with the National Institute of Oceanography of England, to study subsurface currents in the mid-ocean.

The CHAIN made her first long cruise in our service from April to August on extensive geophysical investigations in the Atlantic Ocean and the Mediterranean Sea. The ship has performed extremely well; the comfort of a larger ship is one that our sea-going staff—long used to cramped, uncomfortable quarters —readily has accepted. In November, we were able to take over the manning of the CHAIN with our officers and crew from the Military Sea Transportation Service which, under Captain Wallace S. Olivey, handled the vessel ably under her first year in our service. Altogether the ships of our fleet spent 865 days at sea in 1959 compared with 740 days in 1958. A simple breakdown into major research areas shows that during 1959 our oceanographers spent 2,231 man days at sea in the study of physical oceanography, chemistry and geology; 2,737 man days on underwater acoustics and geophysics and 566 man days on biology.

In a year in which so much of importance transpired, it is somewhat difficult to point to the outstanding event. Probably the first International Oceanographic Congress held at the United Nations, August 31 to September 12, was the highlight of 1959. The Director transferred the Institution's headquarters to New York for the Congress and together with 70 staff members met with the 1,200 oceanographers from around the world. The Congress itself was a resounding success which largely may be attributed to the hard work of Dr. Mary Sears who spent an immeasurable number of hours organizing this important occasion in the history of oceanography.

The CHAIN and the ATLANTIS were tied up at Pier #34 in New York, together with the overshadowing MIKHAIL LOMONOSOV of the Academy of Sciences, U.S.S.R., and the JOSIAH WILLARD GIBBS of the Hudson Laboratories. Nearly a thousand visitors from 27 countries came on board the ATLANTIS and the CHAIN.

Our summer fellowship program had its most successful year in the the history of the Institution. Twelve excellent Fellows were chosen from the 118 applicants applying from four countries. Ten of these were graduating seniors or graduate students and there were two postdoctoral fellows. A total of five students are currently doing year-round graduate research at Woods Hole. A summer course in "Theoretical Studies in Geophysical Fluid Dynamics" was supported by the National Science Foundation and was so successful that repeats in future summers are planned. The enthusiastic response to the course for industry in "Environmental Factors Influencing the Performance of Naval Weapons Systems", which was repeated in December, indicates the growing interest of American industry in oceanography. The public attention created by the report of The National Academy of Sciences' Committee on Oceanography seems to have had a direct influence on the interest of university students in this subject. For example, the number of students attending the introductory course in physical oceanography at the Massachusetts Institute of Technology was nearly twice that of previous years—some 23 persons; of this group four have elected to work toward advanced degrees in oceanography.

A final, and most significant, highlight of the year was the awarding to the Institution by the National Science Foundation of $3,000,000 for the construction of the first research ship to be built in the 1960-1970 program. We are greatly honored to receive this grant which enables us to replace the ATLANTIS with an equally fine ship, uniquely designed, as was the ATLANTIS, for oceanographic research. Design plans are proceeding well and it is anticipated that a very modern replacement should follow promptly the retirement of the ATLANTIS. The Development Program adopted by the Trustees in August has been greatly helped by this grant.

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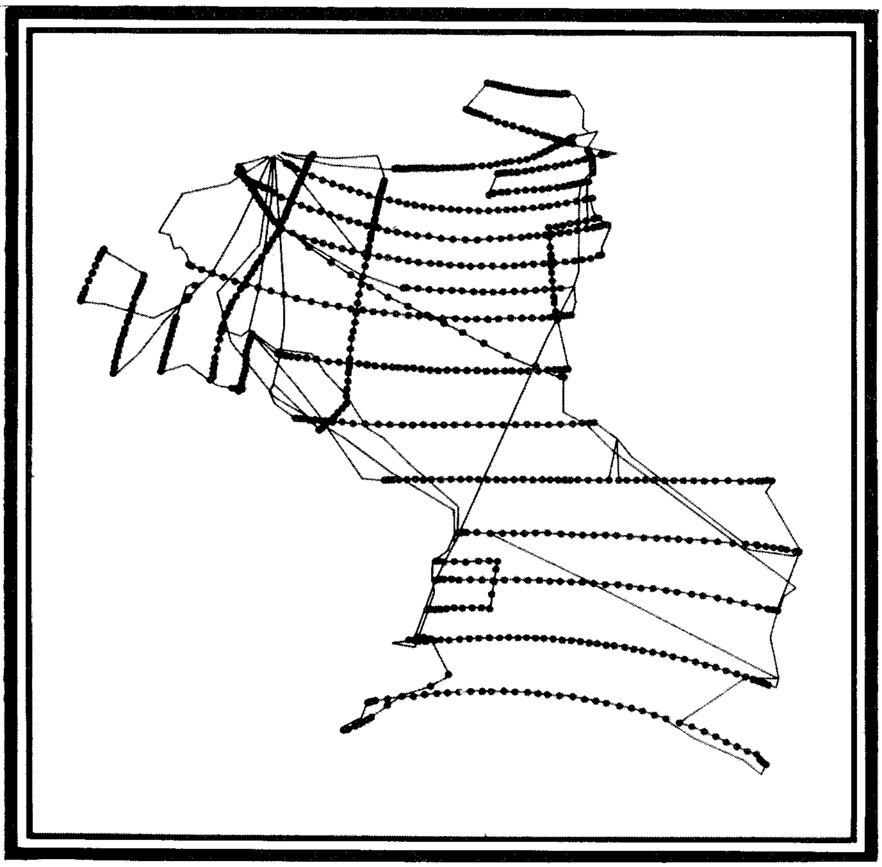
DIRECTOR'S REPORT

The following summaries of our scientific achievements during the year have been compiled with the help of many staff members and the excellent editorial assistance of the Director's Technical Assistant. It is impossible to properly credit the work of each research investigation but appreciation is gratefully acknowledged for the technical work of our entire staff which is herewith recorded.

Respectfully submitted,

Paul M. Fye

Overall picture of the Woods Hole Oceanographic Institution and the National Institute of Oceanography "Atlantic Ocean Survey". Detail shows oceanographic positions and plots of the five cruises on which bathythermograph observations were obtained.



The Atlantic Ocean Atlas, describing the results of the survey will be published June 1960.

PHYSICAL OCEANOGRAPHY

During 1959 the Institution completed the International Geophysical Year field program. In the first seven months of the year, the final cruise under this project was carried out by the ATLANTIS. Four crossings of the Atlantic were completed, including a very long hydrographic section at 32° S latitude between Montevideo, Uruguay and Cape Town, South Africa. One other additional IGY hydrographic section across the Atlantic at 36° N latitude was made by the CHAIN. Computation and tabulation of the ATLANTIS data is now almost completed and when submitted to the International Geophysical Year Data Center will represent the formal termination of our cooperation in this program.

This participation has at one time or another involved a majority of the people working at the Institution, three of our research vessels and two research vessels from other countries. It has included research at the two Arctic Ocean ice stations, flights to sample atmospheric CO^2 along the Atlantic coastline from the equator to Newfoundland and mutual cooperation with uncounted foreign investigators including the crew of a Russian research vessel who collected water samples for a project in which we were involved. Twelve trans-Atlantic hydrographic cross sections were completed as well as four sections in the northeastern Atlantic, four sections in the Caribbean and several intensive hydrographic studies including the area to the west of the Strait of Gibraltar, as well as portions of the Mediterranean and Red Seas and the Gulf of Aden.

An analysis of the Atlantic data is in progress and the descriptive portion is being prepared for presentation in a hydrographic atlas of the Atlantic Ocean. This work is a major effort which should provide a fresh description of the Atlantic Ocean and be of value for many decades.

A north-south section from the northeast of Sable Island to the east of Bermuda was completed in June by the CRAWFORD. These and similar observations made from the CHAIN indicate that conditions in the northern Sargasso Sea are different from those considered to be normal. The thermocline at a number of stations was 300 meters shallower than expected and the temperatures of the upper layers were generally below normal values for that time of year. It has been suggested that this occurrence results from an intrusion of water from the east of the Sargasso Sea as indicated by the temperature—salinity relationships. The north—south CRAWFORD section also showed that there was almost no slope water. Although this was unexpected, not enough previous data were available from this area to exclude the possibility that this absence is not simply a seasonal occurrence. A further study of this problem is being made and it is hoped that the temperature records made by commercial ships on the North Atlantic run may prove helpful.

Studies of sea surface waves have continued to be based mainly on data collected by an instrumented tower in Buzzards Bay. Observations are made by measuring the wetted resistance of three vertical sensing wires which are suspended from the tower down through the sea surface. The wave height data from the individual waves in the array are transmitted by an FM radio link to the laboratory in Woods Hole where it is recorded and subsequently automatically printed on a punched tape which is designed to be fed directly into a computer for analysis. The analysis of these data will deal primarily with the directional spectrum, but it is also planned to make slope frequency measurements.

In addition to the neutrally buoyant float technique, developed by Dr. John Swallow of the National Institute of Oceanography, some other deep-water tracking devices such as parachute drogues were utilized for the direct measurement of currents during the past year. Comparisons of simultaneous measurements by different methods were generally satisfactory.

A remote recording thermograph, placed on the bottom at Browns Ledge last summer, was retrieved and its record analyzed. This experiment demonstrated the tidal influence on temperature at the instrument location and also showed that a persistent wind can cause advection throughout the water column.

An extensive use of neutrally buoyant deep current measuring floats was made in a long term study of the deep circulation around Bermuda. Using the ARIES, and later the ARIES and the CRAWFORD jointly, an anomalous patch of 18°C water was located and traced over a period of many weeks. Deep current measurements made beneath this 18° patch displayed no particular pattern. It was decided that the high velocities of 8 to 12 centimeters per second were not related to this water lens. The lens was defined chiefly by a dip in the isotherms extending to about 1000 meters. Measurements inside it showed a strong (1 knot) clockwise circulation following the isotherms quite closely. The lack of T-S anomalies and slightly higher oxygen values indicate the patch had a relatively local and fairly recent origin. The flushing of the reef waters at Bermuda is considered to be its most likely source. While the large majority of measurements showed a southerly or southwesterly set to the lens, measurements made at points as little as 30 miles apart showed no relationship to one another. Floats only 2 or 3 miles apart did, however, move in nearly the same direction and at comparable speeds. The predominant southerly set encountered in this area is at variance with present theoretical expectations for the deep ocean circulation.

The surface current measuring program also revealed an interesting feature. Ten drift bottles launched during the spring and summer off southern New England were recovered to the southward, some from points beyond Cape Hatteras. Previously, only two bottles launched off southern New England have ever been recovered south of Hatteras. This pronounced southeasterly drift of at least 5 miles a day along the mid-Atlantic seaboard during the month of September may be associated with a period of northeast winds which persisted in the region for over two weeks. The progress of cold coastal water around Cape Hatteras during this period was substantiated in the salinity and temperature data taken at the Diamond Shoal Lightship.

Research into the meanderings and pulsations of the Gulf Stream has shown that on the Blake Plateau in the offing of Onslow Bay, North Carolina, the course and speed of the current is also related to meteorological conditions. Variations in the course of the current have been related to the monthly, semimonthly, and daily tidal frequencies, and also are found to correlate with the synoptic motion of atmospheric low pressure systems leaving the continent by way of the Cape Hatteras storm track.

The lateral motions of the Gulf Stream associated with tidal frequencies range from 5 to 10 nautical miles, while those associated with the passage of meteorological disturbances over the area may be as much as 30 miles. Because these motions of the Gulf Stream have too high a frequency to be studied by traditional dynamic methods, it is of interest to develop methods which provide direct measurements of the time variation of the horizontal pressure gradients in the ocean. Several techniques are under trial or consideration both for shipboard use and for instrumentation on a system of anchored buoys.

Comparing "Atlantis" and "Meteor" Sections of the South Atlantic.

MATHEMATICS AND THEORETICAL OCEANOGRAPHY

A most successful venture was the presentation during the summer of 1959 of an eight weeks' course entitled "Theoretical Studies in Geophysical Fuild Dynamics". The course was supported by a grant from the National Science Foundation, and eight participants were selected from graduate and post-graduate applicants. Each participant was encouraged to formulate a tractable statement of a suitable problem so that he might continue his research upon returning to his own Institution. The introduction to the course concerned the fundamental theory of steady flow and fluid instability in rotating and non-rotating systems. Other topics covered were the statistical theories of turbulence and their applications to isotropic homogeneous fluid motions, conductive instability due to radative heat flux and the problems of wave motion. The course was so well received that it will be presented again during the summer of 1960.

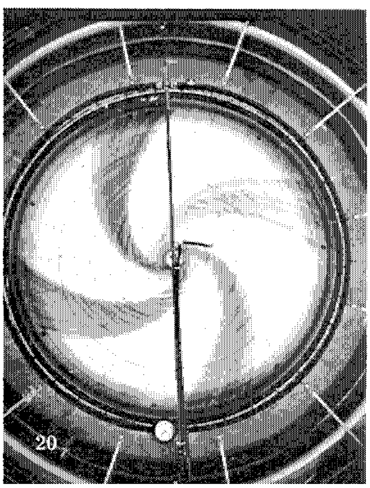
One of the more interesting research projects of the group concerned a study of the instability of the Ekman viscous boundary layer on both theoretical and experimental terms. Preliminary results suggest a more direct coupling between the Ekman boundary layer and its associated geostropic flows than one would expect from experience with boundary layer phenomena in non-rotating systems. Another development is the formulation of a Rayleigh instability criterion for vertical heat and salt transfer. This discovery has possible implications in an understanding of the thermohaline circulation in the ocean. It has been shown that the actual distribution of salt in sub-tropical oceans is in principle very unstable which points out the necessity for finding some mechanism for maintaining the high surface salinities observed at sea. This question has stimulated several experimental and theoretical studies.

