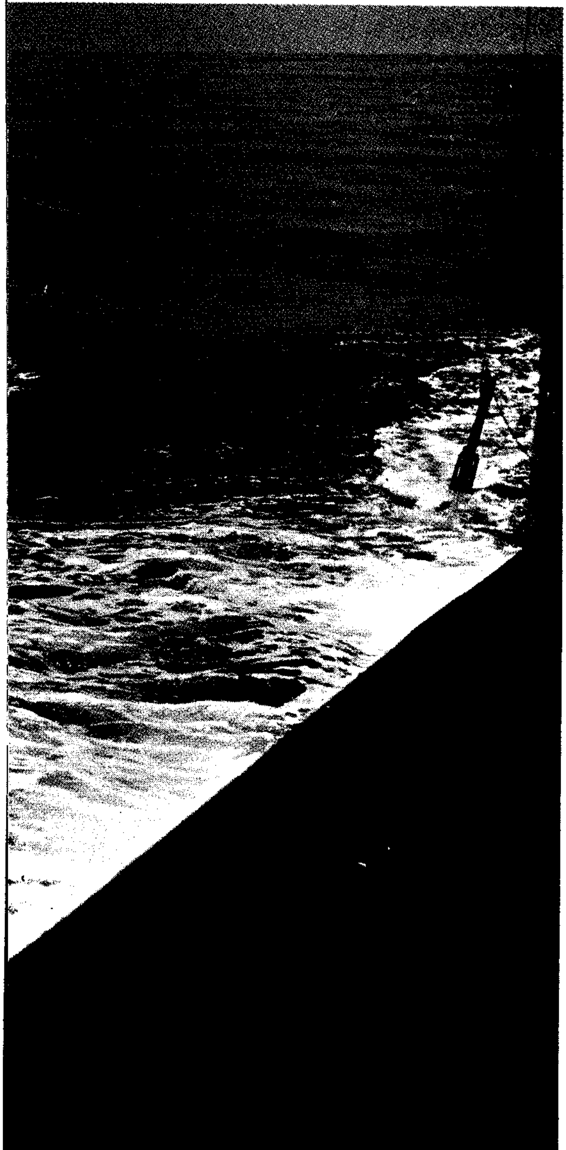

WOODS HOLE • MASSACHUSETTS

THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

CONTENTS

TRUSTEES

As of 31 December 1961

TRUSTEES

EDWARD HANSON SMITH

29 October 1889
29 October 1961

Rear Admiral Edward H. Smith, U.S.C.G. (ret.), the third director of the Institution (1950-1956), was born on Martha's Vineyard with the sea in his blood and with a craving for knowledge about the sea. He was graduated from what is now the Coast Guard Academy in 1914 and a few years later had an opportunity to serve with the International Ice Patrol. It was then that he came to know the Scientific Advisor to the Ice Patrol, Henry B. Bigelow. In the off season, while writing patrol reports, he studied at Harvard University with Dr. Bigelow. On completing his master's degree at Harvard (1924), he studied at the Geofysisk Institutt in Bergen, Norway, with Professor Bjorn Helland-Hansen, who with J. W. Sandström had advanced the method for computing dynamic currents. It was this work that laid the foundation for the present scientific approach of the Ice Patrol.

To learn more about icebergs, he went with the MARION as far as 70° North, then was assigned to Woods Hole in 1933 to command Base 18 on the site of the present aquarium of the U. S. Fish & Wildlife Service. When the base was decommissioned the next year, he remained in Falmouth to write the well-known MARION report which became his doctor's thesis (Harvard, 1934).

Although duty took him elsewhere, he never lost interest in oceanography and in the new Institution established in Woods Hole in 1930. It was therefore most fitting that in 1945 he was elected a Member of the Corporation and a Trustee, a post he held until becoming an Honorary Trustee in 1961. No one had a better background, through training and association with the traditions of Woods Hole, than Admiral Smith when he was elected director. During his term of office the Institution started its permanent growth. The Laboratory of Oceanography was built, the CRAWFORD was acquired and the Institution assumed responsibility for the educational aspects of oceanography. In short, the modernization of the Institution was begun and well established under his leadership.

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DIRECTOR'S REPORT

REVIEW

With the great surge of interest in oceanography in recent years it became apparent that the Institution should augment its long-standing program for the training of interested young people in the various branches of marine science. To this end, three years ago we re-examined our educational policies in some detail. It seems appropriate to devote this portion of our annual report to this important aspect of our work.

Education and research have gone hand in hand at the Institution since it was established. From 1930 through 1958 a total of 320 fellowships had been awarded. In the three-year period since 1958 we have accelerated this part of our educational program and have awarded 141 fellowships. Fortunately, the budget for this purpose has grown markedly — about fourfold — during this period and increased stipends have permitted us to select outstanding students in spite of the increasing competition for the best.

In addition to augmenting our fellowship program, we have improved our educational opportunities through the expansion of our university affiliations, both by continuing to have university faculty members on our staff and, more importantly, by obtaining part-time faculty appointments for Institution staff members. At present 15 of our senior staff hold faculty appointments at 8 universities.

We believe that an oceanographic career is best approached by way of thorough academic training in any one of the basic scientific disciplines, with concentration on the marine aspects of that discipline beginning at the time actual research is started. This opinion is based on the interdisciplinary nature of oceanography and on the research performance and leadership in the field by many scientists with various educational backgrounds. In keeping with this point of view the Institution has traditionally organized its educational activities toward three overlapping purposes: promoting interest in marine research at all academic levels; helping academic institutions to maintain teachers with marine interests on their faculties; and using our own staff and facilities to provide specific educational opportunities not available within the academic framework.

Although these purposes are pursued throughout the year, the greatest activity at Woods Hole naturally occurs during the summer when students and teachers from other institutions have the time to make use of our laboratories and shops, our research vessels and workboats, and the incomparable library we share with the Marine Biological Laboratory. In 1961, for example, there were 146 summer additions to our year-round roll, including 24 student fellows, eight postdoctoral fellows, 21 visiting investigators and 93 students with jobs in the laboratories or at sea. Of this last category, all but three were high school graduates and 39 held bachelor's or advanced degrees. An invasion of this sort, representing nearly a 40 per cent increase in our work force, inevitably puts a strain on our physical plant, but we have always managed to find or create the necessary laboratory space. In recent years the extra scientific berths aboard the CHAIN have made it possible for many budding oceanographers — as well as a number of senior university people — to get a taste of science at sea. Needless to say, summer at the Institution is a challenging and stimulating experience, for hosts and guests alike.

For the past several summers we have offered special courses as well as research opportunities. Since 1952 we have cooperated with the Marine Biological Laboratory in presenting a course in Marine Ecology. More recently, with the financial sponsorship of the National Science Foundation, we have given a summer course in Geophysical Fluid Dynamics. The course includes both lectures and original research. It has attracted considerable national and international interest. Last year there were 19 participants from outside the Institution, including six from European countries, two from Canada, one from India and one from South Africa.

A third course was initiated in 1961 on an experimental basis, largely as a response to a growing demand from universities which teach oceanography but have no sea-going ships. The new course, entitled Observational Physical Oceanography, offers a combination of classroom and field experience. Six students took part during the first year, five of them on fellowships. A series of introductory lectures was followed by a cruise on the CHAIN, after which the students worked up their own data under the supervision of staff oceanographers. The course was quite successful and is being continued. It is our hope eventually to develop similar courses in other areas of our interest, specifically biology, geology and chemistry, and to assign the ATLANTIS to this training program.

The Institution's contribution to education on a year-round basis takes a number of forms. In 1961, nine graduate students were engaged in full time research leading toward doctoral dissertations; three received their degrees during the year. In addition we awarded five year-round postdoctoral fellowships. The recipient of one of these has since joined our staff, indicating the mutual advantages of such a program. In addition, we participate in two continuing seminar programs: the Massachusetts Institute of Technology — Woods Hole Oceanographic Institution Seminar in Thermal Convection which meets once a month at each Institution, and our Monday night Journal Club sessions where papers are presented on the entire spectrum of the marine sciences.

We are also providing more formal opportunities for the continuing education of our own staff. An in-service course in mathematics has been conducted for several years and courses in other subjects, notably foreign languages, have been presented from time to time. Each year the Institution loses a sizable number of employees who return to college, from beginning freshmen to senior investigators whose research needs have spurred them to fill specific educational gaps. Many of these individuals receive support from the Institution's fellowship program. The Institution also encourages employees wishing to further their education by means of university extension courses.

Continued enhancement of the educational opportunities at Woods Hole is imperative as both the Institution and the field of oceanography continue to grow. The impact of our educational program is complex to assess. However, in following up on the summer fellows of one recent year, we have found that more than three out of four are continuing in marine studies. This represents the true rewards of the planning and effort that have gone into this aspect of our work.

RESEARCH

Physical Oceanography

The Romanche Trench. One of the most fruitful cruises of 1961 was a three-and-a-half-month trip by the CHAIN to the eastern equatorial Atlantic in the vicinity of the Romanche Trench. The cruise was divided into three legs, interrupted by stops at Freetown, Sierra Leone. There were some changes in the scientific party between legs; in all, 29 men and women took part. The following listing gives an indication of the amount and variety of work performed:

There were 53 hydrographic stations, four large-volume water sample stations, 675 bathythermograph observations, 78 plankton tows, 24 mid-water trawls, 60 parachute drogue observations, 20 scattering layer stations involving 350 pounds of explosives, 13 velocimeter lowerings, 40 current shear studies, 8 piston coring tube lowerings, 17 Van Veen bottom samplings, and one pipe dredge lowering. Bottom photographs were taken, temperature measurements were made with the towed thermistor chain and a new method of navigation with a gyro-mounted telescope was tested. Routine observations included continuous bottom profiling, continuous observation of atmospheric and oceanic carbon dioxide, dipnet collections of surface organisms and keeping records of sightings of whales, porpoises and birds.

The cruise had three major objectives: an intensive investigation of the Romanche Trench, a deep valley in the mid-Atlantic Ridge on the Equator at 19° West Longitude; locating a low area in the Ridge across which cold deep water from the Western Basin of the Atlantic is flowing into the Eastern Basin; and measurement of the Atlantic Equatorial Undercurrent, a strong current flowing to the eastward beneath the westbound surface current.

Hydrographic stations during the International Geophysical Year had shown that the coolest deep water in the Eastern Basin lay in the vicinity of the Romanche Trench, suggesting that this anomalously cold water was flowing across a sill somewhere in that region. The first leg of this cruise was devoted almost exclusively to an intensive bathymetric survey of both the trench itself and the area along the Ridge to the east, where there was some earlier evidence of a saddle across which the cold water might flow. The ship criss-crossed the area, steaming more than 4,600 miles to complete the survey; the bottom was reconstructed aboard ship with sheets of plastic as the survey progressed.

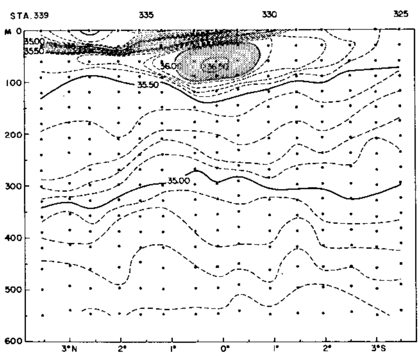
The Romanche Trench lies in the mid-Atlantic Ridge with its long axis oriented east and west. The area deeper than 3500 fathoms is roughly 10 miles wide and 50 miles long. Only two small areas, the larger being about five miles long, showed depths greater than 4000 fathoms. The deepest hole located on the cruise was 4180 fathoms, uncorrected for the speed of sound in water, or 7985 meters, corrected. The bathymetric survey did not disclose the sill depth of the trench, but thermal observations showed that the deep water in the trench has the same potential temperature as that found at 2250 fathoms in the Western Basin; suggesting that the southern boundary of the trench may be almost this deep. At the same time the deep water in the Eastern Basin adjacent to the trench was not so cold, indicating that the sill there is so shallow that it does not permit any significant overflow.

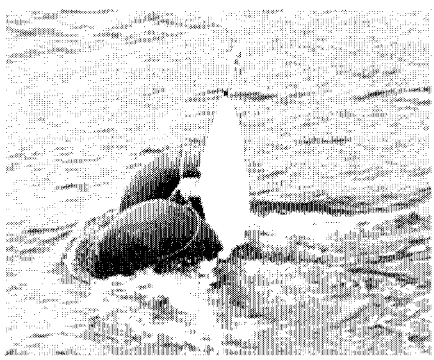
A region about 250 miles east of the trench at about 15° West seems most likely to be the overflow area, with a sill depth of about 3750 meters; hydrographic studies as well as the bathymetry there indicate that the cold Western

Basin water is filtering through a complex system of ridges and valleys into the Eastern Basin. That the overflow of cold water is relatively small is shown by the fact that it is identifiable in only a small area before its characteristic temperature is modified by mixing with the much greater volume of warmer Eastern Basin water as it moves away from the source region. No figures can yet be given for the magnitude of the overflow, but it is believed to be irregular, occurring in surges which may depend upon the rate of formation of bottom water or some phenomenon such as internal waves.

Interest in the eastward-flowing equatorial undercurrents has increased rapidly in the few years since Cromwell and others began investigating the equatorial undercurrent in the Pacific Ocean. The Cromwell Current, as this is often called, is a wide, flat stream running strongly to the eastward just a few meters below the westbound Pacific Equatorial Current. Preliminary observations made during the International Geophysical Year showed the presence of a similar undercurrent in the Atlantic Ocean which was examined in some detail on this cruise of the CHAIN.

Shallow hydrographic stations were made on two north-south sections across the Equator from 3°30′ South to 3°30′ North, at 18°30′ and 13°30′ West. The samples were analyzed for temperature, salinity and oxygen content. In addition, at each station a current meter was lowered to 500 meters to record relative currents. Parachute drogues were also used; two drogues were pulled under by the current but a third, with a more buoyant float, provided an impressive demonstration of the speed of the undercurrent. The





HAHN

Buoy towed by parachute drogue in equatorial undercurrent; Salinity profile across current at 13°30′ West.

float set off to the eastward leaving a wake like an outboard motorboat. The CHAIN followed it for 19 hours; the undercurrent was flowing eastward at about two knots and the surface current was moving westward at a little more than half a knot.

