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International Cooperation in Marine Sciences

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World-wide cooperation among astronomers, meteorologists, and other geophysicists has long been taken for granted. For generations, in peace and war, astronomers have freely communicated their observations across national boundaries, and the international meteorological network has functioned continuously except under conditions of actual war. Such cooperation has lagged in studies of the ocean because of the lack of economic necessity, because of the wide differences in the level of development of marine sciences in different countries and different oceanic regions, and because of the great diversity of the scientific disciplines involved. Yet, like the atmosphere, the ocean cannot be separated into isolated parts; what happens in any part of the sea ultimately affects the waters everywhere. With the scientific resources that are now available, no one country can find out all it needs to know about the oceans except through the cooperative activity of many countries.

Although no part of the oceans has been well described, in certain areas our information is completely inadequate. Very little is known about the inshore waters off the coasts of the Indian Ocean, the east coast of Asia south of latitude 25°N, or the east and west coasts of South America. For any rational development of marine resources, simple but systematic observations are needed in all these coastal regions.

The Indian Ocean is the deep-sea area in which the deficiency of descriptive information is greatest. It is almost completely unexplored, from the scientific point of view. Not much more is known about the South Pacific. Knowledge of the South Atlantic is somewhat better, but more exploration is needed there, as well as in the Arctic Ocean and in the equatorial regions of both the Atlantic and Pacific.

In contrast to the need for elementary description in large oceanic areas, the most advanced methods and ideas of modern mathematics, physics, chemistry, and biology can be employed in studying some aspects of the marine sciences, with remarkable effectiveness. Development of these sciences throughout the world depends, in part, on enlisting the interest of workers in the basic sciences from many different countries in the problems of oceanic research.

On a regional basis, international cooperation in the marine sciences began some fifty years ago, when the countries bordering on the North Sea and the eastern North Atlantic formed the International Council for the Exploration of the Sea. Later the International Association of Physical Oceanography and the International Hydrographic Bureau began to deal with certain aspects of the subject —namely, the movements and properties of sea water and the problems of ocean surveys for navigational purposes. In more recent years, a series of international fisheries commissions has been established. These commissions have initiated cooperative research programs on the biological and environmental factors affecting a particular fishery or a particular part of the ocean. Such regional international organizations as the Pacific Science Association and the Pan American Institute of Geography and History have standing committees that compile and assimilate reports of oceanographic activities and arrange for exchanges of information. But, until the last two years, there has been no organization concerned with all the marine sciences on a world-wide basis, either from the standpoint of the fostering and coordinating of observations or from that of communication between workers in the different sciences of the sea.

The first world-wide attempt to make coordinated scientific observations in all the oceans is being carried out during the International Geophysical Year. Some seventy ships are taking part in an internationally planned program of observations, and many new shore stations are being operated, particularly on oceanic islands, to supplement the previously existing network of observatories.

The United Nations Educational, Scientific, and Cultural Organization, in its natural sciences program, has recently begun to place emphasis on the international development of the sciences of the sea, especially in regions where there has been little emphasis in the past. To guide this work, which is being carried out in cooperation with the Food and Agriculture Organization of the United Nations, UNESCO has established an International Advisory Committee on Marine Sciences. At the same time, the International Council of Scientific Unions, having in mind the successful planning of the IGY program, has established a Special Committee on Oceanic Research, with responsibility for developing an international cooperative program of fundamental research. Each of these committees has now had a formal meeting, and possibilities for the future have been to some extent clarified.

UNESCO's Marine Science Program

UNESCO's nine-man International Advisory Committee on Marine Sciences met in Lima, Peru, in October 1956 under the chairmanship of G. E. R. Deacon, director of the National Institute of Oceanography, near Godalming, England. Other members of the committee, selected to represent different regions and different marine science disciplines, are D. V. Bal (India); Anton F. Bruun (Denmark); Marc Eyries (France); Koji Hidaka (Japan); Luis Howell-Rivero (Cuba); R. Revelle (United States); D. J. Rochford (Aus-

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tralia); and Lev Zenkevitch (U.S.S.R.). Each member serves for three years. The meeting in Lima was preceded by a meeting of an interim committee, with virtually the same members, in Tokyo in October 1955.