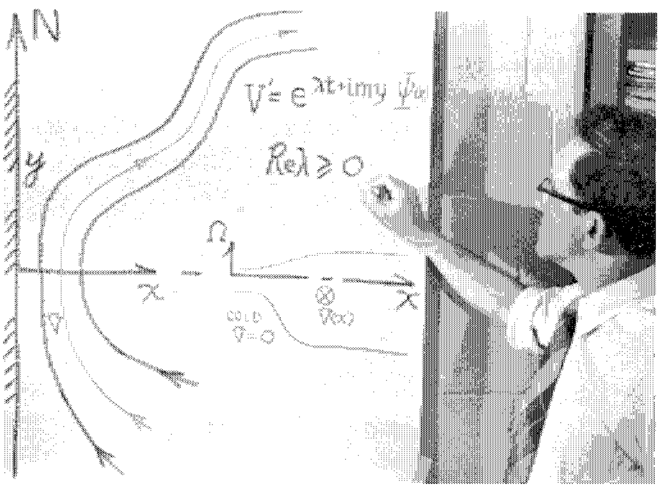
In the experimental studies, it was discovered that the salt convection occurs as long thin vertical columns of the sinking salt water, and intermediate rising columns of fresher water. These succeed in transferring salt vertically through the stable density gradient without a significant transfer of heat. It was further shown that small disturbances, such as very gentle stirring, can prevent the formation of convective elements and inhibit fallout of salt. Presumably something of a similar nature happens in the ocean because a widespread fallout of salt does not seem to prevail. A theoretical analysis of this steady columnar convective regime seems to account qualitatively for its main features.

Other studies undertaken by the group have included an analysis of water mass characteristics of the abyssal circulation of the world ocean. Using a numerical model on the observed data of deep temperature, salinity, radio-carbon, and heat flux through the bottom, it was considered possible to make some fairly definite statements about the composition and time-rates of formation of Pacific—Indian Ocean common water. This study is a generalization of normal water mass analysis. Future work may lead to further refinements and extensions of the method to other oceanographic areas.

Experimental studies of the field of motion produced by electrical forces were made in the hope that these might contribute to an understanding of non-linear fluid processes. Electrical measurements are technically simpler to make than direct thermal or force measurements. However, the problem of interpreting the electrical experiments is not simpler than for thermal studies so that these results are primarily of academic interest.

An estimate of the seasonal change of heat stored in a vertical column of water as a function of latitude and longitude in the North Atlantic has been dependent on the steadily increasing mass of data in the hydrographic file at the Institution. This study is based on the cumulative mean temperatures at standard depths obtained from a large number of bathythermograms. Because the study rests upon such a wealth of detailed information, comparison with the seasonal heat storage caluculated indirectly from meteorological data is particularly interesting. Taking averages for the entire North Atlantic between 20° and 55° N, the two types of estimates agreed within 15%.





Theoretical and Experimental Studies in Geophysical Fluid Dynamics.

The interaction between the sea and the atmosphere is indeed a two-way street which, in a sense, merits a name such as "Meteorological Oceanography" as much as it does the familiar one of "Marine Meteorology". That the latter is now used may indicate man's rapid progress in learning about the effects of the sea on the atmosphere as compared to his slower pace in understanding the effects of air on the sea. Though some work on both is done at the Institution, it is the air above the sea which receives most attention. So much of marine meteorology is yet to be investigated that a wide range of attacks is feasible. The diversity of the work undertaken at the Institution gives some idea of the scope of the problem, and its pioneering status is suggested by the number of instruments developed or improved by Woods Hole investigators.

One of the longer-term research efforts in this field has been an investigation of the modification of air masses over the ocean. The analysis of the flux of heat and water vapor from the sea to the air as continental polar air masses travel southeastward from the United States' eastern coast into the tropics has been the basis for much of this. This work has required that special emphasis be placed on the development of instruments to observe the various atmospheric parameters required for the analysis of the problem and has resulted in an increasing refinement and elaboration of the instrumentation on the R4D airplanes. In particular, fast response temperature and liquid water content instruments proved to be very successful. Using these techniques, field work has been extended to the Atlantic trade wind areas over the ocean to the east of Trinidad. Associated with this has been an analysis of clear and cloudy areas near a cold front. This latter work was based on

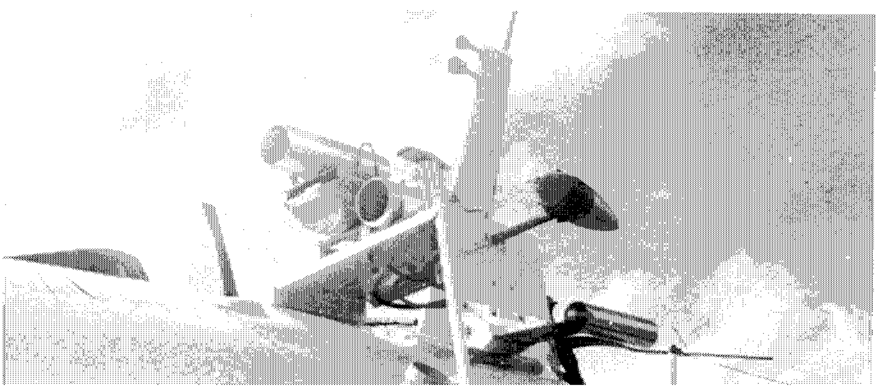
Tropical Cumulonimbus.

photographs made with specially modified cameras which were mounted in the nose of the aircraft.

The work on sea-salt nuclei has been progressing. It has included a continuation of an analysis of orographic rains in Hawaii in an effort to obtain a more complete understanding of the condensation process, and of the origin of the showers themselves. An improved design of the airborne flame spectrometer was completed and installed in the R4D. This instrument, which permits the sampling of atmospheric salt in much smaller parcels of air than was previously possible using the older slide collection techniques, was flown successfully off Trinidad in association with the heat flux measurements, and it is expected to provide unique information regarding the distribution of salt in the cloud region.

The study of the bursting of air bubbles at the sea surface has been continued and has verified the theory that by this process positively charged droplets are injected into the atmosphere. The electrical charge of these particles may not only influence the behavior of the particle within a cloud, but the sum total of these taken over all the nuclei in the cloud appears to give a net positive charge that has been transferred from the ocean to the atmosphere. The amount of charge as a function of bubble and drop size, bubble age and salinity of the water has also been determined. It has been shown to be dependent upon the circumstances under which the bubbles burst. An organic film on the surface of the water can diminish or even prevent the formation of the nuclei.

The tropics were the focus of an extensive analysis of heat balance. The methods utilized range from photographic observation of cloud development to the description of natural processes in terms of applied mathematical models. Convection, heat balance, hurricane energy and a description of cloud geometry were all subjects related to this problem which were studied by staff members and their associates at other Institutions. This work is being continued along many interesting lines, one of which is the investigation of the factors considered important in the inhibition of convection. This research is the offshoot of the concept of the bubble-like growth of cumulus clouds which was developed previously by various members of the Institution.



Meteorological instruments mounted on the R4D.

Detailed examination of the data for 1958 hurricane "Daisy" has indicated the importance of major cloud towers. Assuming reasonable sizes, buoyancies and entrainment rates, model calculation suggests that there should be no particular difficulty in getting penetration of these major towers into the stratosphere in such a hurricane. The good correlation of the theoretical prediction of the characteristics of such major clouds with the photographic measurement of towers in hurricane "Daisy" supports the proposed model. The development of these cloud towers under model conditions also implies updrafts of the order of 50 meters per second. These extreme rise rates have also been indirectly supported by radar and pilot balloon observations along the walls of the hurricane eye. The effect of high humidity conditions in hurricane rain areas reduces downdrafts and turbulence associated with the proximity of updraft and downdraft zones. Cloud towers forming under dryer, unstable conditions indicate that such zones could produce intense turbulence.

UNDERWATER ACOUSTICS

Our interests in the vertical migrations of organisms and in the scattering layer have been continued. Two techniques have been developed in an attempt to obtain photographs of the species involved. One of these involves immersing a sound transducer in the scattering layer and taking a picture when the organism which reflects the sound is expected to be in focus for the camera. The other operates by an automatically triggered camera which depends upon the luminescent flashing of the organism. In both cases successful photographs of either sound scattering or luminescent organisms have been obtained from the various depths in the sea. Broad-band acoustic observations of scattering layers were extended during the year to new localities in the eastern North Atlantic Ocean and in the Mediterranean Sea. These observations employ an explosion as the sound source and give information about sound-scatterers over a wide portion of the sound spectrum. Comparison of such observations from many widely-separated points should do much towards delineating the faunal provinces of the upper part of the high seas.

On a cruise in the deep water south of New England in August an echo-sounder and bathyphotometer were used to make observations of the vertical movement of scattering layers with respect to illumination, a continuation of the work begun three years ago.

It was possible to determine the approximate distribution of a special midwater sound scatterer which has come to our attention in recent years. This feature, popularly known as "Alexander's Acres", is composed of a larger or more numerous sound scatterer, judging from records, than is found in ordinary deep scattering layers. During the spring and summer, the scatterer was found to be almost continuously distributed in the ocean area from the latitude of New Jersey south to Cape Hatteras and from the 200-fathom curve offshore to the Gulf Stream. This feature perhaps represents an exploitable resource, and identification of the responsible organism is an early objective of the scattering layer program.

The National Science Foundation-supported investigation on various aspects of the natural history of whales and porpoises has continued, and particular emphasis has been placed on the production of sound by these animals and its relationship to their behavior. This work was pursued from the ASTERIAS, BEAR and CRAWFORD on cruises in local waters, to the Gulf of Maine and in the deep ocean south of New England. The newly-acquired Helio-Courier aircraft was also used in these investigations and has proved valuable for locating groups of whales and directing surface craft to them. Because of its low-speed characteristics and unobstructed view, this aircraft is excellent for aerial photography of cetaceans and other large sea animals.

Since their discovery in local waters a few years ago, observation of the rare North Atlantic right whale at the time of its springtime, northward migration has become an annual event. Over the period of several weeks in March and April of this year about 30 of these animals were observed in Vineyard Sound and Cape Cod Bay and first extensive recordings of their underwater sounds were made.

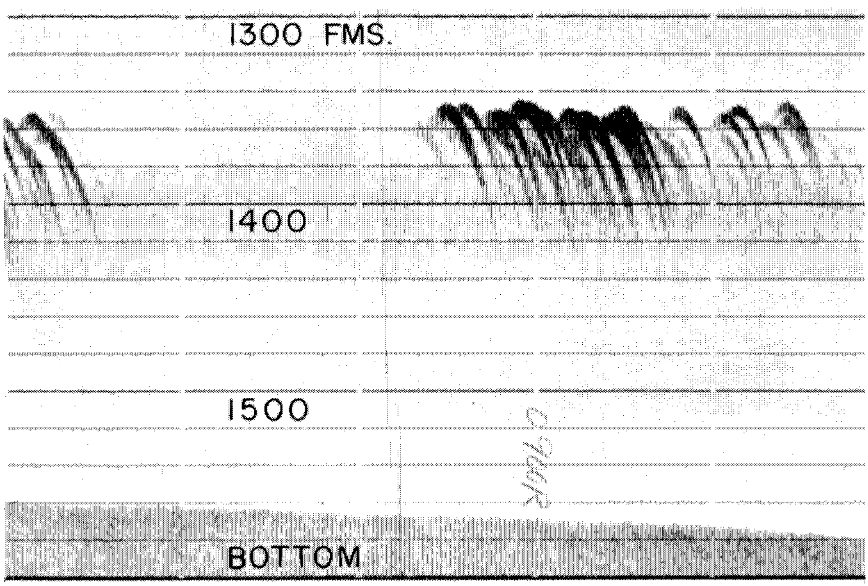
During the summer in deep water to the south of Woods Hole a little-known porpoise, ***Stenella styx,*** was extensively observed and the first positively identified recordings of the underwater sounds of this species were obtained.

The studies of the ocean as a medium for the transmission of sound have continued. The environmental factors which have received most attention in the past year are the sound velocity variations in the water and the shape and reflecting qualities of the bottom. These observations have been made at sea mainly from the CHAIN on a part of her Mediterranean cruise and on a series of cruises designed for just this purpose in the Woods Hole-Bermuda-Bahamas area.

The intricate velocity variations in the upper few hundred feet of the ocean have been ascertained indirectly by making detailed temperature observations with the thermistor chain. Sound transmission experiments conducted with the simultaneous determination of the thermal microstructure of the upper few hundred feet show that very small scale features, such as thin sound channels of only a few miles in length may have relatively large effects on sound transmission.