The undercurrent was also shown clearly by a number of measurements of horizontal shear made with pitotmeters attached to the thermistor chain. The measurements agreed well with those made by the drogues; they also indicated that the current is roughly symmetrical about the Equator with a southern boundary between 1° and 2° South. Evidence of the undercurrent was found at depths from 30 to 500 meters, with the highest speeds between 60 and 100 meters. It appears, however, that the undercurrent is not simply a broad, shallow ribbon but a very complicated stream.

The driving mechanism of the current is not yet known. Students of the Cromwell Current have suggested that vertical mixing at the surface along the Equator is involved. The temperature and oxygen profiles for the Atlantic undercurrent are similar to those of the Cromwell Current, but the salinity picture is quite different. A wide core of high salinity water right on the Equator in the Atlantic indicates that vertical mixing is not a major feature. Analysis of thermal data recorded with the thermistor chain shows that the isotherms diverge approaching the Equator from either side, indicating the presence of the undercurrent. In the same region there also appears to be intense production of internal waves with a period of 10 to 20 minutes and a wave length of 500 to 1000 meters.

Bottom water formation in the Mediterranean. The Mediterranean Sea has become of increasing interest, not only as a feature in its own right but because it can be regarded as a "model ocean" for studying processes which occur in the world oceans on a scale too large for detailed examination. In particular, the problem of bottom water formation in the Mediterranean is being studied as an aid to understanding the same phenomenon in the less accessible Antarctic area. The ATLANTIS spent three winter months in 1961 in the western Mediterranean; extensive hydrographic work was done on the CHAIN in the Eastern Mediterranean in the late summer; and another ATLANTIS cruise has been scheduled for the first few months of 1962. The ultimate purpose of these cruises is to determine the rate of bottom water formation in key Mediterranean areas: the Ligurian, Adriatic, and Cretan seas.

It is believed that new bottom water is formed when outside processes change the character of surface water so that it becomes sufficiently dense to sink to the bottom. In the Antarctic this process is the cooling and salting of the surface water accompanying the formation of sea ice. In the Mediterranean dense water is made by winter cooling and by extensive evaporation which removes fresh water from the sea surface. Accordingly, in conjunction with the hydrographic work measurements were made of humidity, solar radiation and back radiation, wind, precipitation and evaporation. New instrumentation has been and will continue to be developed for measurements of this sort; it is difficult to evaluate the data accumulated so far because of the interference introduced by the ship itself. However, there are indications that daily evaporative cooling in the Mediterranean is so great that the sinking process might be initiated by relatively small temperature changes, rather than large outbreaks of polar air as had been suspected.

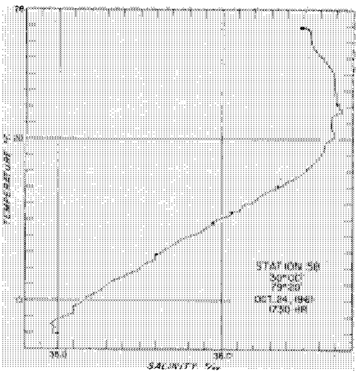
The ATLANTIS made 138 hydrographic stations during her winter cruise, mostly in the Ligurian Sea; the CHAIN added 75 more in the Sea of Marmora, the Aegean Sea and the Cretan Sea. The data from these will be a valuable addition to the surprisingly scanty amount of information about a sea so well-traveled as the Mediterranean. Part of the CHAIN's work included a network of closely spaced stations in the Cretan Sea; the area north of the Island of Rhodes was well covered. Results seem to indicate a deep isolated water mass of high salinity. On the other hand, in a deep of 4500 meters southeast of Rhodes the deep water appears continuous with the surrounding waters but with little vertical mixing below what might be called sill depth at 2500 meters. The data agree with those of the French and earlier ATLANTIS stations except for surface water salinity differences which are probably seasonal effects. Unfortunately the amount of data available is still not sufficient to determine seasonal changes.

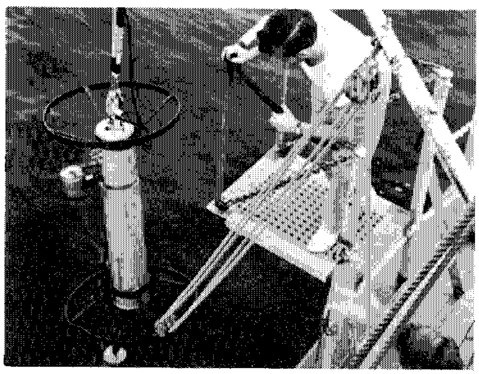
Gyres and Convergences in the North Atlantic. Evidence has been found that the circulation system of the Western North Atlantic may consist of two large gyres separated by a low pressure trough running southeast from the Flemish Cap. Sections made by F. R. S. ANTON DOHRN, V. F. S. GAUSS, R. R. S. DISCOVERY II, S. S. M. LOMONOSOV and the ATLANTIS, CRAWFORD and CHAIN have been examined. From the data were drawn plots of oxygen versus sigma-t, sigma-t profiles, temperature profiles and salinity anomalies; volume and oxygen anomaly transports were computed. The results of the investigation can be summarized as follows:

As it passes the southern extremity of the Grand Banks the Gulf Stream transports water with an oxygen-density relationship closely resembling the Sargasso Sea average established by Richards and Redfield (1955). The currents which flow to the north, off the Flemish Cap, transport water which has a temperature-salinity correlation similar to that of the Sargasso Sea but is richer in oxygen by about 1 ml/l at every sigma-t surface in the pycnocline. For this reason it is suggested that the Gulf Stream does not turn northward after passing the Grand Banks but continues to flow in a southeasterly direction, and that the currents which pass the Flemish Cap are part of a separate northerly gyre. There is evidence of a nearly permanent trough of low pressure between the gyres. It has also proved possible to estimate a new water budget consistent with the distribution of oxygen in the Western North Atlantic.

The area of salinity maximum in the region of the northeast trade winds in mid-Atlantic was examined in a CRAWFORD cruise in March. The salinity maximum is of interest because it is evidently an area where water mass formation is actively taking place as a result of convergence. However, it depends upon trade wind circulation, which was unfortunately well below normal during the CRAWFORD cruise as it has been on two earlier cruises to the area. Current measurements made from the ship with an anchored buoy as a reference point showed a northeasterly flow in the upper 240 meters. Normal currents in the area are westerly; this near-reversal of conditions is thought to be associated with an abatement of the trade winds. It is hoped that in the future productive experiments can be made with unattended instruments in the salinity maximum area.

Gulf Stream meanders. In October and November the CRAWFORD made seventy crossings of the Florida Current off Jacksonville in a study of the meanders of that portion of the Gulf Stream. Earlier analysis of data on the Florida current off Onslow Bay and Miami had indicated that the meanders are actually adding energy to the mean stream instead of dissipating it, as had been suspected. In the CRAWFORD cruise extensive use was made of the new *in situ* salinometer. Initial analysis of the data indicates that the





WRIGHT

Temperature-salinity curve from in situ salinometer lowering; Instrument comes aboard CRAWFORD.

instrument is particularly well suited to this sort of problem, as fine details and hitherto unsuspected time variations were discovered in the temperature and salinity structure of the region. In addition, an anchored buoy with two current meters was placed on the eastern side of the current. Results will be compared with dynamic velocity computations and with coincident surface measurements with the geomagnetic electrokinetograph (GEK). The data will be analyzed to determine the momentum transfer and the mechanism of the kinetic energy balance associated with the meandering of the current.

Non-tidal circulation on the continental shelf. The continuing drift bottle investigation of non-tidal circulation on the continental shelf has been augmented by the introduction of mushroom-shaped bottom drifters of brightly-colored plastic, developed at the Lowestoft Laboratory in England. Several thousand of these have been released with an encouraging percentage of returns. In one area off the Middle Atlantic States more than 26 per cent of the bottom drifters released in the fall were recovered, most of them along the shore. In the same area the only surface drift bottles recovered were those launched near the beach. Thus it appears that the autumnal offshore tendency at the surface is compensated for by a shoreward drift along the bottom, which fits the theory of an estuarine type of circulation on the continental shelf.

A series of cruises was made between Cape Cod and Cape Hatteras in an attempt to monitor any large scale changes in the circulation of the waters on the continental shelf. Some direct measurements of the drift were correlated with the density field and an encouraging result in the form of a regression equation was derived. The equation was used to compute velocity profiles for several sections across the shelf and the difference in these from summer to winter were related to expected seasonal changes in temperature and salinity in the area.

Theoretical and Experimental Hydrodynamics

The theoreticians continue their interest in exploring hydrodynamic phenomena that are related to oceanic circulation and in devising experimental and mathematical models which will permit an analysis of them.

The problem of penetrative convection has been considered by utilizing the peculiar properties of water near its freezing point. When a layer of water is maintained at 0°C at its bottom, while its top is somewhat greater than 4°C, then the system becomes unstable at a critical Rayleigh number, and one inquires as to how deeply the motions go inside the stable warm water. The finite amplitude theory of Malkus and Veronis (1958) was extended to this case. In addition, a different formulation of Malkus's turbulent convection theory is now being developed.

Experimental data on the instability of Ekman boundary layer flow is being analyzed and combined with theoretical investigations. The roll-like waves which are observed in the rotating tank offer a possible explanation of certain geophysical circulations that have banded structure. Construction has begun in the Laboratory of Oceanography of a new hydrodynamics laboratory to replace the one on the Institution dock which had fallen victim to a series of hurricanes over the years.

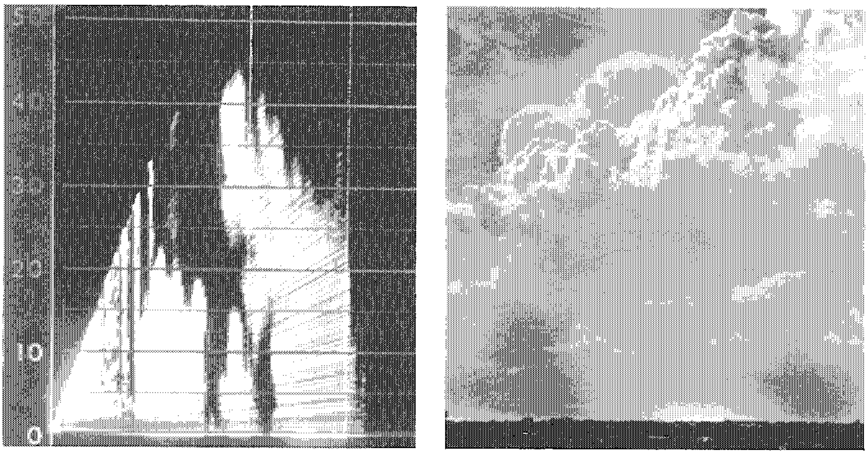
A series of numercial solutions has been completed for the non-linear thermocline problem as formulated by Robinson and Stommel (1959). The calculations were made, using an iterative method of Hartree's for solution of ordinary non-linear differential equations, on the Recomp II computer. It is believed that these new calculations will shed considerable light on which parameters determine the form and amplitude of the abyssal circulation and of the thermocline itself.

Some progress has been made in deriving stability criteria for the problem of the breaking up of jet-like streams into vortices. This bears on the problem of the formation of meanders in ocean currents like the Gulf Stream, and the development of cyclones in the atmosphere. In the Gulf Stream, for example, both the cross stream gradient of density and the mean velocity are known from previous literature to be potent mechanisms for producing unstable waves. The motions which may result when both these mechanisms are present are under discussion.

Marine Meteorology

Meteorology investigations in 1961 fell generally into two interrelated areas: the physics of convection, condensation and cloud formation, and the exchange of energy and matter across the sea surface.

Cloud physics. Laboratory studies of the convection of isolated masses of buoyant fluid, carried out in London and in Woods Hole, have helped in understanding the dynamics of convective clouds. The work was extended by field measurements of subtropical showers made in collaboration with the U. S. Weather Bureau in Miami, Florida. On two occasions giant cumulonimbus clouds with tops as high as 55,000 feet were observed to penetrate into the stratosphere. An analysis of time-lapse photographs and radar measurements showed that the extent to which a cloud penetrated the stratosphere was directly related to the intensity of vertical air motions within the cloud; a result which had been accurately predicted from the laboratory experiments.



RONNE

Radar picture shows cross section of storm cloud at right.

The relationship between the dimensions of visible shower clouds and the echoes received from them on a high-power weather radar was also examined on the Miami trip and a close correspondence was found. The result is doubly valuable because it improves the use of radar for storm warning purposes as well as the interpretation of radar data in basic research.

Cloud photographs from the second of three flights made over the Pacific Ocean in 1957 have provided the data for cloud distribution there. Previous analyses of photographs made during the first flight have shown a pronounced alignment of cumulus clouds. From the maps made from the Flight II photographs, it appears that the upper air circulation exerts a control upon the trends of cloud activity and upon the organization of clouds into lines and groups. The trend toward deeper and more vigorous clouds occurs in discontinuous steps rather than in a continuous build-up from small cumulus to cumulonimbus.

The water vapor distribution data obtained off the Bahama Islands in 1960 from three airplanes flying one above another have been processed. The huge job of data reduction and spectral analysis was accomplished by the Recomp II computer, without which the project would have been impossible. The results give a clear two-dimensional picture of the water vapor distribution in the sub-cloud region of the trade winds. Cross-sectional graphs reveal many intrusions of dry air into the moist lower air. The spectral analysis shows a continuous increase in the variance of the mixing ratio from the 100-meter to the 100-kilometer scale.

The hot wire instruments used in field trips in 1960 to measure liquid water content in clouds and precipitation have now been calibrated. A high speed spark source aided in photographing droplets in the instrument wind tunnel; droplet counts from the photographs have made possible the precise calibration of the instrument's response to water drops. As a consequence final analysis of the cloud data can now be undertaken. This will, in turn, permit determinations to be made of the degree of mixing of buoyant cloud elements with the dry environmental air.

The meteorological instrumentation of the R4D aircraft has been improved by the addition of a microwave refractometer which gives faster measurements of the water vapor content of the air and makes possible more reliable computations of the water vapor flux through the atmosphere. It was used in flights over the Gulf of Maine, Buzzards Bay and Sebago Lake during a severe winter cold spell. An improved radiometer is also being developed for the airplane to measure the net flux of radiation through the atmosphere.