The amount of funds available to UNESCO for promotion of scientific research is not comparable to the expenditure of any major country for this purpose. Consequently, its activities in the sciences must be very largely confined to the planning of international action, facilitation of the making of contacts among scientists of different countries, and exchange of ideas and information.

In accordance with the advice of the International Advisory Committee, the principal objective of UNESCO's marine sciences program is to encourage development of these sciences in regions where little is known about the oceans or the organisms that they contain and where there is economic and social need for increasing the harvest of food from the sea. Up to the present, UNESCO has taken steps toward the realization of this objective by providing (i) fellowships for advanced training of scientists from these regions at major centers of marine research; (ii) intensive training programs, lasting from a few weeks to a few months, for technicians and field workers within such a region; (iii) intraregional conferences that give local scientists opportunities to discuss their common problems; (iv) international symposia, conducted by scientists of wide reputation on general topics in the marine sciences, in countries or regions where these sciences have been little developed; and (v) funds to make possible the joint planning of cooperative observational programs. A modest start has been made in all these directions.

During 1956–57, grants were made for eight fellowships for advanced training, to Hong Kong, Japan, Mexico, Thailand, Argentina, Brazil, India, and the Philippines, respectively. A three-weeks' course in marine biology and taxonomy was held early in 1957 at the Oceanographic Institute at Nhatrang, Vietnam, and a course in research methods in marine biology and physical oceanography was given in São Paulo, Brazil, in 1955. Three meetings of South American marine biologists have been held; the meeting at Lima followed the third such conference, at the marine biology station of the University of Chile at Viña del Mar.

A Western Pacific oceanographic conference was held in Tokyo before the preliminary meeting of the interim committee, in 1955, and a symposium on problems in physical oceanography and biology in the Eastern Pacific, attended by scientists from the United States, Mexico, Peru, Chile, Brazil, Uruguay, and Argentina, in addition to members of the International Advisory Committee, was held prior to the Lima meeting. Travel funds have been provided to enable scientists from Australia, New Zealand, and New Caledonia to consult together concerning a joint study of the circulation of the Southeast Pacific Ocean and Tasman Sea.

The symposium at Lima centered around one of the most remarkable phenomena in the oceans, the Peru Current (the name applied to the north-flowing current along the west coast of South America). As is true of all currents along the eastern boundaries of oceans, this current is shallow, broad, and slow. But its waters are among the most productive on earth. It has been estimated that the guano birds of Peru annually harvest some 2½ million tons of pelagic fish, about 10 percent of the total annual catch of all the world's fisheries. This extraordinarily high fertility depends upon the upwelling of cold, nutrient-rich waters from intermediate depths, and these vertical movements are reflected also in tongues of comparatively cold water extending parallel to the coast. Because it depends upon the speed and direction of the southerly and southeasterly winds, upwelling off the coast of South America is an intermittent and highly variable process.

One of the striking facts brought out at the symposium was the considerable degree of asymmetry between the Peru Current and the corresponding California Current off the west coast of North America. As one looks northward toward the equator, from off the coast of Peru, the coastline trends northwestward, while off the coast of California and Mexico, as one looks southward, the coastline trends southeastward. In the comparatively low latitudes of Peru, the southeasterly trades blow nearly parallel to the coast and are much more intense than the winds to the south. This intensification of the winds accelerates the northwestward flow of the surface waters; consequently, vertical upward motion of the waters from mid-depths takes place on a large scale. Shifts in the wind system are apparently responsible for variations in the southgoing inshore countercurrent and in extreme cases produce the catastrophic series of atmospheric and oceanic events known as "El Niño" (because they occur at Christmas)—severe rainstorms and floods on land and mass mortalities of marine birds and fishes.

This model of the Peru Current and the associated inshore countercurrent is based on tenuous oceanographic observations, and it was clear from the discussions of the symposium that series of measurements very much more complete in time and area are required before a more satisfactory picture can be obtained. A new start is being made toward obtaining the necessary measurements through the recently organized Council for Hydrobiological Investigations of the Peruvian Government.

