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REPORTS OF THE ECONOMIC AND SOCIAL COUNCIL

QUESTION OF THE RESERVATION EXCLUSIVELY FOR PEACEFUL PURPOSES OF THE
SEA-BED AND THE OCEAN FLOOR, AND THE SUBSOIL THEREOF, UNDERLYING THE
HIGH SEAS BEYOND THE LIMITS OF PRESENT NATIONAL JURISDICTION, AND THE
USE OF THEIR RESOURCES IN THE INTERESTS OF MANKIND

Long-term and expanded programme of oceanographic research

Note by the Secretary-General

1. The Secretary-General has the honour to transmit to the General Assembly the "Comprehensive outline of the scope of the long-term and expanded programme of oceanic exploration and research" forwarded to him by the Chairman of the Intergovernmental Oceanographic Commission (see annex).
2. In this connexion, the Secretary-General wishes to recall how the comprehensive outline was initiated and to review briefly the various steps taken for its preparation by the organizations concerned with the formulation and co-ordination of the long-term expanded programme.
3. In paragraph 4 of its resolution 2467 D (XXIII) of 21 December 1968, the General Assembly inter alia requested "the United Nations Educational, Scientific and Cultural Organization that its Intergovernmental Oceanographic Commission ... co-operate with the Secretary-General, in accordance with paragraph 4 of General Assembly resolution 2414 (XXIII) of 17 December 1968 1/ on the resources of the sea in the preparation of the comprehensive outline of the scope of the long-term programme of oceanographic research of which the international Decade of Ocean

1/ Paragraph 4 reads as follows:

"Requests the Secretary-General to present to the Economic and Social Council at its forty-seventh session a comprehensive outline of the scope of this long-term programme, taking into account such scientific recommendations as may be formulated by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization within its terms of reference and in co-operation with other interested international organizations".

Exploration will be an important element ..." and also that it "report through appropriate channels to the General Assembly at its twenty-fourth session on progress made in the implementation of the present resolution".

4. This matter, among others, was considered at length during the meeting of the Bureau and Consultative Council of the Intergovernmental Oceanographic Commission (IOC), held at Woods Hole, Massachusetts, from 3 to 7 February 1969, at which a number of representatives of organizations concerned participated as observers. Lines of action for the preparation of the comprehensive outline were then agreed upon and brought to the attention of the Secretary-General who reported accordingly to the Economic and Social Council at its forty-seventh session (E/4672).

5. Meanwhile, letters have been sent by IOC to all States Members of the United Nations system requesting them to formulate proposals for national and international programmes and agreed activities to be undertaken during the international Decade of Ocean Exploration.

6. A joint working party, nominated by the Scientific Committee for Oceanic Research, the Advisory Committee on Marine Resources Research and the World Meteorological Organization which met in Ponza and Rome, Italy, from 28 April to 7 May 1969, was asked to identify the oceanic research problems that should receive particular attention in the near future and the types of programmes that might best contribute to solving these questions. The conclusions of the Joint Working Party were published in a report entitled Global Ocean Research (La Jolla, California, 1 June 1969).

7. This report, as well as the answers from more than thirty States to the IOC inquiry mentioned above, served as a basis for the discussions of a special working group of IOC which convened in Paris at UNESCO headquarters from 16 to 21 June 1969. In addition to representatives of Member States, those of the United Nations, the Food and Agriculture Organization of the United Nations, the Inter-governmental Maritime Consultative Organization and the World Meteorological Organization and of the main international scientific organizations concerned took an active part in the work of the group. The meeting concluded with the issuance of a draft comprehensive outline of the scope of the long-term and expanded programme of oceanic exploration and research.

8. At the request of IOC, this draft was transmitted for information to members of the Committee on the Peaceful Uses of the Sea Bed and the Ocean Floor beyond the Limits of National Jurisdiction. It was given special consideration by the latter's Economic and Technical Sub-Committee during its second session in August 1969. 2/ Observations and suggestions made during the debates on the subject were transmitted to IOC.