Sea salt nuclei and rain. The work of the salt nuclei project was concentrated largely upon preparation for and execution of a two-month field trip on the island of Hawaii, where previous investigations of orographic rains have been dubbed "Project Shower." Hawaii, largest of the Hawaiian Islands, is particularly suited for this sort of work because of its distance from other land areas to windward, its high annual rainfall and its accessible mountains which permit observations at various levels in the shower clouds. Evaluation of the data from the field trip is expected to help provide an integral picture of the life history of a shower-producing convective cell.

One of the purposes of the trip was to relate the various properties of raindrops in the showers to other variables such as the amounts of airborne salt, the water-vapor distribution in the trade winds, the total rainfall and saltfall on the watershed and the height of the trade inversion. To accomplish this, twenty battery-operated rain recorders were designed and built. The instruments make a photographic record of the number and size of raindrops falling on a glass plate each 30 seconds; about 1,400,000 observations were obtained, making possible a detailed study of the time and space variability of drop number and size in the showers.

Measurements of the sodium content of individual raindrops were made for the first time with a flame spectrophotometer developed at the Institution. The sodium concentration varied between one and twenty parts per million and was inversely related to drop size. Attempts will be made to relate these quantities to a model of shower rain formation.

Instruments were also built to measure potential gradient, space charge, bulk rain current and the charge and size of individual raindrops. The most important finding in this atmospheric-electric work, made with a six-foot cubical Faraday cage which was set up ashore and on the deck of a Coast Guard cutter, was that of the flux of positive charge from ocean to atmosphere in regions of breaking waves and foaming. This confirmed earlier evidence that the sea is a source of positive charge for the atmosphere. It has been estimated on the basis of laboratory experiments that about 160 amperes of positive current are continually flowing from the world ocean into the atmosphere.

The contact of molten lava with sea water forces great quantities of finely divided salt particles into the atmosphere. A study of these particles in steam clouds from the 1960 Kilauea eruption in Hawaii has been published. A major result was finding that the rate of production of the important "giant nuclei" (10^{-9} grams or larger) was very great; a new geochemical fact which may have widespread meterological significance. One way to make clear the magnitude of the production rate is to realize that a few square kilometers of hot lava surface in contact with sea water could, within the lifetime of an eruption, produce enough particles to double the number of giant nuclei in the lower kilometer of the entire earth's atmosphere.

The idea which motivated the first attempts (in 1947) to measure the distribution of sea-salt particles in marine air over the ocean has never been satisfactorily explored. This idea, briefly stated, was that the hygroscopic sea salt particles might cause significant amounts of latent heat of vaporization of water to be released in subsaturated air. Accumulated evidence and experience over the intervening years finally made it possible, in 1961, to construct a reasonable hypothesis which confirms the original idea. It now appears that the release of latent heat in some parts of the lower atmosphere over the sea can be an important factor in the initiation of cumulus clouds.

Convection Theoretical work on the relation between vortical motions in convective clouds and the formation of precipitation has opened up a whole field of problems involving the interaction of a fluid in motion with particle populations in suspension in the fluid. Studies of convection in populations of motile algae (bioconvection) show promise of shedding some light on the formation of intensive downdrafts in and under precipitating clouds.

Winter temperatures in New England. An attempt has been made to put the forecasting of winter temperatures in New England on a more objective basis by devising a geometrical grid as an index of the flow along the Atlantic side of the trans-Arctic Ridge in November. Lines of regression have been calculated relating the index with the winter temperature anomalies in southern New England in 21 cases. Rules are being developed for dealing with other cases in which the index alone does not adequately describe the flow of cold air.

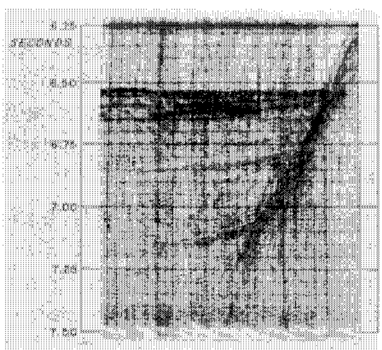
Geophysics and Submarine Geology

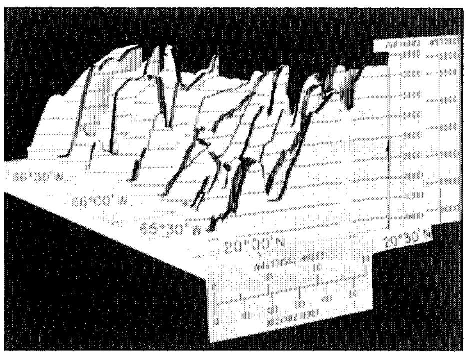
The Mid-Atlantic Ridge. The Mid-Atlantic Ridge is an object of great scientific curiosity. During the past year some of its geological and geophysical characteristics were deciphered by scientists from the Institution. It was suspected that the depth of the Ridge near the equator limits the flow of deep, cold, Antarctic water from the western basin of the South Atlantic into the eastern. Accordingly a rather detailed bathymetric survey of the Ridge, the Romanche Trench, and adjacent waters between 10° and 20°W was made from the CHAIN in January. Geologically this trip was significant because it was one of the first times it was possible to examine the bottom of the Romanche Trench in considerable detail with the aid of anchored buoys for navigational reference. In addition many photographs were taken along the floor of the trench and some very important rock samples were recovered in cores.

On a subsequent cruise of the CHAIN, the Mid-Atlantic Ridge was visited twice more, each time near 29°N Lat., on the way to and from the Mediterranean. On the eastward crossing within a region two hundred miles long in an east-west direction by thirty miles wide, two possible breaks in the wall of the median rift were found. In one, there was a large boulder of volcanic rock with glassy outer surfaces; in the other calcareous sand or ooze. In a nearby depression quite similar to the rift in form, 500 overlapping photographs of the bottom revealed an extensive area of ripples in the sediment. These were presumably formed by bottom currents, but they are so criss-crossed by animal tracks that they are obviously not of recent origin.

Heat flow. In collaboration with a student from Cambridge University, several measurements of heat flow from the earth's interior were made on the same passage. The object was to determine whether the several high readings previously reported in mid-oceanic ridges signify a broad, regional heat maximum there or merely local patches. Although the data have not yet been completely worked up, the latter appears to be true.

Records of Sub-bottom echoes. Identification of sediments in deep-sea basins over extensive areas has been vastly improved by the development of a continuous seismic profiler (CSP), which can continuously record sub-bottom echoes from interfaces between contrasting rocks or sediments more than 1000 meters below the surface of the bottom just as routinely as echo soundings have been collected for many years. This instrument was used in topographically enclosed basins both in the Mediterranean, known to have a bottom of uniformly bedded sediments at least 30 or 40 meters thick, and in the North Atlantic basins where there are characteristic flat plains. In the Mediterranean the source of sediments in such basins is derived from the surrounding land areas and from volcanic ash. In the open ocean, however, it is believed that the sediments come mainly from adjacent submarine slopes. The CSP readily showed that the flat plains are actually formed by horizontally-bedded sediments which partially fill deep depressions in pre-existing surfaces to depths of 500 to 1000 meters. Outside these basin areas and the major abyssal plains, the sediments are by comparison thinner, which supports the generally accepted theory that abyssal plain sediments are transported from the continental slopes by turbidity currents. In the vicinity of Caryn seamount CSP records show at least 1000 meters of sediment horizontally bedded at its base, with the deeper layers dipping away from it. This indicates the likelihood that the seamount is older than the adjacent sediments and strengthens the argument that such sediments were deposited by turbidity currents.





CSP record shows sediment beds dipping away from Caryn Seamount; Model based on Puerto Rico Trench bathymetry was made during CHAIN 19.

Deep-living coral and manganese modules. Topographic investigations on the Blake Plateau which started in 1954 led to the discovery this year of banks of coral at 450 fathoms. Earlier (1955) it had been found that the remarkably smooth-surfaced Blake Plateau is interrupted by sharp local hillocks rising several tens of fathoms above it. Subsequently some of these protuberances were detected as ridges or "welts" along corresponding depressions. During a cruise of the ATLANTIS (1961) these were ascertained to be banks of living coral on at least one major structure. These corals are being examined in collaboration with a scientist from the U. S. National Museum. It had been thought that the strikingly linear boundaries of the depressions in this area were indications of fault zones. However, CSP records reveal that the shallow beds terminate to form the walls of the depressions while deeper bedding continues beneath them without conspicuous evidence of faulting.

During the same cruise several hundred pounds of manganese nodules were collected on the plateau. These nodules and the live coral seem to be mutually exclusive, but their relationship is not yet thoroughly understood. Great interest has been shown in these manganese nodules and their chemical composition and probable mode of deposition, investigations of which are underway or being planned. Parenthetically, this very productive ATLANTIS trip was also part of the summer training program in oceanography. The cruise was under the direction of two experienced submarine geologists who were assisted by seven students ranging from a preparatory school boy to doctoral candidates in geology and geophysics.

Crustal structure. With the Carnegie Institution of Washington, the University of Wisconsin and others, the Institution took part in a cooperative seismic refraction study of the crustal structure beneath the Gulf of Maine. The BEAR acted as listening ship, first near the Maine coast and later near the continental slope between Brown's and George's banks. Shore parties from other institutions recorded signals in Maine while attempts were made at Woods Hole to monitor those received at several localities on Cape Cod, Block Island and Long Island by means of long-distance telephone lines. The reception aboard BEAR was excellent, as were the results from Maine.

The crustal studies in the Mediterranean, on the continental shelf south of Ireland and north of Puerto Rico (for Mohole site selection), all mentioned in previous reports, have been largely completed this year. Although the laboratory analyses of seismic refraction data is an exacting and protracted labor, sufficient information for planning further research has been obtained from a preliminary examination of the field data. The crustal structure, as determined during the Mohole survey, and photographs of the rock on the north wall of the Puerto Rico Trench led directly to successful dredging operations there in 1961. During the CHAIN cruise, four hauls dredged loose rock fragments of various sedimentary and crystalline rock, mostly serpentinite.

One fragment of serpentinite may have been broken off from an outcrop apparently from below the upper boundary of the lowest layer of the earth's crust. The significance of this exciting find is somewhat dimmed by uncertainty of the seismic shots and of the estimates of the depth where the rock was detached. Improving the latter will require the development of new techniques.

Transport of coastal sediments. Existing theory and wave equations did not provide an adequate mechanism for the transportation of fine silts and clays from cliffs along a beach to offshore sites of deposition. Known patterns of sediment distribution required some explanation besides rips and other narrow seaward currents. Furthermore, the wave equations for predicting the movement of particles of water beneath shoaling waves did not allow for any sort of return flow. Experiments from a wave tower located off the Tisbury beach on Martha's Vineyard have shown that there is a net seaward flow in the mid-depth waters beneath shoaling waves. The 1960 wave tower, a steel H-beam driven into the sand, was carried away by a hurricane. A sturdier structure was built in 1961 and equipped with instruments to measure the horizontal component of wave orbits at three points above the bottom simultaneously with observations of wave height, period and length. Despite delays caused by storms, several records were collected. Analysis of the data is still in progress, but it appears certain that the flow is strong enough to move large particles.

Underwater Acoustics

Since World War II the Institution has assisted the Navy in understanding the effects of the oceanic environment on the performance of underwater acoustical devices. An increased understanding of these automatically provides the oceanographer with a new technique for examining the oceans. Acoustical instruments serve observational purposes, such as the various sound pingers introduced by Edgerton and Cousteau to facilitate bottom photography and as adopted by Swallow to measure deep currents. These are now utilized at the Institution to monitor bottom coring operations and deep hydrographic casts. In 1961 they were used for positioning a rock dredge; later an underwater camera was added to photograph the bottom along the projected path of the dredge. This adaptation has greatly increased the efficiency of dredging, if only by assuring that the gear has made prolonged contact with the bottom.

A potential use of sound is to reveal the presence of and to track the movement of water masses by transmitting sound through them. Long distance transmission experiments in support of naval projects in the Bermuda area has produced striking evidence of large scale contrasts in the water masses in the Sargasso Sea. Although this is by no means a fully developed scientific tool, continued investigations may well lead to a powerful method in synoptic oceanography.

New long distance sound transmissions in the eastern Mediterranean in cooperation with NATO's SACLANT Research Center in La Spezia, Italy, have aided in understanding the bottom reflection process and the focusing of sound by variation of its velocity in sea water. Small explosive charges were used as sound sources for such work until a few years ago, when it became evident that the fine scale changes in both distance and time in the ocean would require more rapid observation than the use of explosives would permit. A great advantage was also apparent in correlating successive wave trains received from an impulse source that operated on a precise schedule. The "Sparker" and the "Boomer" (formerly called the "Thumper") were developed partly for this work and partly for seismic reflection work. Both devices were strengthened considerably in 1961: a "Sparker" designed for 25,000-joule electrical output was available for the CHAIN's work in the Mediterranean and a 13,000-joule "Boomer" was used repeatedly on the return trip across the Atlantic. Earlier in the year 5,000-joule "Sparkers" and "Boomers" permitted observations of deep bottom reflections and in horizontal sound transmissions over several tens of miles in the western North Atlantic. An extended use of underwater sound in geophysics and physical oceanography may now be possible with the advent of these new acoustic devices.

CHAIN's 25,000-joule "Sparker" proved capable of recording deep scattering layers from 2 to 20 kilocycles while the ship was underway at full speed. The first demonstration came in a four-day investigation of internal waves in the Strait of Gibraltar in collaboration with a scientist from La Spezia. Later observations were made in the Mediterranean whenever possible. Studies of this sort previously had been made only very laboriously with explosives; now continuous observations can be made of the frequency dependent phenomena of deep scattering layers.

Continuous deep profiles of sound velocity have been made from CHAIN with the National Bureau of Standards velocimeter. In addition, several profiles were made on two ATLANTIS cruises in the western basin of the North Atlantic. Results from these added to previous experience at the Institution and elsewhere suggest that this meter is a significantly better means of determining sound velocity as a function of depth than the earlier method of computing it from temperature, salinity and depth. Since this is the first program of continuous surface-to-bottom of any physical property of the deep sea, it should be watched with great interest by oceanographers for hints of telltale anomalies from which new understanding of deep water masses may come.

Chemistry and Geochemistry

Fallout fission products. Analyses for the fallout fission products strontium-90, cerium-144 and promethium-147 from both surface and deep water samples have continued to accumulate, confirming our belief that the first of these is a good tracer of water movement while the other two are moving principally with sinking particles. In many cases, by making reasonable assumptions about the time of massive delivery of fission products after a bomb-test series, it has been possible to estimate the rate of sinking of particle-populations of differing properties, both chemical and physical.