One of the most important proposals made by the International Advisory Committee has been that an international oceanographic ship should be commissioned and operated, either by UNESCO itself, under contract, or by a group of countries in accordance with the pattern for international operation of research facilities set by CERN (Comité Européen de Recherche Nucléaire). This ship would be used primarily in such a little-known area as the Indian Ocean and could serve both for obtaining scientific information and as a training ship for younger scientists in the bordering countries.

Members of the committee have advised against the establishment, in areas where the marine sciences have been little developed, of international laboratories supported with funds from governments of neighboring countries. But they have stated that new laboratories, endowed by foundations or other private sources (in order to give stability and ensure freedom for research), would be of great value. Marine biology might be emphasized at first, with expansion later into other fields as additional funds become available.

Financial Support

Financial support from UNESCO for scientific work in underdeveloped countries can be obtained in several ways. Under the technical assistance program of the United Nations, funds contributed by many different countries are used to support projects of direct economic benefit requested by the country in which the work is to be done. The Technical Assistance Board of the United Nations decides on the total yearly allocation for each beneficiary country and on the total amount of funds to be handled yearly by each operating agency (UNESCO, Food and Agriculture Organization, World Health Organization, and so on). In 1956, about $1 million was allocated to the Natural Sciences Department of UNESCO. Because the programs are established separately by the various countries that receive assistance, the technical assistance funds cannot be used as a means of developing an internationally coordinated scientific research program. They can be used to send experts, to provide 3- to 12-month fellowships, and to purchase equipment.

UNESCO, through the regular budget established every two years by its General Conference, can assist member states in carrying out educational, scientific, or

cultural projects regardless of their immediate economic repercussion. Requests are submitted by the member states, but there is no priority allocation to the different countries, and the entire program is concentrated in particular fields of science or technology. During 1955–56 UNESCO spent about $100,000 for aid to member states for projects in natural sciences.

In both the technical assistance and the aid-to-member-states programs, the national commissions, advised by the UNESCO Science Cooperation Offices, play an important role in framing and choosing projects. Funds for regional conferences and training programs are provided from the budget of the Science Cooperation Offices.

In addition to the fellowships provided under technical assistance or aid-to-member-states activities, fellowships, generally for 12 months, are granted under the exchange-of-persons program of UNESCO. The number of fellowships for each particular field of activity is decided by UNESCO's General Conference, on the proposal of the director general.

In the field of research, small sums are assigned in the UNESCO budget to specific scientific programs (such as arid-zone and humid-tropics research and marine sciences). Part of these funds are used by UNESCO for research contracts with appropriate scientific institutions to encourage investigations of international scope. The total marine-sciences budget, however, is only $31,770 for 1957 and $22,170 for 1958, and only a small part of this sum is available for research contracts. This year the Geophysical Institute of Bergen, Norway, is being given financial assistance in order that it may participate in a multiple-ship current-measuring operation in the North Atlantic Ocean, to be undertaken jointly with the National Institute of Oceanography (United Kingdom) and the Woods Hole Oceanographic Institution (United States).

Subventions are granted by the General Conference of UNESCO to international scientific organizations for the support of international meetings, publications, and the planning of international activities. For example, the International Council of Scientific Unions received $360,000 in 1955–56 (out of a total of $448,000 granted to all international scientific organizations). The initial expenses of the Special Committee on Oceanic Research were paid from this subvention to the International Council of Scientific Unions.

The UNESCO marine sciences program has also directly supported certain advanced symposia organized by scientific bodies. The recent symposium in Bergen, Norway, held under the auspices of the International Council for the Exploration of the Sea, on the measurement of primary productivity in the sea, and the symposium on the circulation of the deep waters of the ocean, held at the meeting of the International Association of Physical Oceanography in Toronto, Ontario, in September 1957, were both partly financed by UNESCO.

A third area of activity has been that of furnishing scientific assistance to other United Nations organizations; for example, a report on sea and oceanic disposal of atomic wastes has been prepared, under the supervision of H. Charnock of the National Institute of Oceanography (United Kingdom), for the United Nations Scientific Committee on the Effects of Atomic Radiation. A report on scientific considerations related to the continental shelf has been completed by an international group of experts for use in the forthcoming United Nations conference on the Law of the Sea.

UNESCO, because of its broad educational and scientific responsibilities, can draw the attention of the governments of its member states to the importance of marine research without overemphasizing the prospects of immediate useful results. It can stress the longer-range possibilities and the value of the marine sciences as a means of introducing science for its own sake.