Last year our interest in direct measurements of the sound velocity of sea water was reported. This work was continued with the sound velocity meter developed at the National Bureau of Standards. It has been possible to compare for the first time sound velocity profiles made with this instrument with values computed from salinity, temperature and pressure data collected by classical oceanographic methods. This was done at 11 stations in the Mediterranean Sea on the cruise of the CHAIN. These comparisons indicate that there are discrepancies between the values directly observed with this instrument and those computed using Matthews' and Kuwahara's tables; the computed values being in general lower than those measured.

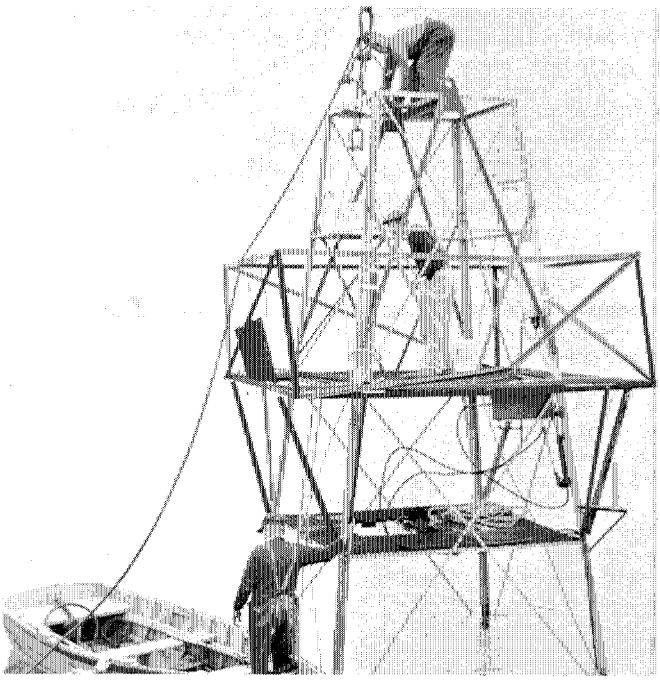
In spite of the success of direct sound velocity measurements, sound velocities based on temperature and salinity data continue



A fathometric record showing "Alexanders Acres" and scattering layers in deep water.

to be useful for underwater acousticians. Reports on the sound-velocity structure of the Mediterranean Sea and a restricted portion of the western North Atlantic have been prepared. Preliminary studies have also been made of the Arctic Ocean and parts of the Norwegian Sea.

Observations in local waters and theoretical work relevant to sound transmission problems were also carried. A number of interesting experiments were conducted from bottom-mounted towers in Buzzards Bay during the spring and fall in order to learn more about the stability of sound transmission paths. In one set of observations the fluctuations in intensity of a 600 cycle-per-second tone were recorded. It was evident from these data that surface waves cause changes in the phase and amplitude of the received sound. In another set, fluctuations of a repetitive spark source were determined. At ranges greater than a mile, large fluctuations in the intensity of the signals received were noted, and at a range of seven miles, the received sound was intermittent with a period of several minutes, much as in radio fading.



Installing the Buzzards Bay tower.

We have continued to examine the ocean bottom and the structure of the crust of the earth beneath the oceans by means of echo-sounding, seismic reflection, and seismic refraction techniques and have studied superficial processes on the ocean floor by means of bottom sampling with rock dredges, grab samplers and core sampling devices, as well as by underwater photography and echo-sounding. The most intensive and exciting events were a cooperative venture with several university laboratories of an area north of Puerto Rico in selecting a possible site for drilling a bore hole to the Mohorovicic discontinuity (the MOHOLE project of the National Academy of Sciences) and an extensive survey of the crustal structure in the Mediterranean Sea between the Côte d'Azur and Corsica. The latter project was carried out in collaboration with the Oceanographic Museum of Monaco and is a continuation of a seismic study of the Mediterranean Sea carried out by this Institution and the Lamont Geological Observatory in 1958. Other especially significant programs were the correlations of core samples with shallow sub-bottom echoes in deep water sediments of the Mediterranean, the application of the deep sonar pinger, originated by Edgerton and Cousteau for bottom photography, to monitoring deep coring operations and the recording of sub-bottom seismic reflection in deep water.

For several years we have been improving the resolution of our echo-sounders by shortening the length of the sound ping and by increasing the writing rate of the graphic recorders. Technical improvements in the recorders have allowed us to record with high resolution (pulse length 0.2 to 0.5 milli-second long and writing rates of about 150 inches per second) routinely from the CHAIN over many hundreds of miles in the North Atlantic and the Mediterranean. Several horizontally stratified sediment "ponds" have been found; two in the Mediterranean were surveyed in some detail. Cores were taken in "ponds" which are now being analyzed and compared with the echo evidence of stratification.

Several other bathymetric projects have been continued from previous years. The northern third of the Blake Plateau, surveyed in some detail over a period of six years when cruising across the area, is a nearly flat plain about a half mile deep lying between the Bahamas and Cape Hatteras. Its low relief seems from the earlier traverses to reflect deep-seated faulting. The principal patterns in this topography have been revealed as a result of several cruises in

1959. Several single seamounts of the North Atlantic were also examined in detail, as well as portions of the mid-Atlantic Ridge and the contact between the abyssal plain of the North Atlantic Basin and the foothills of the Ridge.

For the second successive year we have extended both geophysical and geological cruises to the Mediterranean. Emphasis was given to dredge sampling of the steepest slopes and coring in the basin areas. Sediments dredged on several rather steep slopes along the escarpment between the Peloponnesos and Crete were all terrigenous muds and clays. Rock fragments were found only in a deep gorge running through the Strait of Sicily; elsewhere only fine materials were recovered. Coring in basin areas produced several 25- to 30-foot cores and many more shorter ones. All were taken by a new method in which the lowering was wholly monitored by a sonar pinger attached to the heavy steel cable suspension of the coring apparatus. Echoes from the corer and the ocean floor are recorded on the ship, thus informing the observer of the success or failure of the operation while the apparatus is still on bottom. The short sound pulse bottom echoes of the pinger gave detailed sub-bottom information at the exact core location. A simple apparatus employing ultra-sonic (0.5×10^6 cps) pulses was subsequently used to measure sound velocity every two inches along the cores. In the one core that has been studied in detail the position of abrupt changes in sound velocity agree well with the sub-bottom echoes of the pinger and with changes from clay to sandy layers in the core. We are indebted to Dr. A. B. Wood of the Admiralty Research Laboratory in Great Britain for the loan of the ultra-sonic tranducers used for these sound velocity measurements.

The seismic profiler was also used for a short time to study the coastal shelf south of Cartagena, Spain, and in the Strait of Sicily. A third considerably more detailed survey was made in and to the northwest of the Strait of Messina. A model based on these data suggests the pattern of deposition in the channels leading northwestward from the Strait into the Tyrrhennian Sea. A brief study with a horizontal hydrophone array and explosives in the Balearic Basin suggests local occurrence of a thick horizontally-bedded sedimentary sequence.

By far the most intensive geophysical study was a series of long seismic-refraction profiles made from the CHAIN in cooperation with members of the Oceanographic Museum of Monaco on their ship WINNARETTA SINGER. Early results indicate that the sound velocity, slightly over 8000 meters/second, identified with the Moho is comparatively shallow—about 14 kilometers below sea level. This corroborates results from a nearby profile made in 1958. The two profiles are nearly perpendicular, thus reducing the possibility of a fortuitously high apparent velocity that could result from a profile across a basin structure.

For several years Institution seismographers have been accumulating information on local sediments and shallow bedrock structures in the inland waters near Woods Hole, in the Gulf of Maine, and on the continental shelf from New Jersey out across Georges Bank. In addition, the reconnaissance with the seismic profiler in Cape Cod Bay, on Georges Bank and on the continental shelf clearly demonstrates the potential of this reflection method for studying sediment structures.

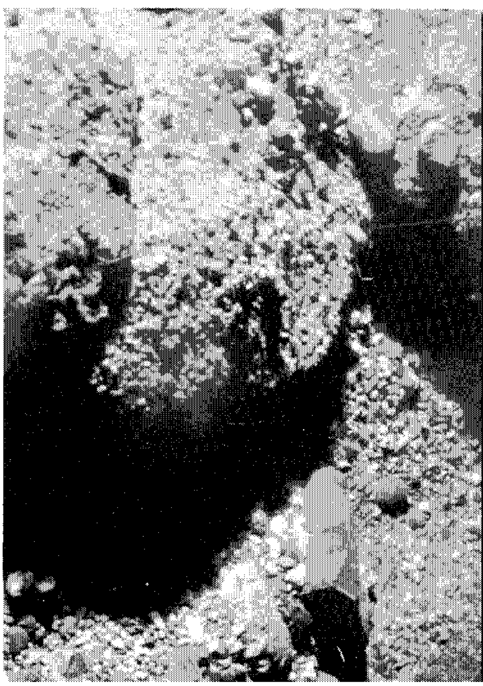
Investigations ten years ago by the Institution and later confirmed by the Lamont Geological Observatory indicated that the earth's crust was very thin along the ridge just north of the Puerto Rico Trench. This is now of special interest to the National Academy of Sciences project for drilling a hole to the Mohorovicic discontinuity. In May and June a detailed pattern of seismic refraction profiles was completed in this area working with the Lamont Geological Observatory, the Agricultural and Mechanical College of Texas and the University of Miami. The seismographers are continuing to analyze the data which indicate a thickness of 10 kilometers from sea level down to the Moho. Other considerations such as probable weather and sea conditions and availability of proper drilling equipment may have as much to do with the final site selection as the thickness of the crust. Some members of the staff are being asked to consider the influence of weather, waves, and currents on the drilling operation.

On the long International Geophysical Year cruise of the ATLANTIS in the South Atlantic during the first half of the year, several long core and dredge samples were taken along a line 2,000 miles to the northeastward from the mouth of the Rio de la Plata off Montevideo to a feature known as the Bromley Plateau in the western Atlantic. The original concept was that sediments in the basin between the Plateau and the continental shelf off Montevideo would be formed as the result of a very slow rate of deposition and would show the effects of the submarine erosion of the Plateau to the eastward and of the introduction of weathered continental rock material from the westward as the result of the outflow of the Rio de la Plata. Instead, the discharge and transport of sediment by the Plata was found to be so great that this material was found all the way out to the flanks of the Bromley Plateau. The pattern of sedimentary deposition which was found fitted that which had been previously known for the western basin of the Atlantic from the latitude of the Amazon northward to the region of ice rafted sediments in the North Atlantic.

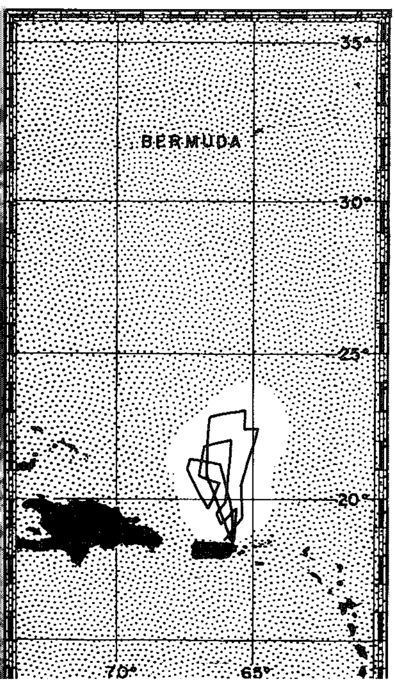
In October and November the ATLANTIS made a cruise along the northern coast of South America continuing the marine geological work of the previous year. Extensive related projects were also undertaken which will greatly enhance the value of the geological program. Venezuela and Colombia cooperated and their scientists were on board the ship during much of the time at sea.

In addition to the novel and effective use of echo-sounding techniques in coring, several purely mechanical advances have been made during this period. One of these, an improved core-barrel coupling, is a simple time-saving device which has been a great help to the operator. This coupling can be used with the older style of tubes as well as the new. It uses common nails driven into peripheral grooves in the coupling and the tube and combines great strength with ease of assembly.

Other changes were devised to enable the operator to obtain samples without contamination from hydrocarbons and to pre-



Photograph of the north wall of the Puerto Rico Trench in about 4000 fathoms of water using an Edgerton Stereo Camera.



ͻHOLE survey area.

serve the sample without loss of connate water. Contamination from oil and grease, usually used in preserving the apparatus, has heretofore prevented some important determinations of trace constituents. We have been searching for a preservative which prevents rust and corrosion, has a low coefficient of friction, is an "acceptable" contaminant, and is applicable to the inside of long tubes. A process in which nickel is chemically deposited upon steel has proven feasible and the appropriate parts of our coring gear have been nickel plated by this method.