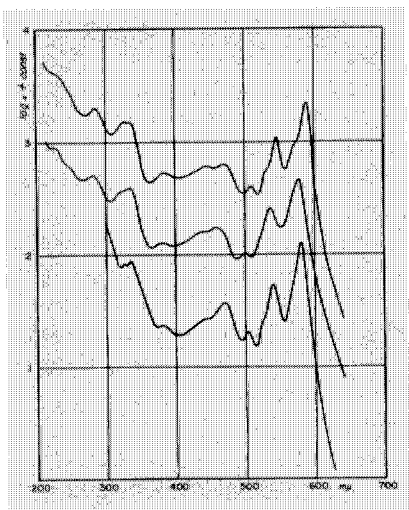
The strontium-90 data continue to show both an inexplicably high rate of delivery to the sea surface and a rate of down-mixing higher than expected. Two samples taken in 1959 from the Chukchi Sea, north of Bering Strait, were analyzed to see if high radioactivity in water of Pacific origin could be discerned as it moved northward into the Arctic Ocean; the samples showed strontium-90 no higher than is found at comparable latitudes in the North Atlantic.

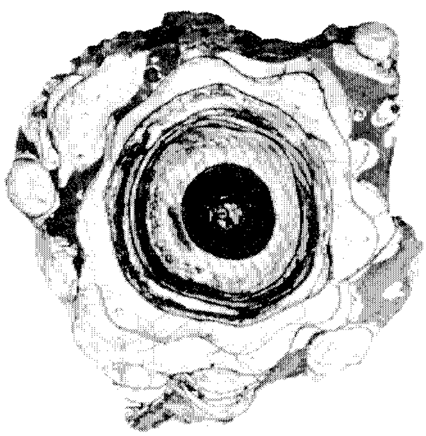
The water sampling program developed well during the year. Six full stations were made on Institution cruises; three additional Chukchi Sea samples have been obtained with the help of the Fisheries Laboratory, University of Washington; surface samples are being taken twice a month on four weather ships in the Atlantic Ocean through cooperation with the U. S. Weather Bureau and the U. S. Coast Guard. The data should provide a good base line to support maximum interpretation of the movements of the new fallout expected in the spring of 1962 as a result of the Russian tests in the fall of 1961.

A series of cores was taken on the CHAIN from the Romanche Trench and from a line across the Sierra Leone and Cape Verde basins to the mid-Atlantic Ridge. The cores are expected to be of special interest as spanning the whole spectrum of variation in terrigenous contribution. They are being subjected to complicated cooperative analyses: major and minor elements at University of Manchester; interstitial water at Harvard University; heavy minerals at Woods Hole and Foraminifera at the United States National Museum. Clay minerals are also being looked at and several other sorts of analyses are still to be farmed out. An abortive coring attempt on the same cruise yielded a small piece of volcanic glass under conditions indicating it must have covered a considerable area on the east slope of the Ridge under about 14 inches of red clay. Analysis of the elements in this glass showed a most unusual composition which has led to much speculation on its origin. Other submarine glass samples will be analyzed for comparison.

A workable method for separating actinium from ocean sediments has been developed; measurable yields of a radioisotope showing a growth curve similar to that of actinium-227 have been obtained from high-uranium Caribbean samples. The next step is to use analysis of the dis-equilibrium between parent isotopes and the daughter actinium-227 to study both the rate of sediment accumulation and the extent of back diffusion of some natural radioelements.

Fossil pigments. The organic chemistry of a heavily pigmented fossil sea lily of Jurassic age has been studied in some detail. Four aromatic hydrocarbons have been identified, the structure of three major pigments has been tentatively established and partial evidence has been obtained for the constitution of a fourth; all the pigments and hydrocarbons are interrelated genetically and structurally. It is now possible to reconstruct the sequence from a simple biogenic pigment to the more complex fossil pigments and the hydrocarbons. Of special interest is the fact that several of the pigments but none of the hydrocarbons have a sterically strained structure. The conversion from the unstable, strained pigments to the stable hydrocarbons has proceeded only to a very small degree in spite of the long exposure in the sedimentary environment. This indicates a very low reactivity in the sediment and an excellent chance for the preservation of unstable biogenic products and reaction intermediates.





SPOONER

Section of fossil Crinoid (Millericrinus) and graph of absorption spectra of Fringelite D, E and F, the three major pigments.

The discovery of unusual aromatic hydrocarbons in the fossil has led to a more general search for such compounds in nature; a great many were found to occur in soil. Most surprising was the finding of 3.4-benzpyrene, a well-known and powerful carcinogen, at concentrations up to 1.3 mg/kg. This means carcinogens may be a much more common and unavoidable part of man's environment than had been suspected.

Work has also been continued on techniques for isolation and identification of very dilute organic compounds in sea water. For isolating non-polar, high-boiling materials the favored procedure now involves a solvent extraction with benzene followed by zone melting of the solution to concentrate the solutes. The concentrate is injected into the gas chromatograph at a temperature sufficiently low to elute the solvent while retaining the solutes; these are then analyzed by temperature programming of the column. This method avoids losses by evaporation and minimizes handling of the extracts.

Salt bridges for GEK cables. The use of salt bridges for cables in GEK technology has been applied successfully both for current measurements at sea and for measuring tidal flow in Woods Hole. With a polyethylene tube across Woods Hole channel from Juniper Point to Nonamesset Island, a continuous record of current flow was obtained. In addition to confirming the basic usefulness of the method, this experiment demonstrated that the Hole acts as a half-wave rectifier, with a total transport from west to east about twice that from east to west. Sea tests aboard the ATLANTIS showed that the salt bridge system permits easy compensation for GEK electrode sensitivity to salinity, temperature, pressure and oxygen tension.

Ion interactions in sea water. Estimation of ion interactions in sea water is needed for evaluation both of ionic activities and of the contributions of various constituents of sea water to its conductivity. To obtain basic data on simplified systems, various properties of mixed strong electrolyte solutions at constant molarity are being investigated. The solutions are: soldium chloride-magnesium chloride; magnesium chloride-magnesium sulfate; magnesium sulfate-sodium sulfate; sodium sulfate-sodium chloride. The molality of the first electrolyte is varied by alternate additions of small amounts of water and second electrolyte so that total molality is maintained at 0.7, in the range of sea water. The activities of the electrolytes, the aqueous vapor pressure of the solutions and their density will be measured; the experimental data will be compared with those predicted by various theories of inter-ionic effects.

Oxygen titration. An experimental study has been made of the Winkler titration method, the classical means of determining dissolved oxygen. Of four published methods for standardizing the titrant, only one was found to be capable of what can loosely be called "nearly adequate" precision and accuracy. Examination of other parts of the procedure showed a wider spread of results than had been estimated and indicated that the absolute value of error may be virtually independent of the concentration of dissolved oxygen in the sample. The results of these experiments are being used as the basis for modifying the procedure.

Zinc in sea water. A method for the determination of zinc in sea water has been developed as the first part of a general study of many of the minor and trace substances in the oceans. A guiding principle of this study has been that in order to describe the distribution of these substances in a manner adequate for present biochemical and geochemical considerations, analyses are necessary on a scale now achieved for major nutrients like phosphate and nitrate. The procedure that has been devised for zinc involves the use of anion exchange resins to collect the element from a large volume of sea water, followed by removal of the zinc from the resin column with a small volume of eluting agent. It is believed that this technique, which will be tested at sea in 1962, will prove suitable for collecting and concentrating several other trace elements.

In addition, the physical chemistry of zinc in sea water is being examined and tracer studies of the mechanisms of zinc accumulation by marine phytoplankton have been started. The sugars and sugar esters in local decapod Crustacea are being examined in relation to the life cycles and ecology of several species; this approach may soon be applied to planktonic Crustacea.

Marine Biology

The biological investigations at the Institution are a combination of laboratory and field studies aimed at understanding the environmental conditions which determine and control the size of populations, their growth and the distribution of individual species in the sea. The work includes organisms ranging in size from bacteria to whales and processes ranging from nutrition and food consumption to the visual physiology of Crustacea.

Arctic copepods. One of the most unusual opportunities of 1961 was provided by a collection of Arctic zooplankton gathered by an automatic sampler installed on the nuclear submarine SEADRAGON, which cruised from the North Atlantic to the Pacific Ocean via the North Pole in the late summer of 1960. The sampler, devised with the help of Institution scientists, took 12 samples every 24 hours while the submarine cruised under the ice: the first horizontal net collecting in this hard-to-reach area. Although limited in size and not too well preserved, the set of samples is valuable because it extends our understanding of the distribution of various copepods. It has been possible to recognize 18 species, of which six are cosmopolitan and 12 are cold water forms restricted to the northern hemisphere. Of these only one appears endemic to the Arctic.

Indicator species. Other work on the geographical distribution of zooplankton suggests that several species of copepods are useful as indicators of the movement of water. For example, the presence of offshore copepods at various times of the year on the Continental Shelf between Delaware Bay and Block Island Sound confirms earlier drift bottle evidence of an inshore flow of oceanic water in that area. Results of a continuing investigation of zooplankton distribution in Buzzards Bay, Cape Cod Bay and the Cape Cod Canal seem to confirm the idea that temperature and salinity are important limiting factors. Samples of some of these copepods have been subjected to laboratory experiments. It has been found that the grazing and predation are reduced when the organisms are transferred to unfavorable temperature conditions. The structure of the mouth parts is correlated with the usual type of feeding, whether filtering or grasping and chewing.

Zooplankton productivity. Other laboratory studies on the feeding of zooplankton have indicated that they have an unusually high efficiency of growth but a relatively poor efficiency of assimilation. For example, of the food ingested only 13% to 50% was assimilated and became useful for the animal's growth and metabolism. But, of this relatively small fraction, from 63% to 91% was transformed into growth of the organism. The well-fed animals appeared to use a mixture of carbohydrates and fats as their source of energy whereas starved animals burned fat almost entirely. When extended to a great many species with a wide variety of food sources, this type of experiment should aid in interpreting the overall energy cycle in the sea and supplement the information obtained from phytoplankton studies on the role of photosynthesis. Additional work on zooplankton feeding has shown that they are very fussy eaters. When fed mixtures of pure algal cultures most of the species tested preferred the larger species of phytoplankton. Although this would appear to place the populations of large phytoplankton under greater pressure than the small ones, such may not always be the case. For example, it was found that two-day-old larvae of a sedentary worm failed to develop if they were starved and could not develop when offered a moderately large species of phytoplankton as food, even though the same phytoplankton was adequate food for five-day-old larvae. On the other hand, a smaller species of phytoplankton was readily ingested by the two-day-old worm larvae and promoted rapid growth when it was available.

Preliminary experiments with two species of crustaceans, a fish and a mollusk indicate that ribonucleic acid, a necessary precursor to protein synthesis, may be used as an indicator of animal growth and as such has possibilities in estimates of zooplankton productivity.

Phosphorus metabolism of unicellular algae. Two interesting and important results have come from a continuing investigation of the phosphorus metabolism of unicellular algae, based upon the utilization of radioactive phosphorus. Even at very low concentrations of inorganic phosphate in the medium the cell is able to assimilate and incorporate phosphorus into protoplasm faster than it can make new protoplasm. Thus it appears that the rate of assimilation of inorganic phosphorus from the medium is unlikely to limit phytoplankton growth in the oceans although the total quantity of phosphorus in the water may limit the size of the population which can ultimately be developed. Bioassays for the availability of phosphorus in sea water continue to show lower concentrations than are determined by chemical analysis. This may reflect the inability of the organism to use some of the organic compounds that are detected chemically; indeed, continuing tests show that different species of unicellular marine algae differ in their ability to use dissolved organic phosphorus. The ability of these algae to assimilate phosphate from sea water depends upon the amount already present within the cell as well as the supply in the external medium. This result is not unexpected but the relationships are still obscure and studies of the internal physiology of the cell as it relates to phosphorus assimilation are being continued.

Other work has shown that dissolved phosphate in sea water can be concentrated at the surface by rising bubbles of air. As the bubbles break at the surface, absorbed surfactant organic binders of phosphate form monomolecular films which are subsequently compressed by a Langmuir type of circulation. The phosphate has been recovered from the rows of slick and foam where it is significantly more concentrated than between the rows. Thus adsorption to the bubbles driven into sea water by breaking waves may be an important mechanism for concentration and increasing the availability of phosphate and other materials in the ocean.

New photosynthesis technique for sparse phytoplankton population. New techniques for studying the photosynthesis of the marine populations of phytoplankton offer promise in areas where the total size of the population is very small. The population is concentrated many times by filtering on a membrane, then the membrane filter is placed in a special apparatus in which the rate of photosynthesis or respiration can be measured with an oxygen electrode. Since the response of such concentrated populations to changes in nutrient content of the water is very rapid this technique may accelerate studies of these interrelationships, which have been of interest for several years.

Nitrification process. The microorganisms responsible for the nitrification process in the sea, which were first successfully isolated from the open sea about two years ago, are now in continuous culture although they have not been freed of all bacterial contamination. It appears that the organisms may not be bacteria at all. They are unlike any known species of bacteria, including their own terrestrial nitrifying counterparts. They are larger than the nitrifying bacteria and have a complicated life cycle; examination with the electron microscope even casts doubt on any close relationship to bacteria. If further investigations substantiate these findings, this organism will be the first known chemosynthetic organism other than true bacteria, a fact which would help explain the failure of previous efforts to isolate nitrifying bacteria from the sea. New media have been devised in which the culture grows about 60 times as fast as in the medium originally used for its isolation; the importance of this more rapid growth to the physiological and biochemical studies now in progress cannot be overemphasized.

Bactericidal activity of sea water. It has been firmly established that a large organic molecule is responsible for the bactericidal activity of sea water. Now the molecule is being purified and separated by flash evaporation and electrophoresis so that specific studies of its chemical nature are rapidly becoming possible in spite of the relatively low concentrations in sea water. The active compound has turned out to be lethal for all Gram-positive bacteria but inactive against all Gram-negative bacteria that have been tested. For years it has been known that the marine bacteria are almost exclusively Gram-negative; this new discovery may point to the reason why. The active material has been found in all samples of sea water tested although it may be much more concentrated in some samples than in others. The fact that it is an inhibitor of penicillin-resistant staphylococci would be of prime importance in the medical field if adequate methods for its development and concentration could be worked out.