For example, at the Tokyo meeting, the interim committee recommended that in certain developed countries, such as Japan, Australia, the countries of Europe, and India, establishment of new national centers for fundamental research on the high seas, at least partly supported with government funds, would be highly desirable. Experience in Great Britain and North America shows that in such laboratories a diversity of disciplines should be represented, including applied mathematics, theoretical and experimental physics and geophysics, chemistry (geochemistry, biochemistry, and analytical chemistry), geology, meteorology, and biology (both experimental biology and natural history). A certain "critical mass" is essential—the scientific staff should number at least ten and preferably more, and these scientists must have adequate support in facilities and technically trained assistance. The research center should have an intimate relationship with one or more universities.

Finally, UNESCO, as an intergovernmental organization, can, by various means, encourage the member states to maintain policies favorable to international scientific work on the oceans. Examples are the facilitating of exchange of scientists between research vessels and laboratories of different countries in the face of political difficulties, the relaxing of customs regulations and of other barriers to the exchange of scientific instruments for use in international cooperative marine investigations, and the maintaining of freedom of scientific research on the continental shelf and offshore waters. Since 1949, the International Law Commission of the United Nations has been engaged in a study of the regimes of the high seas and territorial waters. An international conference of plenipotentiaries to examine the Law of the Sea has been called by the General Assembly of the United Nations, to be held in 1958. UNESCO's International Advisory Committee on Marine Sciences, although recognizing that each country has a right to protect its coastal waters from economic exploitation, and that there are also certain military considerations, has urged that there should be no restriction on scientific studies by research vessels of any nation, provided that the results are published and the work itself is open to exchange of scientists. This viewpoint has been supported by UNESCO's Advisory Committee on Research in the Natural Sciences. In April 1957 the latter committee adopted a resolution urging the director general of UNESCO "to present the International Conference on the Law of the Sea with proposals ensuring freedom of fundamental research on waters, sea bed and subsoil of the continental shelf carried out by any nation with open publication in the interest of all." This committee has further expressed serious concern about the possible consequences of Article 68 of the draft Articles of the Law of the Sea prepared by the International Law Commission, "which in its present form does not guarantee the freedom of scientific research on the physical characteristics, geology and biology of the sea bed and subsoil of the continental shelf."

Special Committee on Oceanic Research

The Special Committee on Oceanic Research of the International Council of Scientific Unions consists of 15 members. Six members were nominated by the International Council of Scientific Unions, four by the International Union of Geodesy and Geophysics, two by the International Union of Biological Sciences, and one each by the International Union of Pure and Applied Physics, the International Union of Pure and Applied Chemistry, and the International Geographical Union. This committee held its first meeting at the Woods Hole Oceanographic Institution from 28 to 30 Aug. 1957, under the chairmanship of director C. O'D. Iselin. Other members present at the meeting were A. F. Bruun (Denmark); G. Bohnecke (Germany);

L. R. A. Capurro (Argentina); G. E. R. Deacon (United Kingdom); M. N. Hill United Kingdom); N. B. Marshall (United Kingdom); Y. Miyake (Japan); H. Mosby (Norway); N. W. Rakestraw (United States); R. Revelle (United States); E. Steeman Nielsen (Denmark); and L. Zenkevitch (U.S.S.R.). Y. Le Grand of France and N. K. Pannikar of India were unable to attend.

The committee took as its first task that of defining the needs for further international scientific cooperation in the marine sciences. It is clear that, as in other sciences, a very large part of the pioneering research and new ideas concerning the oceans must come from individual scientists or small groups working independently. A broadly based international organization can be helpful, however, in several ways. It can serve as a sounding board to emphasize the economic and social importance of greater knowledge of the oceans and can thereby assist marine scientists in different countries to obtain support for their work. By arranging wide dissemination of ship operating schedules, it can help scientists to participate in cruises or to obtain desired data and collections. By pointing out areas where work is needed and the kinds of observations that should be made, it can encourage more efficient use of research vessels. It can facilitate the exchange of techniques, personnel, samples, and data. By sponsoring or encouraging discussions of problems of ocean research at national and international scientific meetings, it can help enlist scientists from other fields. It can arrange for coordinated work, by research vessels at sea and by shore observatories of different countries, in attacking problems where a wide network of observations is needed. It can serve as a mechanism for the standardization and intercalibration of techniques and instruments and can arrange for the introduction of techniques newly developed in one country or laboratory to other scientific groups elsewhere in the world.