9. Finally, on the basis of the various documents mentioned above, as well as of the relevant debate during its sixth session held at UNESCO headquarters in Paris from 2 to 13 September 1969, IOC finalized the comprehensive outline which is transmitted herewith to the General Assembly.

2/ See Official Records of the General Assembly, Twenty-fourth Session, Supplement No. 22 (A/7622 and Corr.1), chapter III.

10. In this connexion, it seems appropriate to draw the attention of the General Assembly to the following statement made by the Chairman of IOC in his letter forwarding the comprehensive outline to the Secretary-General:

"It should ... be borne in mind that the Expanded Programme ... should be used as the basis for its further development. Its scope and emphasis can be expected to undergo gradual changes especially when the Expanded Programme enters its implementation stage".

The Chairman of IOC further informed the Secretary-General:

"For this reason, ICC has decided (resolution VI.2) to establish a group of experts on long-term scientific policy and planning with the object of keeping the Expanded Programme up to date and also of promoting its speedy implementation."

ANNEX

Paris, 13 September 1969

UNITED NATIONS EDUCATIONAL, SCIENTIFIC
AND CULTURAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

COMPREHENSIVE OUTLINE OF THE SCOPE OF THE
LONG-TERM AND EXPANDED PROGRAMME OF
OCEANIC EXPLORATION AND RESEARCH

UNITED NATIONS EDUCATIONAL
SCIENTIFIC AND CULTURAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

COMPREHENSIVE OUTLINE OF THE SCOPE OF THE
LONG-TERM AND EXPANDED PROGRAMME OF
OCEANIC EXPLORATION AND RESEARCH

as approved by the Sixth Session
Unesco, Paris, 2 - 13 September 1969

INTRODUCTION

1. The General Assembly of the United Nations in December 1968 adopted Resolution 2467 (XXIII), which contains the following request to the Intergovernmental Oceanographic Commission (Part D, Section 4 a):

"4. Requests the United Nations Educational, Scientific and Cultural Organization that its Intergovernmental Oceanographic Commission:

(a) Intensify its activities in the scientific field, within its terms of reference and in cooperation with other interested agencies, in particular with regard to co-ordinating the scientific aspects of a long-term and expanded programme of world-wide exploration of the oceans and their resources of which the International Decade of Ocean Exploration will be an important element, including international agency programmes, and expanded international exchange of data from national programmes, and international efforts to strengthen the research capabilities of all interested nations with particular regard to the needs of the developing countries;"

This programme will be referred to further in this document as the Expanded Programme.

2. A Special Working Group of the IOC on the Long-Term and Expanded Programme, established by the IOC Bureau and Consultative Council at its 9th Meeting, met in Paris, 16-21 June 1969, and prepared a "Draft Comprehensive Outline of the Scope of the Long-Term and Expanded Programme

of Oceanic Exploration and Research" (SC/IOC-VI/7 APPENDIX). The Working Group used as the basis of its work the report "Global Ocean Research" prepared by a Joint Working Party of the Advisory Committee on Marine Resources Research of the FAO, the Scientific Committee on Oceanic Research of ICSU, and the AGOR of the World Meteorological Organization, and more than 30 national proposals.

3. The present "Comprehensive Outline of the Scope of the Expanded Programme" as adapted from the Draft Outline reflects comments received on the Draft Outline from Member States, the United Nations Committee on Peaceful Uses of the Sea-bed and Ocean Floor Beyond the Limits of National Jurisdiction, and other interested international organizations. The report "Global Ocean Research" is attached as Appendix I. In adopting this outline, the Sixth Session of the Intergovernmental Oceanographic Commission recognized that, by the very nature of marine science, the outline cannot be exhaustive and that other programmes of equal merit may well arise during the course of the Expanded Programme.

4. The purpose of the Expanded Programme is recognized to be as follows:

"to increase knowledge of the ocean, its contents and the contents of its subsoil, and its interfaces with the land, the atmosphere, and the ocean floor and to improve understanding of processes operating in or affecting the marine environment, with the goal of enhanced utilization of the ocean and its resources for the benefit of mankind."