Light in the sea. Studies of light in the sea have followed three major lines: the direct measurement of light, the effects of suspended plant and inorganic material on the amount of light reaching various depths, and the bioluminescence of marine organisms. Light is not only absorbed in the sea by the particulate matter which is present but it is also changed in wavelength depending upon the amount of living phytoplankton in the water above. The shift in wavelength has been shown to be closely related to the amount of chlorophyll and the various carotenoids in the phytoplankton. In the deep sea, luminescent flashes have been recorded at every locality investigated, from near the surface to depths of more than 2,000 fathoms. The intensity of these bioluminescent flashes is about 100 times greater than that needed to attract crustaceans and more than 10 million times greater than the visual threshold for man and many marine animals. Laboratory studies have been made of various marine species, some of which had been maintained in culture and others which were freshly collected at sea. The luminescent glands of several species have been found to fluoresce in ultraviolet light, revealing the distribution and structure of the light organs to a degree of detail not otherwise possible. Histological examination of these glands and other evidence suggest that some marine species have a luminescence mechanism that differs both physiologically and biochemically from the mechanism which is becoming well understood through studies of terrestrial forms.

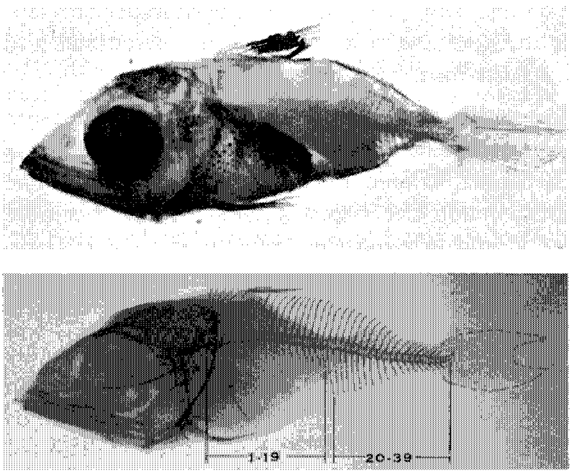
The deep benthos. Studies of the benthos in the deep sea were inaugurated between Woods Hole and Bermuda and have been very successful. New collecting methods have been developed which retain all the smaller organisms that were previously lost. As a result, much larger bottom populations have been found than on earlier surveys, indicating that the deep sea fauna may be much more significant than had been previously supposed. All of the collections from the great depths contain a large number of species but with no single one numerically dominant.

Borers. The buoy line between Woods Hole and Bermuda has provided an opportunity to learn about the attachment of organisms in deep water away from seasonal factors such as temperature and day-length. For this purpose wooden test panels have been attached to the mooring lines of the buoys at various depths. Several of the panels have shown no evidence of attached organisms or borers despite prolonged immersion, but a heavy infestation of a wood-borer, *Xylophaga,* was found on one panel which had been exposed for six months 10 meters above the bottom in 3000 meters of water. *Xylophaga* is not a common form in inshore waters and, because the specimens in the panel were juveniles, complete identification of the species has not been possible. Further tests are proposed in an effort to find out if such borers are common inhabitants of the deep sea.

Fish behavior and distribution. Students of fish behavior have long debated whether schooling is controlled by the eyes or the lateral line system. That vision plays a role has been established by using contact lenses which produce distortions of the visual field and corresponding distortions of schooling behavior. The same investigation has revealed that most fishes are far-sighted but that reef fishes are relatively near-sighted. A special adaptation has been found which permits flying fish to see equally well in air and water, two media of very different optical qualities.

The known distribution patterns of both tuna and swordfish have been extended during the past year. For the first time, catches south of the Grand Bahama Bank related the annual Cat Cay run of bluefin tuna to concentrations previously discovered in the Windward Passage in late April. An apparently separate group of giant bluefins was found ranging over a large area along the Atlantic side of the Bahamas where they were not known to occur previously. The trans-Atlantic migration of giant bluefin tuna was proved by tagging experiments; two specimens made the migration from Cat Cay to Bergen, Norway, in less than four months. Studies of the juveniles of tuna have been made both by X-ray techniques and by normal dissection methods. A nearly complete collection of juvenile tunas is now available for four species; important errors and omissions in the literature on these have been revealed.

BRAY



Larva of blackfin tuna 11.5 mm long. Soft X-ray (retouched) shows vertebral characteristics which distinguish species.

Work has been continued on the elasmobranchs, including sharks and skates, and an account is in preparation on the whiting, or silver hake, of the western Atlantic for inclusion in the memoir series, "Fishes of the Western North Atlantic."

Environmental cetology. Work in environmental cetology has been continued both offshore and nearshore, and even on the beach. A valuable opportunity to make observations on a living *Ziphius,* one of the little-known beaked whales, occured in March when a mature male was stranded on a beach in Newport, Rhode Island. Published information on this whale had been based on dead specimens only. Curiously enough, five months later another *Ziphius* was washed ashore dead on the outer beach at Orleans, Massachusetts.

Observations of migrating right whales in Cape Cod waters were made during April and May from the air and from shipboard. Attempts to take underwater motion pictures of the whales were terminated when one of them carried away the camera with a stroke of its tail.

The acoustic program has continued and the sounds of two previously unrecorded species have been added to the library. The known ranges of three species of porpoise have been extended with the aid of improved harpoons.

Instrumentation

Several of the instrumentation techniques which have been under development at the Institution for the past few years were made operational and applied as parts of working measurement systems in 1961.

Anchored buoy stations. The application of new instrumentation took place on the largest scale in the establishment of a line of anchored buoy stations between Woods Hole and Bermuda, as mentioned in last year's report. The buoy line represents an effort to obtain direct measurements of currents more frequently over a longer period and in a more extended area than has previously been possible. There has been a long-standing need for this sort of nearly-continuous sampling throughout an entire ocean basin.

The line, when complete, will consist of 20 moored buoys set at roughly equal intervals along the rhumb line from Gay Head, Martha's Vineyard, to St. George's, Bermuda. The buoys are foam-filled fiberglas doughnuts eight feet in diameter, painted bright orange for visibility. Each is mounted with a ten-foot tripod which houses wind recording instruments as well as a flashing light and a small radio transmitter as aids in locating the buoy. The anchor lines are half-inch polypropylene rope with current meters and other instruments shackled in at 500-meter intervals. In all, there are about 150 instruments, including wind gauges, current meters, tension meters, depth meters and inclinometers. Each one is self-contained, battery-powered and self-recording so that there are no electrical connections outside the instrument cases. The recordings are made in binary code on slowly-moving photographic film; each instrument can record up to 10,000 readings over a period of 100 days or more. At intervals of three to four months the line must be revisited, the records removed and the instruments recharged with fresh film and batteries. After the film is developed, the data are picked off by photoelectric scanning and fed into a computer for processing.

Fifteen buoy stations were set out in May and June. Long term series current measurements were obtained from all the deep water stations except those in the Gulf Stream, which were swept away; a stronger anchoring system is being devised for the Stream stations. The stations on the continental shelf failed in Hurricanes Esther and Frances, which crossed the line at several points, but the deep stations survived with slight damage to the surface floats. Examination of the data had not begun at year's end.

The buoy line is a good example of cross-fertilization among the disciplines at Woods Hole. The line has been used for corrosion studies in deep water and for collection of deep water biological fouling data. Also, the components of the current meter have been used in shipboard lowerings in studies of the Atlantic Equatorial Undercurrent and in conjunction with Project Mohole. Individual stations have been used by the International Ice Patrol and in measurements of fluctuations in the Florida Current; others are to be used in the Labrador Sea in early 1962 along with Swallow floats and classical hydrographic stations. Finally, the current meter is being modified so that its data can be telemetered to ship or shore by means of transponding radio buoys.

The transponding buoys, developed at Woods Hole several years ago, have been available commercially for about two years. A temperature sensor designed to provide a digital transmission from the buoys has been worked out and anchored stations utilizing this combination are in preparation. The same combination is being used with a recording temperature-and-depth package and parachute drogues to measure currents both in the open ocean and on the continental shelf. The transponding buoy has also been adapted to radio acoustic ranging.

Other systems of current measurement are also being applied. One involves a meter of the rotor type in combination with a camera for recording bottom currents; another recording current meter is being adapted for vertical soundings of horizontal velocity.

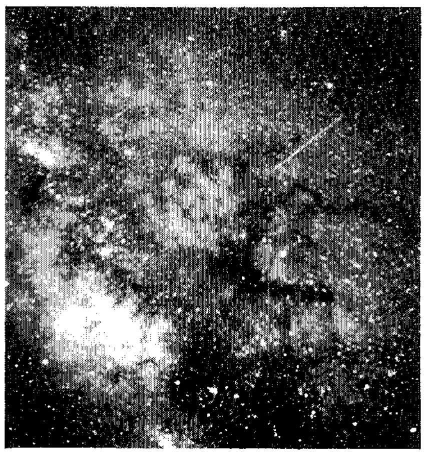
In situ salinometer. Several years of work on conducting cables and salinity sensors have led to an instrument which can be lowered to provide a continuous record of temperature and salinity versus depth. The salinity determinations of the instrument are less accurate than those obtained from Nansen bottle samples, but it has the important advantage that it picks up the fine structure that is not revealed by the discrete sampling of a bottle cast. The instrument was tested last summer and then was used later in the year to replace Nansen bottles in a study of the fluctuations of the Gulf Stream. Its major difficulty has been a long response time of the cell which compensates for pressure and temperature in the conductivity measurement; this is of little importance in the deep ocean where changes occur slowly, but in a region of sharp temperature gradients such as the Gulf Stream it has resulted in many spurious transient excursions of the salinity trace. The work of reducing the cell's response time is under way.

Gyro-Erected Optical Navigation (GEON). A new system for celestial navigation (whose acronym is GEON, for Gyro-Erected Optical Navigation) has been devised. This is a by-product of steps being taken toward the goals of some day determining the shape of the earth at sea and ultimately to determine the slope of the sea surface as an index of ocean current activity in the water column.

GEON consists of an equatorially mounted astronomical telescope equipped with very precise setting circles, all held in the plane of the local meridian by a Sperry Mark 19 Model 3a meridian gyrocompass. This miniature observatory has been mounted on the boat deck of the CHAIN; the system was tested extensively on both the Romanche Trench and the Mediterranean cruises. GEON proved capable of fixing the ship's position to an accuracy of one nautical mile with a single celestial sight. Moreover, because the meridian gyrocompass serves as a level reference the horizon need not be visible; a fix of position can be obtained by day or night provided the sky is not totally obscured.

In addition, the equatorial mounting of the telescope makes it possible to take photographs of star fields in the night sky with exposures as long as an hour. Stars as faint as the 14th magnitude have been photographed while the ship was underway at 13 knots. With a motion-picture camera mounted on the gyrocompass, time-lapse movies have been made, while underway, of

MERCHANT



VON ARX

GEON aboard CHAIN; 15-minute exposure with ship underway shows meteor crossing star clouds of Sagittarius and Ophiuchus.

the development of trade-wind cumulus clouds and of the optical properties of the atmosphere near the horizon.

Steps are being taken to improve the optical and mechanical parts of the equatorial mounting of the GEON system to reduce their contribution to the navigational errors. The ship's speed and the acceleration circuits and computer elements of the gyrocompass are also being modified in an effort to improve its performance. If these changes are successful enough to permit navigation accurate to one-tenth of a nautical mile — the predicted accuracy of the TRANSIT satellite navigational system — it may be possible to combine GEON and TRANSIT observations to obtain information on the slope of the earth's shape at sea to an accuracy in the order of 1 to 10 seconds of arc. Although this is far short of the accuracy required for the detection of sea slopes accompanying geostrophic motions in the water column, it is a firm step toward that goal in a closely related area. Present knowledge of the figure of the earth is based on astro-geodetic measurements from the land — only one-fourth of the earth's surface.

New gravity meter. Associated with the question of the slope of the sea surface is that of the change of geopotential along these slopes. Since gravity is the gradient of geopotential, it is desirable to be able to measure gravity on hydrographic stations as well as surface slope and the vertical distributions of water density so that geostrophic computations can be made without reference to a "level of no motion" or any equivalent assumption. Such an extension of present techniques would permit detection of geostrophic motions that are independent of the field of density within the sea; barotropic motions of this class may account for a large fraction of the total transport in some areas.

Accordingly, a new form of gravity meter has been developed for use aboard surface ships. It employs a stainless steel non-magnetic sphere falling slowly through a column of highly viscous silicone fluid. With careful control of the temperature of the fluid, the fall rate can be shown to be a linear function of the force of gravity. Each gravity measurement requires about an hour and can be made while the deep hydrographic cast is down to ensure that the ship's motion over the earth is so small that the Eötvös force can be neglected. It is expected that an overall accuracy of one part in a million can be achieved at sea with this instrument. A preliminary version was tested on the CHAIN between the latitudes of 1° South and 42° North; the change of gravity with latitude was observed to satisfy Clairaut's formula to an accuracy of 1 part in 10,000.

Instrumented wave tower. A third instrumented wave tower has been erected in Buzzards Bay on the site of the earlier ones which were swept away by autumn storms. It is considerably more sturdy than its predecessors, having been built on four eight-inch steel pipes driven 35 feet into the bay bottom and anchored with a series of flanges. It survived the worst weather of 1961 but has not yet been tested by a hurricane.

The tower is designed so that there is no cross bracing near the sea surface; except for the legs themselves there is nothing to interfere with the movement of the waves from eight feet below mean low water to 14 feet above it, where the instrument platform is located. A fine stainless steel wire is suspended from the platform into the water, measuring the resistance of the wire gives a continuous record of wave heights passing a point in space. At the same time observations of wind speed and direction are made. Converted to a frequency-modulated signal, the data are transmitted on demand to the laboratory, where they are recorded on multi-channel tape. The records can then be sampled in a variety of ways for analysis by computer.

The purpose of the initial experiments is to observe changes in the wave frequency spectra as wind conditions change. It is planned to add a movable boom with additional sensing wires so that directional components can be measured, as another step toward the ultimate goal of understanding the generation of wind waves. The tower may also serve as a base for observational studies of the surface interactions between the water and the atmosphere. Vertical transports of mass and energy and horizontal shear at near-surface layers will be investigated.