The committee considered that its principal objective should be to encourage and coordinate an international program of observation and measurement in the deep ocean. One point of this program would involve an intensive effort to understand the relationships between the dynamics of the upper water layers and the plant and animal populations. Another would be the study of the region from below the thermocline down to the greatest depths of the sea and beneath the sea floor. Because so little is known about this region, its investigation will be, to a large extent, a task of widespread exploration. Such exploration must proceed hand-in-hand with theoretical studies and development of new techniques by individual scientists and must supplement rather than interfere with their work.

In making a decision to concentrate its program in the deep oceanic regions, the committee recognized that geophysical and geological studies of the earth beneath the sea are necessary for elucidating the structure and history of the earth. With regard to the waters and the organisms that they contain, it emphasized three long-range problems that may be critical to the future welfare of mankind.

Long-Range Problems

The first of the long-range problems concerns the use of the deep sea as a receptacle for the waste products of our industrial civilization. This may be a particularly important problem in the future, when very large quantities of poisonous radioactive wastes will be produced through the industrial use of atomic power. We need to know whether we can dispose of at least part of these wastes in the deep sea or whether the circulation of the ocean or the vertical movements of the fauna will result in a rapid transport of dangerous material to levels in the sea from which some of the world's food supplies are derived.

The second problem concerns the oceans as an important source of protein food for many of the world's peoples. With the growth of populations, man's need for food from the sea may be expected to increase rapidly. The living resources of the oceans are by no means infinite, and, like the land, the oceans differ widely in fertility in different parts. The fertile areas are those where nutrient trace substances, essential for plant life, are brought up from the deep waters. To obtain the maximum harvest, the processes by which this occurs must be elucidated.

The third problem is perhaps the least well understood of the three. It concerns the role of the oceans in climatic change. During the last 50 years the average temperature over eastern North America and northern Europe has increased markedly, while elsewhere prolonged droughts have destroyed the work of decades. Will this trend continue over the next 50 years, or will it be reversed? Because we do not have sufficient understanding of the processes that control climate, we are quite unable to make a forecast. Nevertheless, a prediction of future climate would be of inestimable value to society.

The waters of the oceans may play an important role in changing climates. For example, an excess of heat from the sun can be stored in the deep water and slowly released over many years, warming the air. Likewise, the amount of carbon dioxide in the air controls, at least to some extent, the average air temperature and the loss of heat from the earth. Any change in atmospheric carbon dioxide—for example, by addition from fossil fuel combustion—may be damped or modified by the absorption of carbon dioxide in the ocean waters.

New Techniques

For an understanding of each of these three problems, greater knowledge of the rate and character of the exchange between the deep and surface waters of the oceans is required. It is only within the last few years that we have been able to make an effective attempt to gain such knowledge, through theoretical analysis of the thermodynamics and hydrodynamics of the oceans, through laboratory and field experimentation, and through the development and field use of new techniques.

Among these new techniques are: (i) the use of radioactive substances that occur naturally in the water, such as radiocarbon and tritium, for tracing the paths of motion and the mixing of the waters; (ii) the making of direct measurements of the deep currents by using deep current meters or by following free-floating, neutrally buoyant buoys (for these it is necessary to maintain a fixed reference position; this can now be achieved by tautly anchoring a subsurface buoy to the sea bottom); (iii) the measurement, with a new degree of precision, of the salt content of the water and the tracing of the water movements by means of these data on salt content; (iv) the measurement of the heat flow from the interior of the earth into the deep water and use of data on the heating of the water as an index of the time of passage of the water over the bottom; (v) the possible introduction of relatively large amounts of artificially radioactive substances, of the order of tens of thousands of curies or more, into deep ocean areas and the measurement of the dispersion and transport of this material by the deep currents; (vi) detailed biological, chemical, and physical studies of the variations in the sediments of the deep-sea floor as a means of deciphering past changes in the water conditions; and (vii) utilization of new methods of high precision for determining carbon dioxide content in the water and the air.