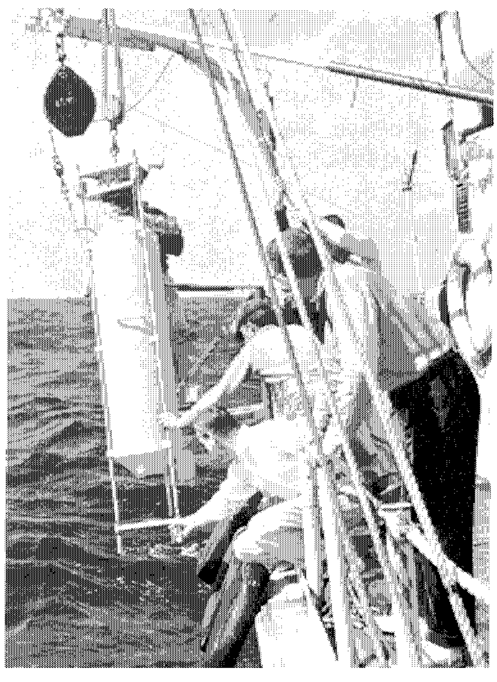
An air operated hydraulic core extruder has been built and successfully used in the field. This consists of a completely portable device which is capable of exerting well-controlled pressures up to 2000 psi upon a free piston placed in the core tube. As the piston advances, sediment is extruded from the tube and sampled by the observer.

CHEMISTRY

Collection of large-volume water samples at sea has continued but at a much slower rate than in previous years. Most of the year's activities were devoted to laboratory investigations of analytical methods or to the analysis of previously obtained material. Our strontium-90 analytical method has been checked by using aliquots of strontium-90 from the National Bureau of Standards which were measured by a calibrated beta counting technique. In addition, several duplicate samples have now been analyzed, and the correspondence between these independently analyzed replicates is very satisfactory. The cerium analytical technique has been speeded up by modifications of several steps in the rare-earth procedure. This has not only provided more consistent and higher yields of cerium, but, at the same time, a complicated series of efficiency evaluations of each step in the procedure has permitted a realistic estimate of the overall confidence limits for the analysis of cerium-144 and promethium-147.

The tabulation of our strontium-90 profiles between latitudes 35°N and 16°S shows that the concentrations of this isotope between the 300 and 500 meter level is approximately 50% of the concentration at the surface. The isotope can also be detected to the 1100 meter level in this region. Rough integration of the vertical strontium gradient in such areas indicates that there is three to four times as much of this isotope below the 100 meter level as there is between the 100 meter level and the surface. Since the amount below 100 meters must be related to introduction times of two to four years ago, this distribution indicates a major and relatively rapid transport of water across the themocline. The complete understanding of this phenomenon is dependent upon an evaluation of the fallout of this isotope over the sea. Either our present model of stratospheric fallout or our evaluations of the efficiency of sampling by land stations must be reconsidered in order to bring the high strontium-90 levels in the ocean in line with our picture of the total strontium-90 path in the atmosphere and ocean.

The occurrence and constitution of several fossil pigments is being investigated. A comparison of their structure with that of the biological parent compounds will help us gain a better understanding of organic reactions in sediments. As one of a series of studies related to the organic chemistry of sea water which have just been initialed, foam fractionation is being examined as one of the potential tools for the enrichment of organic compounds from sea water. In several experiments a lowering of surface tension by 30% has been measured in the early foam fractions, indicating selective removal of the surface-active compounds. We intend to isolate and characterize the materials responsible for this effect.



A large volume water sampler.

Our effort of marine biology has continued to be concentrated in four main areas, all aimed at an understanding of the ecology of the populations in the oceans. These are the ecology, physiology and distribution of the phytoplankton; the feeding, migrations and distribution of the zooplankton; the dynamics and breeding cycles of sedentary bottom populations; and the life cycle and distribution of pelagic fishes, especially of sharks and rays. Closely associated with the phytoplankton work are the investigations of the distribution of essential nutrient chemicals in the water. These projects continue to be supported by Institution funds, by contracts with Atomic Energy Commission and with the Office of Naval Research and by several research grants from the National Science Foundation and from the National Institutes of Health.

The phenomena observed at sea raise questions which can only be answered by an experimental approach in the laboratory. Conversely, the results of the laboratory experiments under idealized conditions must, in turn, be tested under the conditions in nature to determine whether the results are of general application.

One part of the program has been designed to describe and to assist in our understanding of the phytoplankton cycle both in the inshore waters and in the Sargasso Sea. This included an evaluation of the various ways of measuring the photosynthesis or productivity of the phytoplankton crop, the distributions of chloropyll and other plant pigments, and the relationship of the photosynthesis of the phytoplankton to the essential fertilizing elements in the water. Contrary to our previous concepts, large seasonal and annual variations in primary production have been observed in the waters of the Sargasso Sea off Bermuda. It had generally been assumed that this area is one of rather uniform conditions throughout the year.

Until recently it was unfortunate that practically no species of oceanic phytoplankton had been grown in pure culture. Much of our fundamental physiological information about phytoplankton organisms was based on a few tough species which may have abnormal reactions and which might be considered the "weeds" of the sea. We now have nearly a hundred different species in pure cultures and a comparison of their physiology will show how variable their responses may be. Differences in the response of some species to temperature have already been established, but it is dependent upon future work to determine how these may be used to explain the distribution of the phytoplankton organisms in the sea.

Chlorophyll has long been used as an index of the amount of phytoplankton in the water and of the photosynthetic potential of the population. There have, however, been questions concerning the prevalence of "dead" chlorophyll which would be included in the determination but would not contribute to photosynthesis. With the acquisition of the Cary spectrophotometer it has been possible to begin an investigation of this problem. So far this study has indicated that chlorophyll decays very rapidly in the sea but that some of the breakdown products may indeed be included as active chlorophyll with the methods of determination now in use. The distribution and abundance of plants in the sea also has a profound affect on the color of the daylight which reaches various depths, and studies of the effects of the pigments themselves and of the particles and color of the water on the absorption have begun.

From our surveys of the phytoplankton populations at various locations between Woods Hole and Bermuda, it has been possible to relate the distribution of some species to temperature and salinity of the water. Less than a fifth of the species were associated with the extremes of temperature. However, most of the species in our populations are adjusted to a wide range of temperatures which indicates the rather small part played by temperature in seasonal succession of these species.

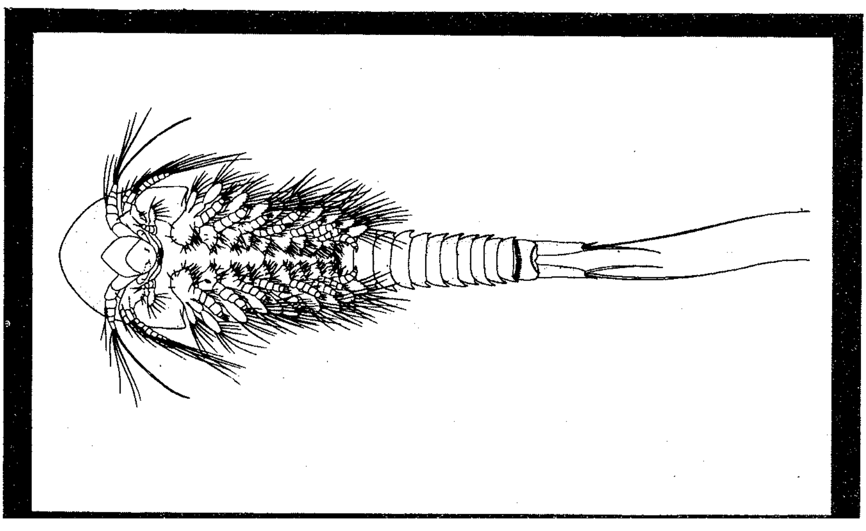
The nutrition of phytoplankton has also been examined both in the laboratory and in field. It has long been known that the physiology of cells deficient in an essential element such as phosphorous or nitrogen is different from that of normal cells, and we have suggested that such a deficiency would reduce the photosynthesis of the populations. While this has been easy to demonstrate in laboratory cultures, it is difficult to determine whether a population in nature is indeed deficient or not. One approach is to enrich the sample of seawater with known fertilizing elements and to determine the rate of photosynthesis before and after enrichment. This approach has demonstrated that in addition to nitrogen and phosphorus several trace elements such as iron and manganese may be limiting to photosynthesis.

One approach to the investigation of deficiences of actual populations is the use of radioisotopes to determine whether or not the cells assimilate these in excess amounts when they are made available. We have initiated experiments using radiophosporous to determine whether our natural populations at sea are deficient in this element. This has proved to be a powerful tool in laboratory experiments, but our studies of the natural populations have barely begun.

With direct chemical methods we are trying to determine the ways in which nitrogen deficiency of the natural population may affect the photosynthesis of these populations. The transformations of nitrogen in the sea are complex, and we have evidence that the plants may not only assimilate nitrogen compounds from the water but may transform them and produce some of the intermediate products of nitrogen metabolism. These observations may help to explain disturbances which have been difficult to understand on the basis of bacterial decomposition alone. The bacterial contributions to the transformation of the nitrogen compounds and of the effects of the phytoplankton population on these transformations is also being actively looked into.

In addition to the intimate relationship between phosphorus and the cycle of plant production in the ocean, this element may be used as a characteristic of water masses. For several years we have been obtaining samples for total phosphorus determinations on practically all of the hydrographic cruises that have left Woods Hole. We now have an extensive coverage of the western North Atlantic, and the data are being worked up to describe the distribution of phosphorus at all depths. Total and inorganic phosphorus determinations were also made on all stations occupied during the International Geophysical Year. These will provide a body of information unequalled in terms of nutrient distributions in both North and South Atlantic oceans.

Our zooplankton work is also a combination of laboratory and field investigations. Feeding experiments have concentrated on the copepod, *Calanus hyperboreus,* because of its large size and



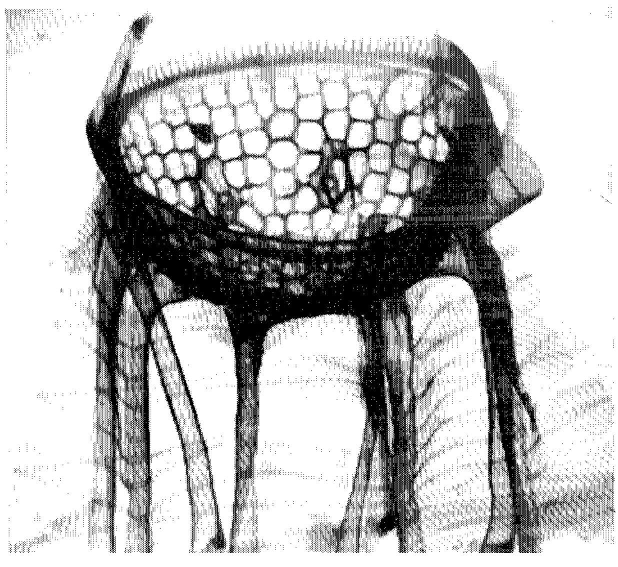
Hutchinsoniella macracantha
a living "fossil"
1/10" long,
from the bottom
of Buzzards Bay.

adaptability to laboratory conditions. Individuals of this species have been maintained for about a year under laboratory conditions where the life cycle seems to follow approximately the same sequence of events as occurs in nature. Although the life cycle has not yet been completed in culture, experimental animals have passed through most stages of their development in the laboratory.

In the laboratory, experiments on the dark and light adaptation of various arthropod eyes and on the responses to polarized light have been continued. If the crustaceans of the sea are, indeed, the organisms which determine the extent and timing of the vertical migrations, these results of dark adaptation will be invaluable in interpreting the results in the natural environment as will the investigations of the conditions of light in the sea. In clear waters various types of luminescent flashing were recorded at different depths, and some of the flashes biologically produced light were found to be a thousand times the intensity of the background light. Of particular interest was a survey of Bahia Fosforescente, Puerto Rico, where the light emitted by agitated water was found to be comparable to moonlight in intensity and over 100 times brighter than the bioluminescence outside the Bay.

Collections to ascertain the distribution of species of zooplankton at various locations between Woods Hole and Bermuda were continued. Dramatic changes in the population as one goes from the coastal waters through the slope water and the Gulf Stream to the Sargasso Sea continue, as in the past, to be impressive. It appears that the coastal waters are often dominated by one or two species of the zooplankton whereas in the Gulf Stream waters and in the Sargasso Sea several groups combined dominate the populations.

Skeletonema costatum an important diatom in New England coastal waters. Half the silicon dioxide cell wall is shown in an electron micrograph, magnified about 5,000 diameters.



The studies of the bottom communities have still been largely confined to the inshore, shallow areas. The types of organisms present in each community are determined not only by the character of the sediments but also by biological competition between the various species. Different types of sediment favor one method of feeding over another, and the character of the bottom population is determined by these differences. Deposit feeders were found to be prevalent in stable sandy sediments in intertidal environments, apparently because in these very shallow waters diatoms and dinoflagellates can grow directly on the sand. In contrast, deposit feeders are not common in sandy bottoms in deeper waters where plant growth is restricted.

The breeding cycle of various sedentary forms was determined in the laboratory. It has been found possible to stimulate both the development of the sexual cells and breeding by controlling temperature for several of the common species. Control of the breeding cycle will not only make it possible to have specimens in various stages of development at various times of year but might ultimately lead to the possibility of controlled genetic studies on marine organisms.

The collection of skates and rays trawled by the U. S. Fish and Wildlife Vessel OREGON chiefly along the Atlantic coast of Central America has continued. The preparation of a DANA report on a collection of sharks from the Atlantic, Pacific and Indian Oceans is also underway.