To help handle the massive quantities of data collected from the wave tower and by other continuous sampling techniques, a system for analogue-to-digital conversion has been installed as a direct link between tape-recorded analogue data and the Recomp II digital computer. This equipment has been used in experimental programs in many areas of research, including analyses of water circulation patterns in shoaling and breaking waves, microstructure of temperature measurements obtained by the thermistor chain in the upper layers of ocean water, and measurements of turbulence and heat exchange from sea surface through different levels of the atmosphere.

Computers. Computers are being used more and more in data reduction, but the laborious process of preparing them in a form that can be put into the computer has posed a problem. During the CHAIN cruise to the Mediterranean a first attempt was made to store data from many sources semi-automatically with an IBM system: navigation fixes, surface and subsurface temperatures, weather observations, water depths and attenuation settings from various instruments. The IBM equipment put data on cards and paper tape and then typed them out on typewriters in two of the ship's laboratories. The success of this experiment indicates a growing use of such methods.

Other techniques. Two other techniques tried during the same cruise were closed-circuit television and two modified versions of the airplane wing that had been tested on the CRAWFORD in 1960. The television cameras were designed for either air or water and, although most of the use was between locations on the ship, some examination was made of the screws and bottom of the ship and various pieces of submerged gear. As a visual link between the bridge and the activities on the fantail the TV greatly reduced the confusions of voice communications. One of the new extendable platforms was a styrofoam-filled aluminum catwalk supported on the outboard end by a streamlined float; the other was an inflatable rubber boom that skimmed along the surface. Used in dredging operations the booms extended the base line of the ship to provide a better means for determining acoustically the position of the dredge on the bottom.

Fleet Operations

Two changes in the research fleet marked the beginning of 1961. The ketch ARIES, which had been used primarily in deep water current measurements in the Bermuda area, was disposed of by sale to Mr. George Theodorocopoulos of New York. At about the same time, through the generosity of Mr. Louis E. Marron, the Institution took title to the 59-foot sportfisherman, the EUGENIE VIII. She was used throughout the year in migratory game fish studies and other biological work. The Japanese long-line technique which had been used on the CRAWFORD was adapted to the EUGENIE VIII with considerable success before she cruised south to work in Florida waters during the winter.

The major cruises of the year were made by the ATLANTIS and the CHAIN. The ATLANTIS spent three months on a winter trip to the Mediterranean. The CHAIN was away three and a half months in the spring in the Eastern Equatorial Atlantic, then spent four months on a trip into the eastern Mediterranean going as far as Istanbul, making scientific investigations on both ocean crossings and returning to Woods Hole the week before Christmas. In the Mediterranean cruises both ships worked extensively with foreign research vessels, including the ARAGONESE of La Spezia, Italy, and the fleet of the Oceanographic Museum in Monaco. Several foreign scientists spent time at sea on our vessels as observers or to carry out investigations and, in Monaco, Prince Rainier and Princess Grace honored the CHAIN by having Thanksgiving dinner aboard.

The longest CRAWFORD cruises were for a study of the salinity-maximum west of the Cape Verde Islands in the spring and, in the fall, a survey of Gulf Stream meanders which required 70 crossings of the Florida Current along the same 30-mile track off Jacksonville, Fla. The BEAR returned from the Bahamas early in the year and spent the winter in the Gulf of Maine on charter to a commercial firm calibrating a new Navy communications facility. During the rest of the year she was used primarily on short cruises in local waters.

The Institution fleet spent a total of 921 days at sea during the year and logged a total of 116,646 miles — a slight decrease from the record figure in 1960. It is interesting to note that in her 30th full year of service the ATLANTIS sailed 26,462 miles, which is more than once around the globe at the Equator and considerably more than the 14,100 miles she sailed in her first year and a half.

Other ships used in Institution work were the fishing vessel CAP'N BILL III, which was chartered frequently for a study of non-tidal drift on the continental shelf, and Mr. J. Seward Johnson's ketch the OCEAN PEARL which was made available in February for current measurements off the Atlantic side of Eleuthera Island in the Bahamas.

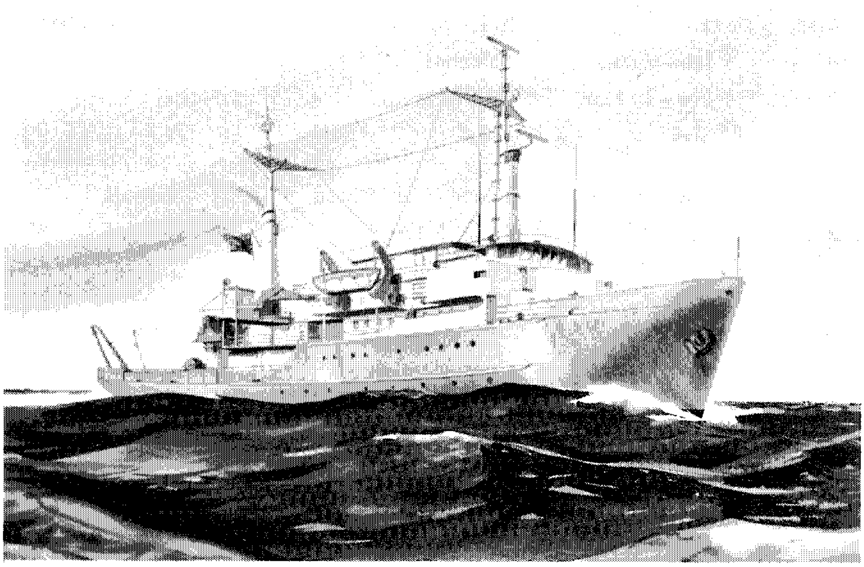
There was only one occasion on which hurricane evasion was necessary. In anticipation of Hurricane Donna in September, the ATLANTIS, the CRAWFORD and the BEAR sought shelter in Boston Harbor and the small craft were moved into the Eel Pond. The storm did no damage to the fleet, the docks or other Institution property.

There were no major foreign flights by the R4D aircraft in 1961. Most of the year's activities consisted of local trips except for some airborne coastal photography, including a flight along the Gulf Coast after the devastating Hurricane Carla. The Helio-Courier made one flight to Nova Scotia for whale spotting; otherwise it was used primarily in local work. On a number of occasions the plane worked in conjunction with the small research vessel ASTERIAS in whale observations in Cape Cod Bay.

A $3,876,000 contract for the construction of a research vessel was awarded in September to the Maryland Shipbuilding and Drydock Co. of Baltimore, Mr. Delivery is scheduled for December, 1962, and it is expected that the new ship's first major cruise will be to the Indian Ocean in early 1963. The new ship was named ATLANTIS II by popular acclaim and she is considered to be a replacement for the original ATLANTIS.

The ATLANTIS II will be built of steel and will have twin propellors powered by a uniflow reciprocating steam engine. Her principal specifications are: overall length, 210 feet; waterline length, 195 feet; beam, 44 feet; draft, 16 feet; displacement, 2,100 tons; cruising speed, 12 knots; range, 8,000 miles. She will have accommodations for a crew of 28 and a scientific party of 25. Among her special features will be anti-roll tanks and bilge keels for increased stability, a bow propulsion unit for maneuverability and an underwater observation chamber in the bow. There will be four fixed laboratories and deck space for portable laboratory units which can be used interchangeably. The ATLANTIS II was designed by the Bethlehem Steel Company's Shipbuilding Division in Quincy, Mass., with M. Rosenblatt & Son of New York as design associates. Hull models were tested in the towing tanks at Stevens Institute in Hoboken, N. J. Design and construction are being financed by The National Science Foundation.

The need for a ship to function as a replacement for the BEAR and the ASTERIAS has become apparent. Preliminary designs have been prepared and conversion possibilities are being considered with the goal of acquiring a multipurpose craft approximately 100 feet long.



ATLANTIS II PAINTING BY MINOT

ATLANTIS — Days at Sea — 214 — Total Miles Sailed — 26,462

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
263	12 Jan.–16 April	Western Mediterranean	82	Miller
264	20 May–25 May	Woods Hole–Bermuda	7	H. L. Sanders
265	31 May–8 June	Woods Hole–Bermuda	9	Corwin
266	20 June–26 July	Blake Plateau	37	Stetson
267	4 Aug.	Local	7	Associates' Cruise
268	8 Aug.–12 Aug.	Woods Hole–Bermuda	5	Scheltema
269	15 Aug.–19 Aug.	Local	5	Mangelsdorf
270	22 Aug.	Local	1	Conover
271	5 Sept.–15 Sept.	Woods Hole–Bermuda	11	Stimson
272	19 Sept.–22 Sept.	Chelsea, Mass.	4	Hurricane Warning
273	26 Sept.–4 Oct.	Woods Hole–Bermuda	9	H. L. Sanders
274	17 Oct.–3 Dec.	Puerto Rico	47	Bruce

BEAR — Days at Sea — 130 — Total Miles Sailed — 10,000

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
258	1 Jan.–6 Jan.	Bahamas	6	Athearn
259	7 Feb.–30 Mar.	Gulf of Maine	51	On Charter
260	10 May	Local	1	Compass Adjustment
261	22 May–26 May	Rhode Island Sound	5	Nalwalk
262	6 June–9 June	Cape Cod Bay	4	Hoskins
263	16 June	Local	1	Engine Adjustment
264	26 June–22 July	Gulf of Maine	27	Fahlquist
265	1 Aug.–11 Aug.	Continental Shelf	11	Backus
	14 Aug.	Local	1	Fejer
266	17 Aug.–28 Aug.	Shelf off Virginia	12	J. E. Sanders, Owen
267	30 Aug.	Local	1	Fejer
268	11 Sept.–15 Sept.	Cape Cod Bay	5	
	22 Sept.	Cape Cod Bay	1	Watkins
	28 Sept.–1 Oct.	Gulf of Maine	4	

CHAIN   Days at Sea — 286   Total Miles Sailed — 42,984

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
14	3 Jan.	Shipyard – Woods Hole	1	
15	9 Jan.–14 Jan.	Woods Hole – Bermuda	6	B. H. Ketchum
16	16 Jan.–21 Jan.	Bermuda – Woods Hole	6	Richardson
17	1 Feb.–17 May	Romanche Trench	104	Hays, Voorhis, Metcalf
18	29 May–4 June	Woods Hole – Bermuda	7	Richardson
19	13 June–7 July	Puerto Rico Trench	25	Hersey
20	20 July–2 Aug.	Woods Hole – Bermuda	13	Richardson
21	16 Aug.–18 Dec.	Mediterranean	124	Hersey, Hays

CRAWFORD   Days at Sea — 191   Total Miles Sailed — 25,200

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
57	3 Jan.	Shipyard – Woods Hole	1	
58	7 Jan.–10 Jan.	Gulf of Maine	4	Curl
59	17 Jan.–22 Jan.	Woods Hole – Bermuda	6	Yentsch
60	24 Jan.–3 Feb.	Chelsea, Mass.		At Shipyard
61	9 Feb.–4 April	Mid-Atlantic Northeast Trades	48	Worthington
62	19 Apr.–8 June	Gulf Stream, Bahamas	45	Mather, Bartlett
63	23 Jun.–4 July	Shelf – Gulf Stream	12	Kuenzler
64	24 July–30 July	Gulf of Maine	7	Clarke
65	4 Aug.	Local	1	Associates' Cruise
66	6 Aug.–9 Aug.	Woods Hole – Bermuda	4	Yentsch
67	13 Aug.–20 Aug.	Continental Shelf	7	B. H. Ketchum
68	28 Aug.–8 Sept.	East of Cape Hatteras	11	Parker
69	19 Sept.–22 Sept.	Chelsea, Mass.		Hurricane Warning
70	2 Oct.–18 Nov.	Florida Current	46	Webster
71	21 Nov.–9 Dec.	Chelsea, Mass.		At Shipyard

PERSONNEL

Honoraria

The following persons were awarded grants, honoraria or fellowships during 1961:

Roger W. Bachman	University of Michigan
Mario R. Capecchi	Antioch College
Frank Carey	Duke University
Robert J. Collier	Harvard University
Hugh Dingle	University of Michigan
Ivar Dugstad	University of Oslo
Walter Eckhart	Pembroke College, University of Cambridge
John Edinger	The Johns Hopkins University
George Field	Princeton University
Nicholas P. Fofonoff	Pacific Oceanographic Group, Nanaimo, British Columbia
Santanu K. Ghose	Florida State University
Philip Gossett	Amherst College
James R. Greaves	University of Minnesota
Kurt Hecht	Brown University
Bertil Hille	Yale University
Louis N. Howard	Massachusetts Institute of Technology
Robert H. Kraichnan	New York University
Frank Lipps	The Johns Hopkins University
Lionel W. MacMillan	University of British Columbia
Eric L. Mills	Yale University
Derek W. Moore	University of Bristol
Martin T. Mork	University of Oslo
S. Nagarajan	New York University
Norman S. Neidell	Imperial College, London, England
J. A. Colin Nicol	The Laboratory, Plymouth, England
Pearn P. Niiler	University of Cambridge
Dennis H. Peregrine	Churchill College, University of Cambridge

Honoraria

Donald C. Rhoads	University of Iowa
Robert S. Rhodes	Stanford University
Steven I. Rosencrans	Massachusetts Institute of Technology
Ira Rubinoff	Harvard University
Peter M. Saunders	Imperial College, London, England
Robert K. Sexton	Brooklyn College
Fred C. Shure	University of Michigan
Edward A. Spiegel	New York University
Bruce A. Warren	Massachusetts Institute of Technology
Charles G. Wing	Bowdoin College

Visitors

Scientists from this and many other countries honored the Institution with visits during 1961. Among these were:

Tokiharu Abe	Tokaiku Suisan Kenkyujo, Tokyo
Masateru Anraku	University of Hokkaido
Karl Banse	University of Washington
N. F. Barber	Dominion Physical Laboratory, D.S.I.R New Zealand
Willard Bascom	National Academy of Sciences
Neil L. Brown	Division of Fisheries and Oceanography, CSIRO, Cronulla
R. W. Burling	New Zealand Oceanographic Institute, D.S.I.R.
R. Morrison Cassie	New Zealand Oceanographic Institute, D.S.I.R.
Vivienne Cassie	New Zealand Oceanographic Institute, D.S.I.R.
Roland A. Cox	National Institute of Oceanography, Great Britain
Ronald I. Currie	National Institute of Oceanography, Great Britain
L. R. Day	Fisheries Research Board of Canada
Günter Dietrich	Institut für Meereskunde, Kiel, W. Germany
L. A. Earlston Doe	Bedford Oceanographic Institute, Canada
R. Dorrestein	K. Nederlands Meteorologisch Instituut, De Bilt