In achieving this purpose, the Commission should take into account the needs and interests of developing countries.

5. The proposals for the Expanded Programme contained in the Draft Outline cover also the International Decade of Ocean Exploration as an important element of this Programme as defined by UN Resolution 2467 D (XXIII). In order to understand better the relationship between these programmes, the Working Group recommended that the implementation of the Expanded Programme be started as soon as feasible after its adoption, preferably in 1970, and that the International Decade of Ocean Exploration be recognized as the acceleration phase of the Expanded Programme.

6. Various steps are under way to broaden the base of the IOC and to strengthen the cooperation between IOC and other interested bodies of the United Nations System. The IOC Sixth Session decided that the broadened IOC, in close cooperation with other interested bodies, accept the proposed responsibilities to (1) develop the scientific content and form of the Expanded Programme, and (2) to co-ordinate its implementation.

7. During the early years of the Expanded Programme major emphasis must be given to detailed planning. Although it is not now possible to identify all the ongoing and scheduled activities relevant to the purposes of the Expanded Programme, there are certain activities that can clearly contribute to its initial phases, such as:

- a. Co-operative investigations, such as that under way in the Kuroshio and adjacent regions, and those planned or projected in the Caribbean, Mediterranean, Southern Ocean and North Atlantic.
- b. Those elements of IGOSs that relate to the research on the scales and frequencies of oceanic phenomena, investigations of ocean-atmosphere interaction directed towards understanding of the ocean, and studies of variability required for the design of the eventual operating system.
- c. Those elements of World Weather Watch and the Global Atmospheric Research Programme that concern oceanic phenomena and the influence on them of atmospheric conditions and processes.
- d. Those elements of the regular and field programmes of international agencies dealing with scientific aspects of marine resources and their environment.

8. It was recognized that a number of co-operative investigations are being carried out by international organizations outside the UN System, such as ICES and ICMF. Such investigations may be highly relevant to the purpose of the Expanded Programme and ways must be found to facilitate their co-ordination with programmes being implemented within the UN System. For example, an IOC/ICES/ICMF Co-ordinating Group for the North Atlantic has already been established with this end in view.

It was also noted that a number of supporting activities within the UN System and by other organizations will contribute importantly to implementation of the Expanded Programme. These include activities related to data and information management; training, education and manpower; instrumentation and methods; technology and supporting facilities and services; assistance to developing countries; legal aspects of scientific investigation. Comment on these matters is given later in this document.

9. During the development of the Expanded Programme, new co-operative projects will be presented for possible inclusion. In the view of the IOC Sixth Session the following criteria could be applied as appropriate in the selection of co-operative projects:

- (1) Member States are willing to participate actively in the project.
- (2) The project can be carried out most effectively through international co-operative action.
- (3) The project has a sound scientific basis and is well designed to yield significant new information.

- (4) The project will provide information and understanding that will contribute to the goal of enhanced utilization of the ocean and its resources.
- (5) The project will help meet the needs of developing countries.

A project that satisfied all these criteria would be an extremely strong candidate for inclusion in the Expanded Programme. It will not be necessary in each case that all criteria be met, but the willingness of Member States to participate is clearly essential.

PART I

SCIENTIFIC CONTENT OF THE EXPANDED PROGRAMME

1. PROBLEMS OF OCEAN-ATMOSPHERE INTERACTION, OCEAN CIRCULATION, VARIABILITY, AND TSUNAMIS

Introduction

The Ocean and the atmosphere are two parts of a vast thermal engine with a common source of energy, solar radiation. The two parts interact strongly and continuously with each other. Progress in many problems in oceanography and in meteorology is largely dependent upon close collaboration between oceanographers and meteorologists. For example, the transfer of heat, water and momentum between the earth's surface (over 70 per cent of the area being water) and the overlying atmosphere constitutes one of the major problems concerning the structure and behaviour of the ocean and the atmosphere.