The life span and migrations of sailfish and marlin are now better known. This information has resulted from recapture of fish tagged in the western North Atlantic. For the first time trans-Atlantic migration of bluefin tuna has been established, and a heretofore unknown wintering ground of medium bluefin tuna in the Gulf Stream has been discovered. Data are now available to permit a revision of the taxonomy of the four western North Atlantic species of the genus *Seriola* and to make the first direct comparison of bluefin tuna populations from California, Spain and the western Atlantic.

INSTRUMENTATION

This year has seen the fruition of several of the instrument systems which have been under development at Woods Hole. The transponding radio buoy has been sent out for commercial manufacture and about eighteen have been bought for use as drifting current indicators and for radio-acoustic ranging. In addition to our own uses, four have been purchased by the Fisheries Research Board of Canada and four by the Scripps Institution of Oceanography. Because of this demand and an indicated increase in the use of these buoys in the near future, the design has been let out to another company for modification to increase reliability and ease of servicing. This will lead to a somewhat more expensive version which should be more adaptable to long term use.

With the acquisition of the ARIES for use in following the deep circulation by means of the Swallow float, the Electronics Department assisted by making much of the equipment needed for this work. In addition to the more usual equipment needed on any research vessel, navigation by means of Loran C was desired but receiving equipment was not available. A simple inexpensive set was developed which has provided this project with navigational control varying from a few yards in the Cape Hatteras area to about 250 yards in the vicinity of Bermuda. The ARIES is one of the few vessels in the world using this navigational system successfully. Also as part of the deep current program, an improved pinger was developed which provides a useful increase in range.

A 12 Channel FM telemetry system using a VHF radio link and recording on magnetic tape has been developed for the wave research program. During the late summer it was used from a tower installed in Buzzards Bay to record six channels of wave data and wind direction and speed. This equipment has provided the best records we have ever obtained for machine computation of surface wave power spectra and the first data for computation of directional spectra. An unfortunate accident in which the Buzzards Bay tower collapsed (apparently caused by a boat tying up to it) set back the work for about two months, but the equipment was used from a tower off the Florida coast this winter. In October a meeting was held at Woods Hole at which oceanographers from several laboratories accepted this telemetry system as a basic one for recording oceanographic data.

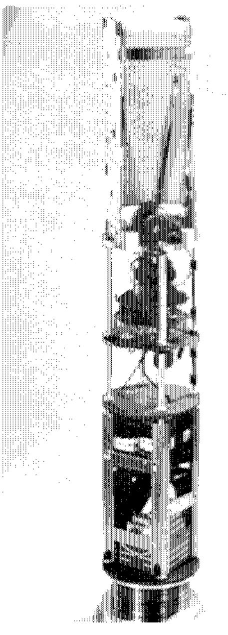
Now that the shipboard salinometer for measurement of the salinity of water samples brought up in Nansen bottles has become standard on our vessels, emphasis is being placed on development of a cable-lowered *in situ* salinometer. Conductivity cells of the electrode type and also the toroidal induction type are under development. As a necessary adjunct to this problem studies have been made of the effect of carbon dioxide and oxygen on conductivity and experiments have been started to improve the measurements of the pressure effect. These have become important due to the increased precision of the conductivity bridge salinometers themselves. If a conductivity type salinometer is used as an *in situ* meter, the effect of pressure on conductivity will have to be evaluated.

Another set of equipment which has been developed for use on the Texas Towers is a string of thermisters, one every ten feet, which is programmed to a digitizing system which punches paper in a form useful for machine computation. These data will be processed to obtain the spectra of internal waves and thermal noise.

A new method for the acquisition of data has been tried this year. This is the use of vertical instrument vehicles which are dropped free of the ship and carried to the bottom by weights. At the bottom or at a selected mid-depth the weights are released and the vehicle returns rapidly to the surface by means of its own buoyancy. The vehicle itself is a streamlined device 6 feet long and 2 feet in diameter, the upper half of which forms a tank holding 50 gallons of gasoline to provide buoyancy. Instruments are contained in pressure proof cases in the tail of the vehicle. A considerable number of tests were run to determine the action of the vehicle under various load conditions. Measurements of stability

Unattended (waxpaper) thermograph.

hermistor chain.



were also undertaken, and although oscillations with amplitudes in excess of 15° were encountered, the vehicle performed very successfully. Various ascent and descent rates were achieved using combinations of parachutes and weights, and it was found that pay loads of 50 lbs. weight in water could be achieved and still give ascent rates three times that of a standard hydrographic winch. Although most of the instrumentation used in the vehicle was designed to test its performance, instruments recording temperature and dissolved oxygen have also been used successfully at much higher data-acquisition rates than is currently possible with cable-lowered gear. These measurements were compared with similar observation taken by normal hydrographic techniques in the same area and clearly illustrated fine structure features which could not have been found by normal procedures.

It is well known that the method of computation of dynamic sections, now widely employed in the study of oceanic circulation, excludes measurements of the horizontal pressure gradients which remain unchanged with depth. While steady forces, such as the trade wind, acting over a period of several years will produce motions whose amplitude are strongly depth dependent, there is a spectrum of motion, almost independent of depth produced by such transient forces as intense storms. Methods for investigating these latter effects on a regional scale require either a network of sensitive piezometers to detect the time dependent changes of the slopes of the isobaric surfaces in the volume of the sea or some means for measuring the regional inclination of the sea surface.

An instrument for measuring the regional slope of the sea surface has been built for the latter purpose. It has sufficient angular resolution to measure regional tilts in the order of one part in a million. The errors caused by atmospheric refraction, surface waves and barometric pressure gradients are being studied from land stations. A sea-going version of this apparatus requires that a gyro-pendulum be constructed to provide an indication of the direction of local gravity at the ship's position to the same high order of accuracy as that of the tilt measurements. The gyro-pendulum problem poses serious technical difficulties. But the rate of improvement of these devices, which are integral parts of modern inertial and star tracking navigation systems, is sufficiently great to anticipate that the necessary accuracies may be obtained within the next decade.

FLEET OPERATIONS

Undoubtedly the most significant development related to our fleet during the year was the National Science Foundation's grant to the Institution of $3,000,000 for the construction of a new research vessel. As discussed elsewhere in this report, this grant is one of the utmost importance, not only for the Institution's future but for the future of American oceanography.

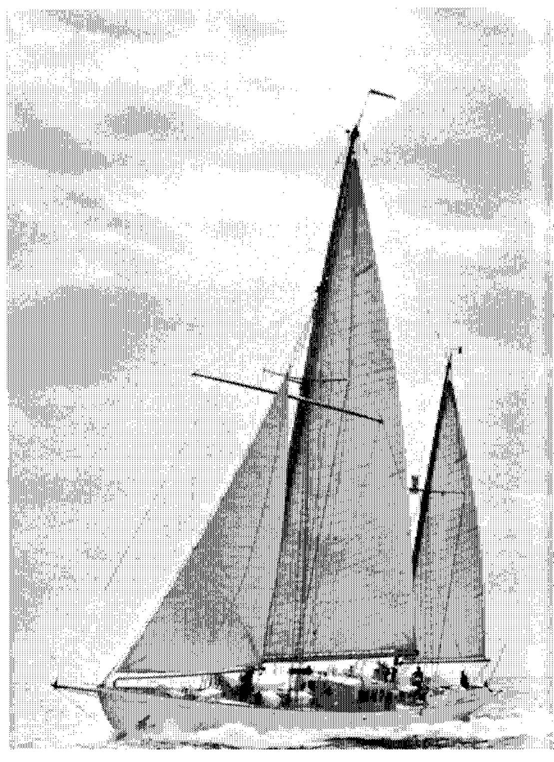
Three other important developments took place with respect to the Institution's fleet. In January the ARIES was acquired through the generosity of Mr. Richard J. Reynolds. She was taken over by the Institution in Hamilton, Bermuda, and after a very rough passage to Woods Hole, she was modified for oceanographic research. She returned to Bermuda in June and has been used there on a deep buoy tracking program ever since. This program is expected to continue throughout most of 1960.

In July the Institution purchased a five-passenger Helio-Courier light aircraft. This plane has been used on floats since her acquisition and in favorable weather can be landed in front of the Institution and beached at the end of Water Street near the Fish and Wildlife Service building. This capability contributes considerably to the convenience of using this plane and has proved a valuable asset in light of the cessation of railway transportation to the Cape area. This particular aircraft was chosen for its unusual flight characteristics. Automatic slots on the leading edges of the wings and other slow-speed design features allow the plane to be flown as slow as 30 knots. In even moderate winds this gives the plane almost helicopter-like hovering characteristics. On the other hand, a high performance engine, the automatic slots, and controllable flaps give it a short take-off distance and a cruising speed of 130 knots. As the wing design requires no bearing struts, these features combine to make the plane uniquely suitable for a number of projects, and the Helio will more than adequately replace our five-passenger Stinson.

The third major change in the status of the fleet was the Institution's take-over of the operation of the CHAIN from the Military Sea Transportation Service. The ceremonies took place on November 13th in the Bethlehem Steel Company yard in East Boston where the ship was docked for final conversion to oceanographic use.

The CHAIN was used almost continuously, being away from Woods Hole 210 days compared to 161 days for YAMACRAW and CHAIN combined in 1958. Most of these operations were in the western Atlantic, but in the early summer a three and one-half month cruise to the eastern Mediterranean was undertaken to further the earlier geophysical studies in the area by the ATLANTIS and YAMACRAW. On a portion of this cruise successful joint ship operations were carried out with French scientists from the Museum at Monaco. The CHAIN returned from this cruise in time to go to New York for the first International Oceanographic Congress which was held at the United Nations in early September. She tied up at a pier in the Hudson River with several other research vessels. All of the research vessels were open to those attending the Congress.

The ATLANTIS, on the other hand, began the year with an extensive seven month's cruise to the South Atlantic. This was the last International Geophysical Year cruise undertaken by the Institution and was delayed more than a year due to the 1958 difficulties with the ATLANTIS' main engine. The ship made four crossings of the Atlantic Ocean, including one long crossing at 32° South between Montevideo, Uruguay, and Cape Town, South Africa. The remainder of the ATLANTIS' operations were in the western North Atlantic; and, like the CHAIN, was sent to the International Oceanographic Congress in New York. The contrast in size between the 142-foot ATLANTIS and the 337-foot MIKHAIL LOMONOSOV of the U.S.S.R. was very striking.



R.V. Aries.

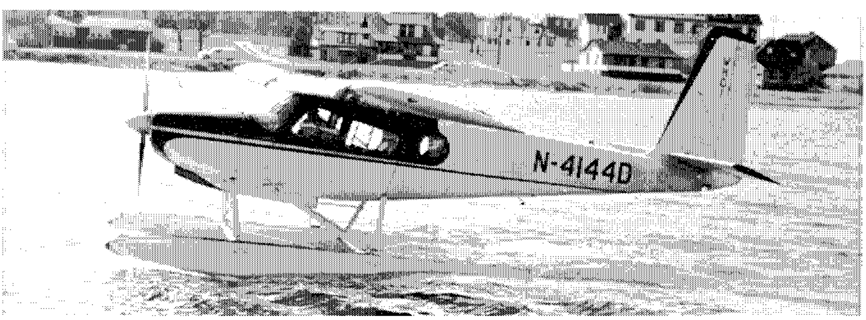
The CRAWFORD operated for most of the year in the western North Atlantic Ocean, and as a result of yard periods in the beginning and at the end of the year, put in fewer days at sea than during the heavy International Geophysical Year operations. In the late fall and early winter she operated out of St. George's, Bermuda, in association with the ARIES. The availability of two ships for the deep buoy tracking work and the superior speed and range of the CRAWFORD added considerably to this long-term program of deep current measurement.

As is generally the case, the BEAR operated out of Woods Hole for most of the year. In May and June, however, she took part in the well-publicized MOHOLE survey north of Puerto Rico. This work was done in conjunction with the VEMA of the Lamont Geological Observatory, the JOSIAH WILLARD GIBBS of the Hudson Laboratory and the HIDALGO of the Agricultural and Mechanical College, Texas. This multi-ship seismic survey was one of the first of this sort ever undertaken in this country. The use of multiple receiving ships had previously been attempted by the U.S.S.R. in the Black Sea.

Our DC3-type, Navy-supplied aircraft was used extensively by several investigators. Most of the operations were between Woods Hole and Bermuda, but several southern flights were made and one twenty-day flight in the Trinidad area was carried out in late fall. Scientific instrumentation on this aircraft has become increasingly refined, and the plane is becoming a more and more important tool for meteorological research.

Considering the year as a whole, the Institution's operations at sea increased considerably in 1959. In 1959 the fleet put in 864 days at sea compared to 741 in 1958, the highest year heretofore. This increase can be accounted for by the addition of the ARIES to the fleet.

The level of aircraft operations was comparable to that of last year, but the Institution's research staff has shown an increasing interest in obtaining the use of a four-engine airplane for use in mid-ocean and at high altitudes, and such a facility will have to be acquired in the near future.