Visitors

T. Engelsen	N.D.R.E., Bergen, Norway
M. P. Foache	French Navy
G. E. Fogg	Westfield College, University of London
William L. Ford	Defence Research Board, Canada
Y. Fujii	Transportation Research Institute, Japan
David Garner	New Zealand Oceanographic Institute, D.S.I.R.
T. F. W. Harris	C.S.I.R., South Africa
E. M. Hassan	New York University
M. R. Howe	Liverpool University
M. Inoue	Tokai University, Japan
Hideo Kawai	Tohoku Regional Fisheries Research Laboratory
Fritz Koczy	University of Miami, Coral Gables, Florida
Wolfgang Krauss	Institut für Meereskunde, Kiel, W. Germany
G. Lambert	French Atomic Energy Commission
L. M. Lauzier	Fisheries Research Board of Canada
Arthur J. Lee	Fisheries Laboratory, Lowestoft
John R. Longard	Canadian Joint Staff, Washington
Hugh McLellan	Agriculture and Mechanical College of Texas
Yasuo Miyake	Meteorological Research Institute, Tokyo
Håkon Mosby	Universitet i Bergen
W. D. Nesteroff	Sorbonne, University of Paris
J. A. C. Nicol	The Laboratory, Plymouth, England
G. D. Nicholls	Manchester University, Great Britain
Makoto Omori	Hokkaido University
Gote Östlund	Swedish Geological Survey
E. Pastel	Office de la Recherche Scientifique et Technique Outre Mer
Charles E. Renn	Johns Hopkins University
V. Romanovsky	Centre de Recherches et d'Etudes Océanographiques, Paris, France
P. Slizewicz	French Atomic Energy Commission
M. J. Tucker	National Institute of Oceanography, Great Britain
K. Umshohara	Research Institute of Japan, Defense Agency
Georg Wüst	Universität Kiel, W. Germany

Employees and Staff

The following were in the employ of the Institution for the twelve-month period ending December 31, 1961.

Allen, Ethel B.
Allen, Norman T.
Anders, Wilbur J.
Andersen, Neil R.
Andersen, Nellie T.
Anraku, Masateru
Athearn, William D.
Backus, Cyril
Backus, Harold
Backus, Jeanne
Backus, Richard H.
Barbour, Rose L.
Barrett, Joseph R., Jr.
Barstow, Elmer M.
Bartlett, Martin R.
Baxter, Lincoln II
Baylor, Edward R.
Bazner, Kenneth E.
Behrens, Henry G.
Bergstrom, Stanley W.
Betterly, Robert
Birch, Francis J.
Blanchard, Daniel J.
Blanchard, Duncan C.
Blumer, Max
Bodman, Ralph H.
Bowen, Vaughan T.
Bowman, Warren O.
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Bradshaw, Alvin L.
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Brockhurst, Robert R.
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Cabral, John P.
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Carlson, Eric B.
Carlson, Ruth H. E.
Caron, Henri L.
Carritt, Dayton E.
Carter, Alwyn L.
Carter, Richard J.
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Coughlin, Brooks W.
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Day, Joseph V.
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Devitt, Howard B.
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Dimock, Alan D.
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Frank, Winifred H.
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Fuglister, Cecelia B.
Fuglister, Frederick C.
Fye, Paul M.
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Gallagher, William F.
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Giese, Graham S.
Gifford, James E.
Gill, Barbara L.
Gingrass, Norman
Graham, John W.

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Howe, Paul M.
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Howland, Paul C.
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Iselin, Columbus O'D
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John, Alfred C.
Johnston, Alexander T.
Kahler, Yolande A.
Kanwisher, John W.
Karram, Calvin D.
Ketchum, Bostwick H.
Ketchum, David D.
Knott, Sydney T., Jr.
Kostrzewa, John A.
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Kuenzler, Edward J.
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Matousek, William J.
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McCormack, Eileen M.
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Pasley, Gale G., Jr.
Patterson, John E.
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Pierce, George E.
Pierce, Samuel F.
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Pimental, John M.
Poole, Stanley E.
Pratt, Richard M.
Price, Don L.
Prostredny, Evelyn
Randall, Vivian H.
Reitzel, John S.
Ribeiro, Joseph
Richardson, William S.
Riegel, Richard E., Jr.
Rogers, Henry A., Jr.
Rogers, M. Dorothy
Ronne, F. Claude
Rooth, Claës G. H.
Rose, Lawrence
Rossby, Harriet A.
Roy, Alfred J.
Ryther, John H.
Sachs, Peter L.
Salthouse, James E.
Sanders, Howard L.
Sawyer, Harold E.
Scheltema, Rudolf S.
Schevill, William E.
Schleicher, Karl E.
Schroeder, Elizabeth H.
Schroeder, William C.
Sears, Mary
Seibert, Harry
Shaleski, Eleanor M.
Sharp, Arnold G.
Shields, William J.
Shodin, Leonard F.
Shultz, William S.
Silverman, Maxwell
Slabaugh, Luther V.
Snyder, Robert M.
Soderland, Eloise M.
Solberg, Otto

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Spooner, Charles E.
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Stanbrough, Jess H., Jr.
Stansfield, Richard
Stern, Melvin E.
Stetson, Thomas R.
Stevens, Raymond G.
Stillman, Stephen L.
Stimpson, John W.
Stimson, Paul B.
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Sutcliffe, Thomas O.L.
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Tometich, Louis J.
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Watson, Margaret E.
Watson, Stanley W.
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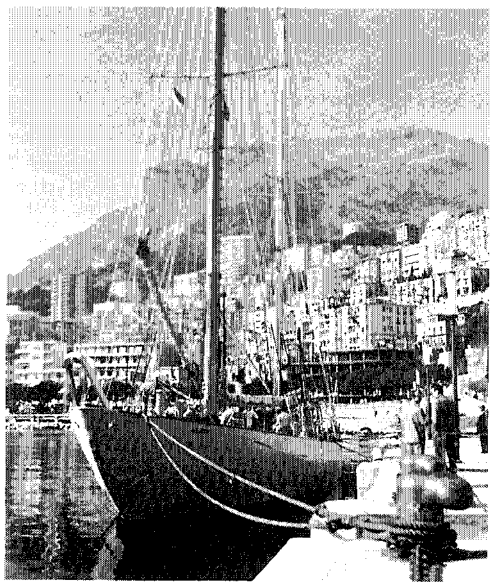
Webster, T. Ferris
Weeks, Robert G.
Welch, Linda E.
Whitney, Geoffrey G., Jr.
Wilde, Phillips B.
Wilharm, Larry
Wilkins, Charles H.
Williams, George A.
Wilson, Esther N.
Wing, Asa S.
Wing, Carleton R.
Winslow, Elisha F.
Witzell, Warren E.
Woodcock, Alfred H.
Woodward, Fred C., Jr.
Woodward, Ruth F.
Worthington, L. Valentine
Wright, W. Redwood
Yentsch, Anne L.
Yentsch, Charles S.
Zeigler, John M.



Monaco, February 1961

MUNNS

Publications

During 1961, sixty-two papers bearing contribution numbers were published. See *Author, Subject-Locality, Taxonomic Index* published in 1957 for a complete list through 1956 and subsequent annual reports for the publications appearing since 1956. These are also listed in the back of the annual volume of *Collected Reprints.*

No. 1045. ALFRED C. REDFIELD. The Tidal System of Lake Maracaibo, Venezuela. *Limnol. and Oceanogr.*, Vol. 6, No. 1, pp. 1-12. 1961.

No. 1050. S. M. MARSHALL and A. P. ORR. On the Biology of *Calanus finmarchicus.* XII. The Phosphorus Cycle: Excretion, Egg Production, Autolysis. *Jour. Mar, Biol. Assoc., U. K.*, Vol. 41, pp. 463-483. 1961.
R. J. CONOVER. Addendum. The Turnover of Phosphorus by *Calanus finmarchicus. Jour. Mar. Biol. Assoc., U. K.*, Vol. 41, pp. 484-488. 1961.

No. 1057. FRANCIS A. RICHARDS and BRUCE B. BENSON. Nitrogen/Argon and Nitrogen Isotope Ratios in Two Anaerobic Environments, the Cariaco Trench in the Caribbean Sea and Dramsfjord, Norway. *Deep-Sea Res.*, Vol. 7, No. 4, pp. 254-264. 1961.

No. 1063. MAX BLUMER and GILBERT OMENN. Fossil Chlorins in a Triassic Sediment. *Nature,* Vol. 191, No. 4784, pp. 161-162. 1961.

No. 1066. EARL E. HAYS. Comparison of Directly Measured Sound Velocities with Values Calculated from Hydrographic Data. *Jour. Acoust. Soc., Amer.*, Vol. 33, No. 1, pp. 85-88. 1961.

No. 1072. GEORGE D. GRICE. Calanoid Copepods from Equatorial Waters of the Pacific Ocean. *Fish. Bull., U. S. Fish and Wildlife Service (Fish. Bull.* No. 186) Vol. 61, pp. 171-246. 1961.

No. 1085. RICHARD H. BACKUS. Stranded Killer Whale in the Bahamas. *Jour. Mammal.*, Vol. 42, No. 3, pp. 418-419. 1961.

No. 1109. ROBERT L. EDWARDS. The Fishes of Richmond Gulf, Ungava, Canada. *Proc. Amer. Philosoph. Soc.*, Vol. 105, No. 2, pp. 196-205. 1961.

No. 1110. JOYCE C. LEWIN. The Dissolution of Silica from Diatom Walls. *Geochimica et Cosmochimica Acta,* Vol. 21, pp. 182-198. 1961.

No. 1114. J. E. G. RAYMONT and ROBERT J. CONOVER. Further Investigations on Carbohydrate Content of Marine Zooplankton. *Limnol. and Oceanogr.*, Vol. 6, No. 2, pp. 154-164. 1961.

No. 1118. J. H. RYTHER, D. W. MENZEL and R. F. VACCARO. Diurnal Variations in Some Chemical and Biological Properties of the Sargasso Sea. *Limnol. and Oceanogr.*, Vol. 6, No. 2, pp. 149-153. 1961.

No. 1119. D. W. MENZEL and J. H. RYTHER. Annual Variations in Primary Production of the Sargasso Sea off Bermuda. *Deep-Sea Res.*, Vol. 7, No. 4, pp. 282-288. 1961.

No. 1120. JOHN H. RYTHER and DAVID W. MENZEL. Primary Production in the Southwest Sargassa Sea, January–February, 1960. *Bull. Mar. Sci., Gulf and Caribbean,* Vol. 11, No. 3, pp. 381-388. 1961.

No. 1121. DAVID W. MENZEL and JOHN H. RYTHER. Zooplankton in the Sargasso Sea off Bermuda and its Relation to Organic Production. *Jour. du Conseil,* Vol. 26, No. 3, pp. 250-258. 1961.

Publications

No. 1122. R. M. Pratt. Erratic Boulders from Great Meteor Seamount. *Deep-Sea Res.*, Vol. 8, No. 2, pp. 152-153. 1961.

No. 1123. D. W. Menzel and J. H. Ryther. Nutrients Limiting the Production of Phytoplankton in the Sargasso Sea, with Special Reference to Iron. *Deep-Sea Res.*, Vol. 7, No. 4, pp. 276-281. 1961.

No. 1127. George D. Grice. *Candacia ketchumi*, a New Calanoid Copepod from the North-Western Part of the Sargasso Sea. *Crustaceana,* Vol. 2, No. 2, pp. 126-131. 1961.

No. 1129. J. C. Swallow and L. V. Worthington. An Observation of a Deep Countercurrent in the Western North Atlantic. *Deep-Sea Res.*, Vol. 8, No. 1, pp. 1-19. 1961.

No. 1131. H. G. Farmer and D. D. Ketchum. Chap. 5. An Instrumentation System for Wave Measurements, Recording and Analysis. *Proc. Seventh Cong. Coastal Eng., The Hague, Netherlands, Aug. 1960, (Publ. Counc. Wave Res., Eng.)* Vol. 1, Ch. 5, pp. 77-99. 1961.

No. 1132. Rudolf S. Scheltema. Metamorphosis of the Veliger Larvae of *Nassarius obsoletus* (Gastropoda) in Response to Bottom Sediment. *Biol. Bull.*, Vol. 120, No. 1, pp. 92-109. 1961.

No. 1135. A. B. Arons, A. P. Ingersoll, and T. Green III. Experimentally Observed Instability of a Laminar Ekman Flow in a Rotating Basin. *Tellus,* Vol. 13, No. 1, pp. 31-39. 1961.

No. 1136. T. T. Sugihara and Vaughan T. Bowen. Radioactive Rare Earths from Fallout for a Study of Particle Movement in the Sea. In: Radioisotopes in the Physical Sciences and Industry, pp. 57-65. 1961.

No. 1137. Hartley Hoskins and S. T. Knott. Geophysical Investigation of Cape Cod Bay, Massachusetts, Using the Continuous Seismic Profiler. *Jour. Geol.*, Vol. 69, No. 3, pp. 330-340. 1961.

No. 1138. W. V. R. Malkus and G. Veronis. Surface Electroconvection. *The Physics of Fluids,* Vol. 4, No. 1, pp. 13-23. 1961.

No. 1139. Joseph Levine. A Spherical Vortex Model of the Buoyant Thermal in Cumulus and Dry Convection. *Schweizer Aero-Revue,* Zurich, Vol. 36, No. 2, pp. 100-101. 1961.

No. 1144. Parker D. Trask. Sedimentation in a Modern Geosyncline off the Arid Coast of Peru and Northern Chile. *Internat. Geol. Congr., XXI Session, Norden, 1960, Internat. Assoc. of Sedimentology,* Pt. 23, pp. 103-118. 1961.

No. 1145. Joanne S. Malkus, Claude Ronne and Margaret Chaffee. Cloud Patterns in Hurricane Daisy, 1958. *Tellus,* Vol. 13, No. 1, pp. 8-30. 1961.