This transfer has as components motions so small that they cannot be resolved by any foreseeable observation network; nor could they be analysed adequately by any foreseeable computer. Their magnitudes and properties must be expressed in terms of "average" values of atmospheric and oceanic parameters. In various ocean-atmosphere projects considerable effort is being applied to the measurement at isolated points and using elaborate instruments and equipment, of the fluxes of heat, water and momentum. Methods are also being sought for expressing these fluxes in terms of the larger scale parameters.

In research into problems of such complexity, simplification is generally an essential preliminary if progress is to be achieved. A major aim must be the development of an ocean-atmosphere model of global application. But first the feasibility of such models must be assessed and for this purpose it is best to choose problems which permit simplifying assumptions in order to develop and test the quantitative and predictive worth of comparatively simple numerical techniques. Such steps are valuable not only for theoretical work. Whenever possible they should be tried as an essential part of the planning of any large scale observational programme.

The development of ocean-atmosphere models must be a joint effort on the part of meteorologists and oceanographers. The weather systems which are generated and maintained by the fluxes of heat, water and momentum will affect the temperature structure of the ocean through the generation of turbulence and of currents in the sea. In turn, the air-sea interaction processes will be affected by changes in the temperature structure of the ocean. In some way or other all these changes must be taken into account in numerical models. Thus the air-sea interface is of importance to both meteorologist and oceanographer and must be considered in studies of any large scale aspects of the ocean or the atmosphere.

The horizontal and vertical movements of ocean waters are among the most striking manifestations of dynamic and heat interaction in the ocean and a most important link in the chain of its internal energy and matter exchange. Oceanic circulation serves to redistribute the heat and substance of the ocean between the various latitudes and depths and is thus a source of enormous reserves of heat. Similarly the large amount of heat released by the ocean to the atmosphere at high latitudes through freezing of the uppermost layers of the ocean, and the modified effect of the ice cover on the weather in these regions, are of great importance in the overall heat exchange balance.

Of particular importance is the investigation of frontal processes and frontal zones in the ocean, and of the associated upwelling and sinking phenomena. The frontal zones are also of interest because of the associated biological activity.

Study of many aspects of the variability of the oceanic environment depends on the results of research on ocean water circulation. The variability of the environment in time and space has a bearing on the dynamics of marine ecosystems. Knowledge of the short-term and long-term variability of physical characteristics, are important for forecasting weather conditions. Investigation of the internal waves and tides in the open ocean is also important since in a number of areas they determine the dynamics and intermingling of the waters.

The tsunami is among the most disastrous of ocean phenomena. Originating in areas where underwater earthquakes and volcanic eruptions occur and spreading over the ocean for many thousands of miles, this sea wave or series of waves ("tsunami"), marked by low-frequency oscillation, possesses enormous energy. In the open ocean the tsunami is barely noticeable; but at the coastline its height may reach 35 metres under certain conditions. The tsunami occurs most frequently in the Pacific Ocean, but is also to be observed in other oceans.

A. Ocean-Atmosphere Interaction

Project 1.1 Small-scale ocean-atmosphere interaction studies.

Programme Outline - The programme includes investigation of the adjacent boundary layers of the ocean and the atmosphere and of their structure in relation to waves, heat, water and chemical elements exchange, including a closer study of oceanic turbulence and turbulent exchange of momentum and heat at all pertinent scales, the exchange of chemical elements such as halogens and carbondioxide as affected by turbulence and breaking waves, as well as departures from geostrophic approximation at different levels within those layers. Small-scale vertical gradient measurements with modern methods in both the ocean and the atmosphere should be made and examined in relation to larger scale distributions and phenomena. Wind effect on the sea surface should be studied further. Multi-ship operations of various patterns, using arrays of buoys and masts, would

be needed for these purposes. Upper-ocean data should be expeditiously exchanged. These investigations should be conducted in different regions. They are of particular interest in the equatorial and tropical regions where more stable winds and currents predominate.