Five-Year Program of Deep-Sea Research

Deep-sea exploration, because it involves the use of relatively large and heavily equipped ships for long periods, is the most expensive kind of oceanic research. An adequate program of exploration is beyond the resources of any one

country. Moreover, the total cost will be minimized through planned international cooperation in the use of ships and facilities.

For the first two or three years the principal effort will be devoted to exchange and standardization of techniques, collection of samples for analysis and study by different laboratories, and exchange of data that can serve to guide further exploration. During this stage of development, effort will necessarily be concentrated in the North and South Atlantic and in the North and South Pacific oceans.

With adequate preparation during the first years, it should be possible, during the third or fourth years (provided that adequate funds and ships are made available), to make a combined assault on the largest unexplored area on earth, the Indian Ocean. This area is of special interest to physical oceanographers because seasonal reversals in wind direction that are not known elsewhere provide opportunity for studying the transient state in the wind-driven currents. Few scientific vessels have ever visited the Indian Ocean, and almost none of the new techniques have been applied there.

It would be anticipated that, in addition to scientists from the Northern Hemisphere, scientists and students from the countries bordering on the Indian Ocean would take part in this series of simultaneous expeditions. The expeditions would thus not only serve their primary purpose of exploration but would also have a lasting effect in encouraging and developing the marine sciences and fisheries in those countries.

It is estimated that at least 16 ships from 11 different countries could be enlisted. Each research vessel would spend approximately eight months at sea. The combined scientific party on all the ships would total about 125 persons; at least 25 of these might come from countries bordering on the Indian Ocean area, and it would be desirable to give many of the latter a year's prior training in centers of advanced oceanic research. At least 100 scientist-years would be required for working up the results.

During subsequent years, when the present extreme difficulties of making measurements at depths of several thousand meters and of obtaining accurate positions on the high seas have been sufficiently overcome, a tracer experiment, in which a large quantity of artificially radioactive material would be used, should be undertaken in some suitable deep-sea area. This will involve very careful international planning and coordination.

Organization and Budget

The Special Committee on Oceanic Research has set up five working groups, each consisting of five to seven active research workers in a particular field. These groups, with their conveners, are as follows: (i) group on the measurement of artificial radioactivity (Y. Miyake, Japan); (ii) group on the measurement of carbon dioxide in the air and the sea and its exchange rate (N. W. Rakestraw, United States); (iii) group on the measurement of standing crops of phytoplankton and zooplankton and the productivity of the sea (N. B. Marshall, United Kingdom); (iv) group on the measurement of the physical properties of sea water (H. Mosby, Norway); (v) group on exploration of the Indian Ocean (C. O'D. Iselin, United States).

Revelle, Deacon, and Bohnecke were nominated as chairman, vice chairman, and secretary, respectively, of the Special Committee on Oceanic Research. They will function as an executive committee responsible for the detailed administration of the committee's operations. Iselin and Zenkevitch were nominated as members of the finance committee to prepare the budget. These nominations have been confirmed by the International Council of Scientific Unions.

A program of international cooperation in deep-sea research cannot be carried out successfully without the enthusiastic support of existing international marine science organizations. Every effort will be made to utilize their facilities and procedures.

In organizing its scientific program, the Special Committee on Oceanic Research will also invite the cooperation of qualified academies or research councils of different countries, and each participating organization will be requested to designate a corresponding member to the Special Committee.

The total expenditures for the proposed year-long program of exploration of the Indian Ocean would be about $4 million, largely for ship costs. Half of this amount could come from the normal operating funds for ships and marine research laboratories of the participating countries, but additional sums totaling approximately $2 million must be raised. The Special Committee itself will need funds to establish a secretariat to maintain a flow of information about new methods, designs of instruments, and plans among the different countries; to pay for meetings of working groups of specialists who are developing and standardizing new techniques or planning expeditions; to make possible the transfer of key scientific personnel to the laboratories and ships where they can give training in, or learn from others, the use of specialized techniques and methods—for example, the seismic refraction methods of studying suboceanic structure that have been so successfully developed in the United States and England. An estimated annual budget of $45,500 a year for the next five years would cover these costs.

Note

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