No. 1146. Dean F. Bumpus. Drift bottle records for the Gulf of Maine, Georges Bank, and the Bay of Fundy, 1956-58. *U. S. Fish and Wildlife Service, Spec. Sci. Rept., Fish.*, No. 378, pp. 1-127. 1961.

No. 1147. R. R. Brockhurst, J. G. Bruce, Jr. and A. B. Arons. Refraction of Underwater Shock Waves by a Strong Velocity Gradient. *Jour. Acoust. Soc., Amer.*, Vol. 33, No. 4, pp. 452-456. 1961.

No. 1148. W. V. R. Malkus. Similarity arguments for fully developed turbulence, *Nuovo Cimento* Ser. 10, Vol. 22 (Suppl. 1): 376-384. 1961.

Publications

No. 1150. JACK McLACHLAN. The Effect of Salinity on Growth and Chlorophyll Content in Representative Classes of Unicellular Marine Algae. *Canadian Jour. Microbiol.*, Vol. 7, pp. 399-406. 1961.

No. 1152. PETER M. SAUNDERS. An Observational Study of Cumulus. *Jour. Meteorol.*, Vol. 18, No. 4, pp. 451-467. 1961.

No. 1153. BRUCE B. BENSON and PETER D. M. PARKER. Nitrogen/Argon and Nitrogen Isotope Ratios in Aerobic Sea Water. *Deep-Sea Res.*, Vol. 7, No. 4, pp. 237-253. 1961.

No. 1154. BRUCE B. BENSON and PETER D. M. PARKER. Relations among the Solubilities of Nitrogen, Argon and Oxygen in Distilled Water and Sea Water. *Jour. Phys. Chem.*, Vol. 65, pp. 1489-1496. 1961.

No. 1155. M. BLUMER and G. S. OMENN. Fossil Porphyrins: Uncomplexed Chlorins in a Triassic Sediment. *Geochimica et Cosmochimica Acta*, Vol. 25, pp. 81-90. 1961.

No. 1156. HERBERT RIEHL and JOANNE MALKUS. Some Aspects of Hurricane Daisy, 1958. *Tellus*, Vol. 13, No. 2, pp. 181-213. 1961. (Also, published as *National Hurricane Research Project, Rept.* No. 46 [multilithed]).

No. 1157. PIERRE WELANDER. Theory of Very Long Waves in a Zonal Atmospheric Flow. *Tellus*, Vol. 13, No. 2, pp. 140-155. 1961.

No. 1158. JOHN M. ZEIGLER and SHERWOOD D. TUTTLE. Beach Changes Based on Daily Measurements of Four Cape Cod Beaches. *Jour. Geol.*, Vol. 69, No. 5, pp. 583-599. 1961.

No. 1159. R. C. DUGDALE, DAVID W. MENZEL and JOHN H. RYTHER. Nitrogen Fixation in the Sargasso Sea. *Deep-Sea Res.* Vol. 7, No. 4, pp. 298-300. 1961.

No. 1160. FLOYD M. SOULE, PETER A. MORRILL and ALFRED P. FRANCESCHETTI. Physical Oceanography of the Grand Banks Region and the Labrador Sea in 1960. *U. S. Coast Guard Bull.*, No. 46, pp. 31-114. 1961.

No. 1165. RICHARD CIFELLI. 227. *Globigerina incompta*, a New Species of Pelagic Foraminifera from the North Atlantic. *Contrib. Cushman Found. Foram. Res.*, Vol. 12, Pt. 3, pp. 83-86, Pl. 4. 1961.

No. 1166. MELVIN E. STERN. The Stability of Thermoclinic Jets. *Tellus*, Vol. 13, No. 4, pp. 503-508. 1961.

No. 1167. WOLFGANG WIESER and JOHN KANWISHER. Ecological and Physiological Studies on Marine Nematodes from a Small Salt Marsh near Woods Hole, Massachusetts. *Limnol. and Oceanogr.*, Vol. 6, No. 3, pp. 262-270. 1961.

No. 1168. RAYMOND SIEVER, ROBERT M. GARRELS, JOHN KANWISHER and ROBERT A. BERNER. Interstitial Waters of Recent Marine Muds off Cape Cod. *Science*, Vol. 134, No. 3485, pp. 1071-1072. 1961.

No. 1170. BERT BOLIN and HENRY STOMMEL. On the Abyssal Circulation of the World Ocean. IV. Origin and Rate of Circulation of Deep Ocean Water as Determined with the Aid of Tracers. *Deep-Sea Res.*, Vol. 8, No. 2, pp. 95-110. 1961.

No. 1171. A. H. WOODCOCK and A. T. SPENCER. Lava-Sea-Air Contact Areas as Sources of Sea-Salt Particles in the Atmosphere. *Jour. Geophys. Res.*, Vol. 66, No. 9, pp. 2873-2887. 1961.

Publications

No. 1173. FERRIS WEBSTER. A Description of Gulf Stream Meanders off Onslow Bay. *Deep-Sea Res.*, Vol. 8, No. 2, pp. 130-143. 1961.

No. 1174. FERRIS WEBSTER. The Effect of Meanders on the Kinetic Energy Balance of the Gulf Stream. *Tellus*, Vol. 13, No. 3, pp. 392-401. 1961.

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TREASURER'S REPORT

The accounts for the year 1961 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds at December 31, 1961, was $3,549,925 of which $1,086,345 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 $5,980,290. Endowment fund investments and income received therefrom are summarized in Schedule C.

The plant fund accounts on the Balance Sheet reflect the changes during the year resulting from the sale of the Aries, the acquisition of two parcels of real estate, and the work on the new research vessel, as well as the usual addition to the plant reserve funds resulting from depreciation accruals and write-offs of deferred charges.

Income received on endowment assets was $190,208 for the year ended December 31, 1961, compared with $192,354 the previous year. Included in endowment income is $5,731 of parking lot income, which represented a 5 per cent return on this investment. The balance of the parking lot income, amounting to $11,786, was transferred to endowment assets, to amortize the costs of this property. A loss of $3,747.00 on 38 Water Street property incurred during renovation of the property for the new tenant was charged against endowment income. This makes a net real estate income included in endowment income of $1,984 for the year 1961. Endowment income represented a return on endowment fund assets of 3.2 per cent at year-end market quotation, 5.4 per cent on the book amount and 7.7 per cent on the contributed amount of the endowment fund.

Endowment income was allocated for 1961 operating expenses at the rate of 6 per cent of the book amount of original endowment funds, or $146,262. Of the balance of endowment income, $43,946, there was transferred to the income and salary stabilization reserve $42,984 and to unexpended balance of gifts from Oceanographic Associates as income from investment of life memberships $962.

The Institution's 1961 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to $111,661. The trust is administered by three trustees. The balance of the old Retirement Fund, administered by the Treasurer, amounted to $75,931 as at December 31, 1961. The 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 1961. Interest totalling $2,871 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 80 cents was spent for direct costs of research activity, 15 cents for general and administration expenses and 5 cents for plant operation and miscellaneous. Administrative salaries amounted to only 5 cents of each dollar of total expense. Included in the 15 cents of general and administration expenses was 4 cents for staff benefits (group insurance, social security taxes, and contributions to retirement plan).

LYBRAND, ROSS BROS. & MONTGOMERY
ACCOUNTANTS AND AUDITORS
80 FEDERAL ST. LI 2-3700

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1961 and the related statements of income, operating expenses and unappropriated general fund and of changes in funds 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 statements present fairly the financial position of Woods Hole Oceanographic Institution at December 31, 1961 and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

Boston, Massachusetts
March 23, 1962

Lybrand, Ross Bros. + Montgomery

BALANCE SHEET

As at December 31, 1961

ASSETS

Endowment Fund Assets:		
Investments (Schedule C):		
Bonds (market quotations $1,858,641)		$1,918,334
Stocks (market quotations $3,897,958)		1,407,900
Real estate		162,390
		3,488,624
Cash		61,301
		3,549,925
Plant Fund Assets (note):		
Laboratory plant and equipment		920,425
Vessels and equipment		514,967
Other property		254,541
Vessels under construction		481,084
Total plant		2,171,017
Advance to current funds		821,282
		2,992,299
Current Fund Assets:		
Cash		919,883
Time deposit		50,000
Accounts receivable:		
U. S. Government	$230,241	
Other	10,873	241,114
Unbilled costs on research contracts:		
U. S. Government	758,194	
Other	11,337	769,531
Supplies inventories		43,128
Deferred charges		43,000
		2,066,656
Less advance from plant funds		821,282
		1,245,374
		$7,787,598

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

BALANCE SHEET

As at December 31, 1961

LIABILITIES

Endowment Funds:		
Unrestricted as to income	$2,000,000	
Unrestricted as to principal and income	42,160	$2,042,160
For upkeep of plant		419,420
Henry Bryant Bigelow Chair of Oceanography		2,000
Accumulated net gain on sales of investments		1,086,345
		3,549,925
Plant Funds:		
Invested in plant		2,171,017
Unexpended:		
Fund for design and construction of a research vessel		377,812
Fund for acquisition of capital assets		247,000
General plant and equipment reserve		144,366
Fund for construction of a small vessel		52,104
		2,992,299
Current Liabilities and Funds:		
Accounts payable and accrued expenses		226,737
Contribution payable to employees' retirement plan and trust		111,661
Unexpended balances of gifts and grants for research:		
Government	432,504	
Other	90,879	523,383
General fund:		
Income and salary stabilization reserve	354,441	
Unappropriated	29,152	383,593
		1,245,374
		$7,787,598

STATEMENT OF INCOME, OPERATING EXPENSES AND UNAPPROPRIATED GENERAL FUND

For the Year Ended December 31, 1961

Income:		
For sponsored research (including $1,027,309 gifts and grants expanded):		
For direct costs		$4,284,949
For indirect costs		952,316
Fees for use of facilities		144,236
		5,381,501
Endowment income (Schedule C)	$190,208	
Less amounts added to income and salary stabilization reserve ($42,984) and to unexpended balance of gifts from Oceanographic Associates ($962)	43,946	146,262
Miscellaneous		6,890
Total income availed of		5,534,653
Operating Expenses:		
Direct costs of research activity (Schedule A):		
Salaries and wages		1,404,702
Vessel operations		1,230,257
Materials and services		1,628,565
Travel		116,373
		4,379,897
Indirect costs:		
General and administration (Schedule B)	801,366	
Plant operation (Schedule B)	277,578	
Miscellaneous	6,526	1,085,470
Total operating expenses		5,465,367
Excess of income		69,286
Additions to plant from current funds — books and equipment purchased		43,799
		25,487
Unappropriated general fund, January 1, 1961		3,665
Unappropriated general fund, December 31, 1961		$ 29,152

STATEMENT OF CHANGES IN FUNDS

For the Year Ended December 31, 1961

	Endowment Funds	Plant Funds: Invested in Plant	Plant Funds: Unexpended	Unexpended Balances of Gifts and Grants for Research (note)	General Fund
BALANCE, December 31, 1960	$3,483,053	$2,005,387	$353,373	$ 473,549	$315,122
Gifts (including Associates life membership dues) and grants received	8,876		759,000*	1,077,143	
Additions from current year's revenues:					
Books and equipment purchased		43,799			
Provision for depreciation			95,877		
Provision for income and salary stabilization reserve					42,984
Excess of income over provisions and expenses					25,487
Net gain on sales of investments	57,996				
Proceeds from sale of assets			84,985		
Cost of assets disposed of		(300,437)			
Invested in plant		422,268	(422,268)		
Expended				(1,027,309)	
Funds received in 1961 applied to 1960 expenditures			(49,685)		
BALANCE, December 31, 1961	$3,549,925	$2,171,017	$821,282	$ 523,383	$383,593

*Includes $750,000 received on grant for design and construction of a research vessel.

NOTE — Unexpended balances consist of amounts received in advance of expenditure, and do not include receipts or expenditures under reimbursement type contracts.

Schedule A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1961

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U. S. GOVERNMENT CONTRACTS	$1,374,607	$1,148,586	$1,554,804	$105,388	$4,183,385
OTHER SPONSORED RESEARCH	7,250	59,967	31,930	2,417	101,564
Total direct costs of sponsored research	1,381,857	1,208,553	1,586,734	107,805	4,284,949
INSTITUTION RESEARCH	22,845	21,704	41,831	8,568	94,948
Total direct costs of research	$1,404,702	$1,230,257	$1,628,565*	$116,373	$4,379,897

*Includes grants and fellowships:

U. S. Government contracts	$21,200
Other sponsored research	23,146
Institution research	25,280
	$69,626

Schedule B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1961

GENERAL AND ADMINISTRATION

General Expenses:		
Staff benefits:		
Contributions to retirement plan		$111,661
Social security taxes		54,217
Employee health benefits		20,769
Group insurance		6,779
		193,426
Shop services		136,532
Housing, net		1,421
Administration Expenses:		
Salaries and wages	$287,632	
Insurance, travel, supplies and other	182,355	469,987
		$801,366

PLANT OPERATION

Salaries and wages		$ 67,898
Provision for depreciation (credited to general plant and equipment reserve)		76,456
Other repair costs	$52,518	
Heat, light and power	32,164	
Other	48,542	133,224
		$277,578

Schedule C

SUMMARY OF INVESTMENTS

As at December 31, 1961

	Book Amount	% of Total	Market Quotation	% of Total	Endowment Income
BONDS:					
Government	$ 536,330	15.37	$ 533,946	9.02	$ 18,020
Railroad	410,325	11.76	379,080	6.40	19,923
Public utility	360,673	10.34	344,051	5.81	14,369
Industrial	435,299	12.48	422,445	7.14	17,893
Financial and investment	175,707	5.04	179,119	3.03	7,379
Total bonds	1,918,334	54.99	1,858,641	31.40	77,584
STOCKS:					
Preferred	259,746	7.45	250,988	4.24	12,500
Common:					
Public utility	330,728	9.48	1,148,152	19.40	29,069
Industrial	560,092	16.05	1,874,099	31.66	51,068
Miscellaneous	257,334	7.38	624,719	10.55	18,003
Total common stocks	1,148,154	32.91	3,646,970	61.61	98,140
Total stocks	1,407,900	40.36	3,897,958	65.85	110,640
REAL ESTATE	162,390	4.65	162,390*	2.75	1,984
Total investments	$3,488,624	100.00	$5,918,989	100.00	$190,208

*At book amount.