Helio Courier

With the ATLANTIS' projected retirement date only a year and a half in the future, the Ship Design Committee has been accelerating their activities in developing the specifications for her replacement. The general design characteristics arrived at by the Institution Ship Committee call for a vessel of approximately 175 feet overall length and a gross registered tonnange of 850 tons. By comparison, the ATLANTIS is 142 feet in overall length and has a gross registered tonnage of 293 tons. The new ship's surface speed is expected to be in excess of 12 knots and its range at sea at a 10 knot speed is estimated to be about 10,000 miles. Several special features are being considered, including a below-waterline bow observation chamber, a center well, active stabilization, specialized winches, cranes and hoisting equipment, and such laboratory features as a chemical bench, aquaria and large freezing facilities. In addition special consideration will be given to the acoustical characteristics of the vessel, and it is hoped that a very low noise level can be achieved for silent ship operation. A stabilized platform is also being considered for gravity measurements at sea and several specialized navigational aids are being planned. A high degree of maneuverability is also considered necessary and a bow propulsion unit for maneuvering is being studied. Thus our current progress in oceanography is symbolized by improvements in the research fleet.

ATLANTIS

Cruise No.	Dates	Areas of Operation	Days	Chief Scientist
247	31 Jan.—7 June	Woods Hole—South Africa	107	Miller
	10 Jun.—23 Jul.	South Africa—Woods Hole	39	Munns
248	27 Jul.—22 Aug.	Boston—Yard	27	
249	29 Aug.—13 Sept.	International Oceanographic Congress	16	
250	22 Sept.—27 Oct.	Bermuda Area	27	Bunce
251	4 Nov.—2 Dec.	Blake Plateau	25	Stetson
252	9 Dec.—25 Dec.	Bermuda Area	28	Swallow

CHAIN

Cruise No.	Dates	Areas of Operation	Days	Chief Scientist
4	12 Jan.—15 Feb.	Bermuda—Nassau	40	Hersey
5	9 Mar.—25 Mar.	Bermuda Area	9	Hersey
6	27 Mar.—3 Apr.	Shipyard and Sea Trials	8	
7	8 Apr.—18 May	Woods Hole—Cadiz, Spain	32	Worthington
	19 May—12 Jul.	Mediterranean	56	Hersey
	15 Jul.—17 Aug.	Spain—Woods Hole	34	Hays
8	29 Aug.—17 Sept.	International Oceanographic Congress	5	
9	22 Sept.—26 Oct.	Bermuda Area	34	Hersey
10	9 Nov.—	Boston, Yard for inventory WHOI takeover and conversion		

CRAWFORD

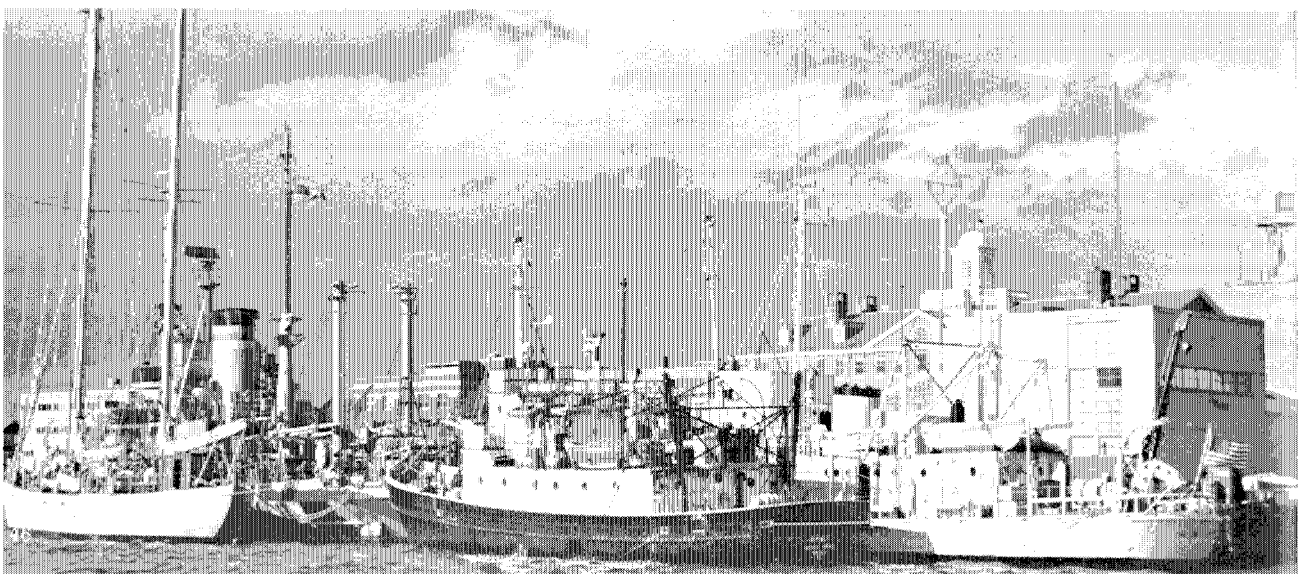
Cruise No.	Dates	Areas of Operation	Days	Chief Scientist
23	3 Feb.— 6 Feb.	Boston Yard	4	
24	25 Feb.—15 Mar.	Bermuda Area	17	Ryther, Curl, Ketchum
25	1 Apr.—21 Apr.	Boston Yard	21	
26	22 Apr.—24 Apr.	Shelf	3	Curl
27	18 May—28 May	Gulf Stream	9	Ketchum
28	10 Jun.—30 Jun.	Gulf Stream	19	Worthington, Bumpus
29	15 Jul.—30 Jul.	Shelf	16	Vine
30	4 Aug.— 7 Aug.	Shelf	4	Clarke
31	12 Aug.—18 Aug.	Shelf	7	Clarke
32	20 Aug.—25 Aug.	Shelf	6	Backus
33	21 Sept.—25 Sept.	Shelf	5	Bowen
34	6 Oct.—30 Oct.	Bermuda Area	22	Stommel
	5 Nov.—3 Dec.	Bermuda Area	25	Swallow
35	15 Dec.—20 Dec.	Bermuda—Woods Hole	6	Ketchum
36	23 Dec.—	Boston Yard		

ARIES

Cruise No.	Dates	Areas of Operation	Days	Chief Scientist
	19 Jan.—ARIES became property of WHOI at Bermuda.			
1	9 Mar.—16 Mar.	Bermuda—Woods Hole	8	
2	10 May—10 May	Local	1	Swallow
3	25 May—29 May	Fairhaven Yard	5	
4	4 Jun.—9 Jun.	Woods Hole—Bermuda	6	Swallow
5-16	20 Jun.—18 Nov.	Bermuda Area	103	Swallow
17-19	24 Nov.—13 Dec.	Bermuda Area	19	Volkmann
20	14 Dec.—	Bermuda, Yard		

BEAR

Cruise No.	Dates	Areas of Operation	Days	Chief Scientist
203-214	11 Feb.—1 May	Local	28	Frantz, Schevill, Day, Davis Fahlquist, Voorhis, Bunce
215	14 May—27 Jun.	North of Puerto Rico	42	Fahlquist
216-230	29 Jul.—18 Dec.	Local	67	Curl, Zeigler, Knott, Backus, Bunce, Voorhis, Athearn, Baxter, Conover
231	30 Dec.—	New Beford, wet storage		



The following persons were awarded grants, honoraria or fellowships during 1959:

WALTER H. ADEY	Massachusetts Institute of Technology
ROBERT A. BERNER	Harvard University
ESTEBAN BOLTOVSKOY	Servicio de Hidrografia Naval, Buenos Aires, Argentina
JOHN T. CONOVER	University of Texas
DENNIS J. CRISP	Marine Biological Station, University College of North Wales, Anglesey
PHILIP G. DRAZIN	Massachusetts Institute of Technology
ERIK ERIKSSON	Institute of Meteorology, University of Stockholm, Stockholm, Sweden
JOHN S. FARLOW, III	Johns Hopkins University
STIG FONSELIUS	Institute of Meterology, University of Stockholm, Stockholm, Sweden
ERNST FØYN	University of Oslo, Oslo, Norway
MICHAEL GARSTANG	Florida State University
IVAN C. GETTING	Harvard University
JOHN G. GILLE	Massachusetts Institute of Technology
EDWARD J. GREEN	Massachusetts Institute of Technology
STINA GRIPENBERG	Havforskingsinstitutet, Helsinki, Finland
DONALD J. HALL	University of Michigan
LOUIS N. HOWARD	Massachusetts Institute of Technology
SIDNEY HSIAO	Department of Zoology & Entomology, University of Hawaii, Honolulu, Hawaii
ROBERT H. KRAICHNAN	New York University
JOSEPH LEVINE	Massachusetts Institute of Technology
WILLIAM S. MADDUX	Rutgers University
DAVID A. MCGILL	Yale University
CHRISTIAN MYERS	George Washington High School, Alexandria, Virginia
GÖTE ÖSTLUND	Radioactive Dating Laboratory, Geological Survey of Sweden, Stockholm, Sweden
THOMAS O. PHILLIPS	Princeton University
ROBERT A. PHINNEY	Massachusetts Institute of Technology
JOHN E. G. RAYMONT	The University, Southampton, England
JOHN S. REITZEL	Harvard University
HERBERT RIEHL	University of Chicago
ALLAN R. ROBINSON	Harvard University
PHILIP SAFFMAN	Cambridge University, England
PETER M. SAUNDERS	Department of Meteorology, Imperial College of Science & Technology, London, England
VINCENT J. SCHAEFER	Munitalp Foundation, Schenectady, New York
DAVID H. SHONTING	Massachusetts Institute of Technology
THEODORE J. SMAYDA	University of Rhode Island
EDWARD A. SPEIGEL	University of California
EDWARD D. STROUP	Johns Hopkins University
LYNN R. SYKES	Massachusetts Institute of Technology
B. SAMUEL TANENBAUM	Yale University
AARNO VOIPIO	Havforskingsinstitutet, Helsinki, Finland
THOMAS F. WEBSTER	Massachusetts Institute of Technology
TORBIN WOLFF	Universitets Zoologiske Museum, Copenhagen, Denmark
GEORG WÜST	Institute für Meereskunde, Kiel, Germany

VISITORS

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

Masateru Anraku	Faculty of Fisheries, Hokkaido University, Hokkaido, Japan
Moshe A. Avnimelech	Department of Geology, Hebrew University, Jerusalem, Israel
Esteban Boltovskoy	Servicio de Hidrographia Naval, Buenos Aires, Argentina
Francis Bernard	Zoologie Génerâle, Faculté des Sciences, Université d'Alger, Algiers, Algeria
Michelle F. Bernard	Zoologie Génerâle, Faculté des Sciences, Université d'Alger, Algiers, Algeria
Bert Bolin	International Meteorological Institute, Stockholm, Sweden
W. Brandhorst	Estacion de Biologia Marina, Universidad de Chile, Vina del Mar, Chile
J. D. Bromhall	Fisheries Research Unit, University of Hong Kong, Hong Kong, B.C.C.
Margarethe Brongersma-Sanders	Geologisch-Meteorologisch Laboratorium, Rijksuniversiteit te Leiden, Netherlands
Neil L. Brown	Commonwealth Scientific and Industrial Research Organization, Cronulla, Australia
H. O. Bull	Dove Marine Laboratory, Cullercoats, Northumberland, Great Britain
Tso-You Chu	National Taiwan University, Taiwan, National China
Carl W. Correns	Sedimentpetrographisches Institut, Göttingen, Germany
James Crease	National Institute of Oceanography, England
Dennis J. Crisp	Marine Biological Station, University College of North Wales, Anglesey
A. DeMaio	Istituto Universitario Naval Napoli, Naples, Italy
Ingvar Emilsson	Instituto Oceanografico, Universidade de Sao Paulo, Sao Paulo, Brasil
Erik Eriksson	Institute of Meteorology, Stockholm, Sweden
Stig Fonselius	Institute of Meteorology, Stockholm, Sweden
Ernst Føyn	University of Oslo, Oslo, Norway
Roland S. Glover	Oceanographic Laboratory, Scottish Marine Biological Association, Edinburgh, Scotland
Stina Gripenberg	Havforskningsinstitutet, Helsinki, Finland
Masayoshi A. Hatanaka	Tohôku University, Japan
Shoitiro Hayami	Geophysical Institute, Kyoto University, Japan
Hildegard Hass	Sedimentpetrographisches Institut, Göttingen, Germany
M. N. Hill	Department of Geodesy and Geophysics, Cambridge University, Great Britain

George F. Humphrey	Commonwealth Scientific and Industrial Research Organization, Cronulla, Australia
S. Ishiguro	Nagasaki Marine Observatory, Japan
Hideo Iwasaki	Tohôku University, Japan
Wolfgang Krauss	Institut für Meereskunde der Universität, Kiel, Germany
Anna M. Mani	Instrument Division, Meteorological Service of India
Maurice Menaché	Chef, Service Central d'Océanographic Physique, Office de la Recherche Scientifique et Technique Outre Mer, Paris, France
Sigeru D. Motoda	Faculty of Fisheries, Hokkaido University, Hokkaido, Japan
Masito Nakano	Meteorological Research Institute, Tokyo, Japan
Kurt W. Ockelmann	Marine Biological Laboratory, Helsingör, Denmark
Göte Östlund	Radioactive Dating Laboratory, Geological Survey of Sweden, Stockholm, Sweden
Ramon L. Perez-Mena	Ministry of Mines, Venezuela
H. Postma	Zoologisch Station, Den Helder, Holland
Claës G. H. Rooth	Institute of Meteorology, Stockholm, Sweden
Tadayoshi Sasaki	Scientific Research Institution, Tokyo, Japan
Peter M. Saunders	Department of Meteorology, Imperial College of Science and Technology, London, England
Hellmuth A. Sievers	Departamento de Navegacion e Hidrografia de la Armada, Valparaiso, Chile
Jens Smed	Bureau du Conseil International pour l'Exploration de la Mer, Charlottenlund Slot, Charlottenlund, Denmark
C. C. Stavropoulos	South African Council for Scientific and Industrial Research, Union of South Africa
Bernard Saint-Guily	Centre National de la Recherche Scientifique au Museum, Paris, France
Unnstein Stefansson	Fisheries Research Institute, Reykjavik, Iceland
John C. Swallow	National Institute of Oceanography, England
Paul Tchernia	Laboratoire d'Océanographie Physique au Museum, Paris, France
J. Verwey	Zoologisch Station, Buitenhaven 27, Den Helder, Holland
Aarno Voipio	Havforskningsinstitutet, Helsinki, Finland
K. H. Wedepohl	Sedimentpetrographisches Institut, Göttingen, Germany
John D. H. Wiseman	British Museum (N. H.) London, England
Torben Wolff	Universtets Zoologiske Museum, Copenhagen, Denmark
Georg Wüst	Institut für Meereskunde, Kiel, Germany

EMPLOYEES AND STAFF

The following personnel were in the employ of the Institution for the twelve-month period ending December 31, 1959.

Ethel B. Allen
Norman T. Allen
Nellie E. Anderson
Herbert A. Ashmore
William D. Athearn
Cyril Backus
Harold Backus
Jeanne M. Backus
Richard H. Backus
Rose L. Barbour
Joseph R. Barrett, Jr.
Elmer M. Barstow
Martin R. Bartlett
Lincoln Baxter, II
Edward R. Baylor
Henry G. Behrens
James S. Bercaw
Stanley W. Bergstrom
Robert Betterley
Duncan C. Blanchard
Ralph H. Bodman
George H. Boltz
Jane B. Boltz
Vaughan T. Bowen
Warren O. Bowman
Mabel D. Bradley
Alvin L. Bradshaw
Winfield S. Bray
Robert R. Brockhurst
Joseph C. Brown
Margaret Brown
John G. Bruce, Jr.
Kirk Bryan, Jr.
Edwin T. Bryant
John Q. Bumer
Dean F. Bumpus
Elizabeth T. Bunce
Andrew F. Bunker
Charles A. Burnham
John P. Cabral
John V. Cabral
Henry A. Cain
Sybil A. Campbell
Angelo Cangiamila
Ruth H. E. Carlson
Henri L. Caron
Alwyn L. Carter
David F. Casiles
James J. Cavanaugh
Constance W. Chadwick
Margaret A. Chaffee
Agnes C. Chalmers
Joseph Chase
John A. Christian
Edward H. Chute
David B. Clarke
George L. Clarke
William H. Clarkin
Arthur D. Colburn, Jr.
John W. Condon
William J. Conley
Robert J. Conover
Hans Cook
Nathaniel Corwin
Jerome M. Cotter
Brooks W. Coughlin
Marion W. Crocker
Porter A. Crouse
Elizabeth L. Curl
Herbert C. Curl, Jr.
Lee C. Davis
C. Godfrey Day
Joseph V. Day
Charles D. Densmore
Richard H. Dimmock
Willard Dow
William M. Dunkle, Jr.
Richard S. Edwards
Stanley N. Eldridge
Davis A. Fahlquist
Alan J. Faller
Harlow G. Farmer
Gregory Farnum
Sandra K. Ferguson
Alice H. Ferris
George A. Ferris
Frederick E. Fielden
Stanley O. Fisher
Richard A. Fitzgerald
Donald B. Foster
David H. Frantz
John G. Fraser
Frederick C. Fuglister
Paul M. Fye
Gloria S. Gallagher
Rosemary Gallagher
William F. Gallagher
Michael Garstang
Fred Gaskell
John W. Gates
Lambert C. Gates
Graham S. Giese
James E. Gifford
Barbara L. Gill
Norman Gingrass
Florence E. Glaeser
John W. Graham
Carlton W. Grant
Robert R. L. Guillard
Jan Hahn
Peter A. Hall
James E. Hanks
Kaleroy L. Hatzikon
Carlyle R. Hayes
Earl E. Hays
Helen C. Hays
John B. Hersey
George L. Hilton
Lloyd D. Hoadley
Harry L. Hodgkins
Sloat F. Hodgson
Alfred Hoffman
Roy Holmes
Paul M. Howe
Myron P. Howland, Jr.
Paul C. Howland
Edward M. Hulburt
Otis E. Hunt
Charles S. Innis, Jr.
Columbus O'D. Iselin
Delmar R. Jenkins
Alfred C. John
Barbara R. Johnson
Henry R. Johnson
Yolande A. Kahler
John W. Kanwisher
Willard E. Ketchen
Bostwick H. Ketchum
David D. Ketchum
Sydney T. Knott, Jr.
John A. Kostrzewa

Joseph L. Lambert
Anne E. Langenheim
Delia M. Lavin
Richard G. Leahy
Joseph Levine
Joyce C. Lewin
Robert R. Longyear
Thomas Lyon
Harvey MacKillop
Duane E. Maddux
Joanne S. Malkus
Willem V. R. Malkus
Ann Martin
George E. Martin
Frank J. Mather, III
Francis S. Matthews
Clement L. McCann, Jr.
Margaret E. McCloskey
Eileen M. McCormack
Joseph M. McElliott
John McGilvray
Florence K. Mellor
William G. Metcalf
Arthur R. Miller
Francis Minot
Juanita A. Mogardo
Wendell A. Mordy
Clayton B. Morehouse
Kenneth Morrison
Joseph C. Motta
Robert G. Munns
Eugene J. Mysona
A. Conrad Neumann
James S. Nicholson
Alice B. Nilsson
Mary Ortolani
Betty P. Ostiguy
David M. Owen
Michael Palmieri, Jr.
Gale G. Pasley, Jr.
Helen F. Phillips
Samuel F. Pierce
John F. Pike
John M. Pimental
Stanley E. Poole
Richard M. Pratt
William S. Richardson
Helen M. Roberts
Henry A. Rogers, Jr.
Mary D. Rogers
F. Claude Ronne
Nicholas A. Rosa
Lawrence Rose
John H. Ryther
James E. Salthouse
John D. Sandblom
Howard L. Sanders
Harold E. Sawyer
William E. Schevill
John L. Schilling
Karl E. Schleicher
Elizabeth H. Schroeder
William C. Schroeder
Mary Sears
Harry H. Seibert
Arnold G. Sharp
William J. Shields
William S. Shultz
Raymond Siever
Luther V. Slabaugh
Eloise M. Soderland
Otto Solberg
James H. Souza
Thomas A. Souza
Elizabeth C. Sparks
Allard T. Spencer
Charles E. Spooner
Robert J. Stanley
Richard Stansfield
Melvin E. Stern
Thomas R. Stetson
Raymond G. Stevens
Stephen L. Stillman
John W. Stimpson
Paul B. Stimson
Henry M. Stommel
Thomas T. Sugihara
Thomas O. L. Sutcliffe
Herman Tasha
Louis J. Tometich
Wendell K. Tripp
Harry J. Turner, Jr.
Ralph F. Vaccaro
Ronald A. Veeder
George Veronis
Allyn C. Vine
Gordon H. Volkmann
William S. von Arx
Carl R. von Dannenberg
Arthur D. Voorhis
Robert G. Walden
Jean D. Walker
William A. Watkins
Margaret E. Watson
Stanley W. Watson
Robert G. Weeks
Geoffrey G. Whitney, Jr.
Phillips B. Wilde
Charles H. Wilkins
George A. Williams
Edward Wilson
Esther N. Wilson
Asa S. Wing
Carleton R. Wing
Warren E. Witzell
Alfred H. Woodcock
Fred C. Woodward, Jr.
L. Valentine Worthington
Charles S. Yentsch
Javan D. York
John M. Zeigler

It should be noted that Dr. Max Blumer, an organic chemist, arrived in Woods Hole on 9 November 1959 to join the group working in geochemistry.

PUBLICATIONS

During 1959, sixty-three papers bearing contribution numbers were published. See Author, Subject-Locality, Taxonomic Index published in 1957 for a complete list through 1956.

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No. 872 P. F. SCHOLANDER and JOHN KROG. Countercurrent Heat Exchange and Vascular Bundles in Sloths. (Published in 1957). *Jour. Applied Physiol.*, Vol. 10, No. 3, pp. 405-411. 1957. (Not included in *Collected Reprints*).

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No. 947 WILLIAM C. SCHROEDER. The Lobster, *Homarus americanus*, and the Red Crab, *Geryon quinquedens*, in the Offshore Waters of the Western North Atlantic. *Deep-Sea Research*, Vol. 5, pp. 266-282. 1959.

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No. 950 H. BARNES and MARGARET BARNES. A Comparison of the Annual Growth Patterns of *Balanus balanoides* (L.) with Particular Reference to the Effect of Food and Temperature. *Oikos*, Vol. 10, No. 1, pp. 1-18. 1959.

No. 954 BERNHARD HAURWITZ, HENRY STOMMEL and WALTER H. MUNK. On the Thermal Unrest in the Ocean. In: The Atmosphere and the Sea in Motion (The Rossby Memorial Volume), pp. 74-94. Rockefeller Institute Press, New York. 1959.

No. 956 JOHN M. ZEIGLER, CARLYLE R. HAYES and SHERWOOD D. TUTTLE. Beach Changes during Storms on Outer Cape Cod, Massachusetts. *Jour. Geology*, Vol. 67, No. 3, pp. 318-336. 1959.

No. 961 ROBERT H. GIBBS, JR., and BRUCE B. COLLETTE. On the Identification, Distribution, and Biology of the Dolphins, *Coryphaena hippurus* and *C. equiselis*. *Bull. Mar. Sci. Gulf and Carib.*, Vol. 9, No. 2, pp. 117-152. 1959.

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No. 964 THEODORE J. SMAYDA. The Seasonal Incoming Radiation in Norwegian and Arctic Waters, and Indirect Methods of Measurement. *Jour. du Conseil*, Vol. 24, No. 2, pp. 215-220. 1959.

No. 967 JOANNE S. MALKUS and GEORG WITT. The Evolution of a Convective Element: A Numerical Calculation. In: The Atmosphere and the Sea in Motion (The Rossby Memorial Volume), pp. 425-439. Rockefeller Institute Press, New York. 1959.

No. 971 FRANCES L. PARKER and WILLIAM D. ATHEARN. Ecology of Marsh Foraminifera in Poponesset Bay, Massachusetts. *Journ. Paleont.*, Vol. 33, No. 2, pp. 333-343. 1959.

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No. 975 JACK MCLACHLAN and GUY C. MCLEOD. The Use of Conversion Factors for the Determination of the Concentration of Nutrients in Culture Media. *Limnol. and Oceanogr.,* Vol. 4, No. 2, pp. 218-219. 1959.

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No. 987 ALAN J. FALLER and WILLIAM S. VON ARX. The Modeling of Fluid Flow on a Planetary Scale. *Proceedings of the Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research,* pp. 53-72. 1959.

No. 988 JOHN M. ZEIGLER. Origin of the Sea Islands of the Southeastern United States. *Geogr. Rev.,* Vol. 49, No. 2, pp. 221-237. 1959.

No. 989 MALCOLM S. GORDON. Ionic Regulation in the Brown Trout *(Salmo trutta L.)*. *Jour. Exper. Biol.,* Vol. 36, No. 2, pp. 227-252. 1959.

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No. 996 EDWARD R. BAYLOR. The Responses of Snails to Polarized Light. *Jour. Exper. Biol.,* Vol. 36, No. 2, pp. 369-376. 1959.

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No. 999 C. B. OFFICER, J. I. EWING, J. F. HENNION, D. G. HARKRIDER and D. E. MILLER. Geophysical Investigations in the Eastern Caribbean: Summary of 1955 and 1956 Cruises. In: Physics and Chemistry of the Earth, Vol. 3, pp. 17-109. Pergamon Press, New York. 1959.

No. 1002 HARRY J. TURNER, JR. and JAMES E. HANKS. Infestation of *Pecten irradians* by *Polydora. The Nautilus,* Vol. 72, No. 4, pp. 109-111. 1959.

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No. 1008 Henry Stommel. Florida Straits Transports: June 1956 — July 1958. *Bull. Mar. Sci. Gulf and Carib.,* Vol. 9, No. 2, pp. 222-223. 1959.

No. 1010 Jack McLachlan and Charles S. Yentsch. Observations on the Growth of *Dunaliella euchlora* in Culture. *Biol. Bull.,* Vol. 116, No. 3, pp. 461-471. 1959.

No. 1011 John W. Graham. Metabolically Induced Precipitation of Trace Elements from Sea Water. *Science,* Vol. 129, No. 3360, pp. 1428-1429. 1959.

No. 1012 Joseph Levine. Spherical Vortex Theory of Bubble-Like Motion in Cumulus Clouds. *Jour. Meteorol.,* Vol. 16, No. 6, pp. 653-662. 1959.

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No. 1014 John Kanwisher. Polarographic Oxygen Electrode. *Limnol. and Oceanogr.,* Vol. 4, No. 2, pp. 210-217. 1959.

No. 1015 L. V. Worthington. The 18° Water in the Sargasso Sea. *Deep-Sea Research,* Vol. 5, pp. 297-305. 1959.

No. 1016 John H. Ryther. Potential Productivity of the Sea. *Science,* Vol. 130, No. 3376, pp. 602-608. 1959.

No. 1017 John W. Graham and Susan C. Cooper. Biological Origin of Manganese-rich Deposits of the Sea Floor. *Nature,* Vol. 183, pp. 1050-1051. 1959.

No. 1019 George L. Clarke and Charles J. Hubbard. Quantitative Records of the Luminescent Flashing of Oceanic Animals at Great Depths. *Limnol. and Oceanogr.,* Vol. 4, No. 2, pp. 163-180. 1959.

No. 1020 Richard Barakat. A Note on the Transient Stage of the Random Dispersal of Logistic Populations. *Bull. Math. Biophysics,* Vol. 21, pp. 141-151. 1959.

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No. 1026 JOHN H. RYTHER and R. R. L. GUILLARD. Enrichment Experiments as a Means of Studying Nutrients Limiting to Phytoplankton Production. *Deep-Sea Research,* Vol. 6, pp. 65-69. 1959.

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No. 1029 IRVING I. SCHELL. On a Criterion of Representativeness of Sea Surface Temperature Data. *Bull. Amer. Meteorol. Soc.,* Vol. 40, No. 11, pp. 571-574. 1959.

No. 1030 J. S. HART and LAURENCE IRVING. The Energetics of Harbor Seals in Air and in Water with Special Consideration of Seasonal Changes. *Canad. Jour. Zool.,* Vol. 37, pp. 447-457. 1959.

No. 1032 JOSEPH CHASE. Wind-Induced Changes in the Water Column along the East Coast of the United States. *Jour. Geophys. Res.,* Vol. 64, No. 8, pp. 1013-1022. 1959.

No. 1036 E-AN ZEN. Mineralogy and Petrography of Marine Bottom Sediment Samples off the Coast of Peru and Chile. *Jour. Sed. Petrol.,* Vol. 29, No. 4, pp. 513-539. 1959.

No. 1037 H. BARNES and MARGARET BARNES. Note on Stimulation of Cirripede Nauplii. *Oikos,* Vol. 10, No. 1, pp. 19-23. 1959.

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No. 1047 DAVID A. MCGILL, NATHANIEL CORWIN, and BOSTWICK H. KETCHUM. The Temperature Correction of Oceanic Inorganic Phosphorus Analyses. *Deep-Sea Research,* Vol. 6, pp. 60-64. 1959.

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No. 1060 KARL E. SCHLEICHER. A Note on the Constancy of the T/S Relationship in a Water Mass. *Deutsche Hydrogr. Zeitschr.,* Vol. 12, No. 3 (Ergänzungsheft Reihe B (4°)), pp. 46-48. 1959.

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TREASURER'S REPORT
FOR THE YEAR 1959

The accounts for the year 1959 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds at December 31, 1959 was \$3,400,922 of which \$96,191 represented accumulated net gains from sales of investments. The market value of endowment assets on the same date, including real estate at book amount, was \$5,150,329. Endowment fund investments and income received therefrom are summarized in Schedule D.

Income received on endowment assets was \$188,639 for the year ended December 31, 1959, compared with \$178,607 the previous year. Included in endowment income was \$6,420 of real estate income representing a 5% return on this investment. The balance of real estate income, \$7,949, was transferred to endowment assets to amortize cost of property. Endowment income represented a return on endowment fund assets of 3.7% at year-end market quotation, 5.5% on the book amount and 7.7% on the contributed amount of the endowment fund.

Endowment income was allocated for 1959 operating expenses at the rate of 5.5% of the book amount of original endowment funds, or \$133,131. Of the balance of endowment income, \$55,508, there was transferred to the income and salary stabilization reserve \$54,683 and to unexpended balance of gifts from Oceanographic Associates as income from investment of life memberships \$825.

A general review with our auditors of our method of accounting for plant items on the balance sheet has resulted in the institution of certain changes in the balance sheet presentation. These changes are detailed in the note on page 59 following the balance sheet. We believe these changes result in a balance sheet that more accurately reflects the funds invested in plant and the cash properly allocable to plant funds.

The details of unexpended balance 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 \$60,273, plus \$2,380 net rebate of real estate taxes paid in 1956. Expenditures and allocations to specific projects amounted to \$12,563, increasing the balance on hand from \$89,918 at December 31, 1958 to \$140,008 at December 31, 1959.

The Institution's 1959 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to \$83,871. The trust is administered by three trustees. The balance of the old Retirement Fund, administered by the Treasurer, amounted to $70,438 as at December 31, 1959. 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 1959. Interest totalling $2,297 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 79.7 cents was spent for direct costs of research activity, 14.1 cents for general and administration expenses and 6.2 cents for plant operation and miscellaneous. Administrative salaries amounted to only 5.4 cents of each dollar of total expense. Included in the 14.1 cents of general and administration expenses was 3.3 cents for staff benefits (group insurance, social security taxes, and contributions to retirement plan).

LYBRAND, ROSS BROS. & MONTGOMERY
ACCOUNTANTS AND AUDITORS

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1959 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, 1959 and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

Boston, Massachusetts
April 8, 1960

Lybrand, Ross Bros. & Montgomery

BALANCE SHEET *As at December 31, 1959*

ASSETS

Endowment fund assets:			
Investments (Schedule D):			
Bonds (market quotations $1,703,716)		$1,836,255	
Stocks (market quotations $3,290,728)		1,408,782	
Real estate		120,470	
		3,365,507	
Cash		35,415	
		3,400,922	
Plant fund assets (note B):			
Laboratory plant and equipment		707,841	
Vessels and equipment		812,998	
Other property		161,541	
Total plant		1,682,380	
Advance to current funds		62,011	
		1,744,391	
Current fund assets:			
Cash		374,628	
Marketable security		246	
Accounts receivable:			
U. S. Government	$168,745		
Other	17,971	186,716	
Unbilled costs on research contracts:			
U. S. Government	620,155		
Other	50,805	670,960	
Supply inventories		28,967	
Deferred charges		32,046	
		1,293,563	
Less advance from plant funds		62,011	
		1,231,552	
		$6,376,865	

LIABILITIES

Endowment Funds:		
Unrestricted		$2,017,311
For upkeep of plant		419,420
Henry Bryant Bigelow Chair of Oceanography		2,000
Accumulated net gain on sale of investments		962,191
		3,400,922
Plant funds:		
Invested in plant		1,682,380
Unexpended:		
Fund for purchase and reconditioning of boat Aries		4,306
General plant and equipment reserve (note A)		57,705
		1,744,391
Current liabilities and funds:		
Accounts payable and accrued expenses		208,039
Contribution payable to employees' retirement plan and trust		83,871
Unexpended balances of gifts and grants for research:		
Government	$466,639	
Other (Schedule C)	163,265	629,904
General fund:		
Income and salary stabilization reserve	266,082	
Unappropriated	43,656	309,738
		1,231,552
		$6,376,865

The appended notes are an integral part of this balance sheet.

NOTES TO BALANCE SHEET

For the Year Ended December 31, 1959

A — General plant and equipment reserve was reclassified in 1959 from current funds. Changes in this fund were as follows:

Balance January 1, 1959		$244,084
Additions to reserve:		
Depreciation and amortization charged to operating expenses:		
In 1959		64,563
In prior years (credited directly to asset accounts in those years)		54,017
Proceeds from sale of Caryn in 1958 tranferred from fund for purchase and reconditioning of boat Aries		16,000
		378,664
Charges against reserve:		
Amount added to plant fund assets in 1959:		
Costs of Crawford reconditioning:		
Prior years	$238,274	
1959	9,985	
Cost of electronic equipment purchased in 1957	31,055	
Cost of Helio aircraft purchased in 1959	41,645	320,959
Balance December 31, 1959		$ 57,705

B — 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, 1959

Income:		
Receipts for sponsored research:		
For direct costs		$2,919,804
For indirect costs		692,791
Fees for use of facilities		98,166
		3,710,761
Endowment income (Schedule D)	$188,639	
Less amounts added to income and salary stabilization reserve ($54,683) and unexpended balance of gifts from Oceanographic Associates as income from investment of life memberships ($825)	55,508	133,131
Miscellaneous		17,433
Total income availed of		3,861,325
Operating expenses:		
Direct costs of research activity (Schedule A):		
Salaries and wages		1,125,539
Vessel operations		738,304
Materials and services		1,032,756
Travel		135,290
		3,031,889
Indirect costs:		
General and administration (Schedule B)	536,012	
Plant operation (Schedule B)	222,403	
Miscellaneous	11,717	770,132
Total operating expenses		3,802,021
Excess of income		59,304
Additions to plant from current funds — books and equipment purchased		36,766
		22,538
Unappropriated general fund, January 1, 1959		21,118
Unappropriated general fund, December 31, 1959		$ 43,656

SCHEDULE A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1959

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. Government contracts	$1,057,926	$715,685	$ 956,413	$127,146	$2,857,170
Other sponsored research	23,028	670	35,269	3,667	62,634
Total direct costs of sponsored research.	1,080,954	716,355	991,682	130,813	2,919,804
Institution research	44,585	21,949	41,074	4,477	112,085
Total direct costs of **research**	$1,125,539	$738,304	$1,032,756*	$135,290	$3,031,889

* Includes grants and fellowships:

U.S. Government contracts	$ 11,025
Other sponsored research	8,750
Institution research	22,531
	$42,306

SCHEDULE B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1959

GENERAL AND ADMINISTRATION		
General expenses:		
Staff benefits:		
Contributions to retirement plan		$ 83,871
Social security taxes		35,079
Group insurance		5,859
		124,809
Shop services		102,814
Housing, net		5,720
Administration expenses:		
Salaries and wages	$205,326	
Insurance, travel, supplies and other	97,343	302,669
		$536,012
PLANT OPERATION		
Salaries and wages		51,234
Provision for depreciation (credited to general plant and equipment reserve)		44,068
Other repair costs	25,695	
Heat, light and power	22,656	
Vessel design studies	57,452	
Other	21,298	127,101
		$222,403

SCHEDULE C

SUMMARY OF GIFTS AND RECEIPTS FOR RESEARCH

For the Year Ended December 31, 1959

	Unexpended Balance January 1, 1959	Received	Expended Direct Costs	Expended Indirect Costs	Other Charges or (Credits)	Unexpended Balance December 31, 1959
Bermuda Biological Station for Research		$ 12,839	$12,258	$ 581		
Commonwealth of Massachusetts — shellfish propagation		9,857	5,753	4,104		
Manufacture, sale, and calibration of instruments		22,762	23,697	7,970	($7,470) (a) (1,435) (b)	
Lou Marron science fund — pelagic fish studies	$ 386	500	886			
Massachusetts Institute of Technology — Institute for Atmospheric Research		2,713	1,917	796		
National Academy of Sciences — project Nobska		40	40			
Oceanographic Associates:						
Deuterium studies	51	1,000	645	236		$ 170
Fellowships		8,750	8,750			
Unappropriated	89,918	60,273 (9,750)			2,813 (c) (2,380) (d)	140,008
Research Corporation — instrument fund	2,687				(400) (e)	3,087
Sundry work for others		7,397	6,803	594		
Towns of Brookhaven and Islip, New York — Great South Bay survey	783	2,000	1,885	898		
Other gifts	5,000	15,000				20,000
	$98,825	$133,381	$62,634	$15,179	($8,872)	$163,265

(a) Charged to income.
(b) charged to other projects.
(c) Miscellaneous expenditures.
(d) Net rebate of real estate taxes paid in 1956.
(e) Sale of equipment.

SCHEDULE D

SUMMARY OF INVESTMENTS

As at December 31, 1959

	Book Amount	% of Total	Market Quotation	% of Total	Endowment Income
Bonds:					
U. S. Government	$ 460,615	13.69	$ 447,329	8.75	$ 10,323
Railroad	479,718	14.25	425,064	8.31	20,146
Public utility	392,368	11.66	360,197	7.04	17,499
Industrial	348,587	10.36	312,213	6.10	14,527
Financial and investment	154,967	4.60	158,913	3.11	8,305
Total bonds	1,836,255	54.56	1,703,716	33.31	70,800
Stocks:					
Preferred	252,508	7.50	223,363	4.37	12,470
Common:					
Public utility	371,138	11.03	846,028	16.54	26,833
Industrial	594,041	17.65	1,832,870	35.83	57,448
Miscellaneous	191,095	5.68	388,467	7.59	14,668
Total common stocks	1,156,274	34.36	3,067,365	59.96	98,949
Total stocks	1,408,782	41.86	3,290,728	64.33	111,419
Real estate	120,470	3.58	120,470*	2.36	6,420
Total investments .	$3,365,507	100.00	$5,114,914	100.00	$188.639

* At book amount.