In addition, instrumental measurements of wind waves will be organized to obtain wave spectra which represent the kind of data which has multiple uses, e.g. in ship-designing. Such data should include two dimensional wave spectra and statistical information on wave steepness. Consideration should also be given to the possibility of analysing in spectral form wave data from trawlers and also to the possibility of improving techniques of visual observations including those made on breaking waves and cross seas.

Project 1.2 Investigations of the heat and water exchange through the ocean-atmosphere interface (medium scale).

Programme Outline - The enormous accumulation of heat in the surface waters in low latitudes and its effect upon the formation of tropical storms should be a subject of special interest. Otherwise, detailed studies of the heat exchange through the surface are important in all areas for estimating the total heat budget of the ocean. Studies of thermo-haline structure would permit correlation between the heat exchange through the ocean surface and the peculiarity of the deeper water circulation.

Project 1.3 Larger-scale ocean-atmosphere interaction studies from storm-surges to the coupling of quasi-permanent baric centres of the atmosphere with the major features of the oceanic circulation.

Programme Outline - Studies of storm-surges and development of prediction methods will require improved sea-level measurements (cf. also Project 1.16) and the establishment of files of compatible atmospheric and oceanic data. Such files covering entire oceans will permit important correlations between major dynamical features of the atmosphere and the ocean. The development of IGOS (cf. Section 5) will contribute greatly to these large-scale studies.

Project 1.4 Special study of scales and frequencies involved in ocean-atmosphere interaction.

Programme Outline - Numerous studies require a monitoring network. No network can be effectively designed without knowledge of the scales and frequencies of fluctuations of environmental characteristics, including wind and current velocity. Pilot studies are underway in some fields and should be extended to others. The same studies will contribute to the investigation of oceanic variability as such (cf. Project 1.14) and will allow determination of the required accuracy of measurements in the ocean as related to the scales of phenomena.

B. Water Circulation and Distribution of Properties in the Ocean

Ocean circulation redistributes heat and other properties between different latitudes and depths. Upwellings, which bring rich reserves of nutrients to the surface of the ocean, are parts of the general circulation which affect the biological productivity in a most radical way.

Little can be studied in the ocean without thorough knowledge of the circulation. So far, the general circulation of the world ocean is understood in a gross way. Knowledge of details is very uneven. Not only the major currents, but the less clearly defined and the less permanent features, need to be examined further.

Among the various projects suggested the most important are the following:

Project 1.5 Studies of mixing, and diffusion, both vertical and horizontal, at all pertinent scales, and of the processes which cause them such as surface effects, turbulence, internal waves, convection, overturning etc. The degree or intensity of overturning in connection with winter cooling should be studied thoroughly.

Programme Outline - Special observations and measurements will be required, of the type described under Projects 1.1 and 1.4. The orientation of the programme and the methods of data treatment would be different. The results obtained will be applicable in Projects 1.7 to 1.12.

Project 1.6 Detailed investigations of the zonal flows recently discovered in middle and low latitudes.

Programme Outline - Arrays of buoys with current meters and sections repeated synchronously by several ships would constitute the backbone of such investigations. Important planning and coordination experience can be drawn from the EQUALANT expeditions conducted by the IOC during 1963-64.

Project 1.7 Investigation of the processes converting surface water into intermediate, deep, and bottom water, of the rates of such conversion, and of the subsequent return path of these waters to the surface, including further transformation involved and particularly problems of underflows beneath eastern and western boundary currents.

Programme Outline - These investigations would be planned and conducted in accordance with the methodology developed for each specific case. Use of modern instrumentation, such as STDs or continuous chemical analysers, may be particularly desirable. In some areas research submarines may provide a means of conducting observations and measurements under ice.

Project 1.8 Studies of budgets of water, heat, salt, and nutrients in various ocean basins.

Programme Outline -- Depending upon the size of each specific basin and the character of the water exchange with neighbouring basins (through straits, passages, shallow areas, etc.) detailed surveys of physical and chemical properties would be designed to last shorter or longer periods of time. In certain cases the use of fast or continuously recording devices would be strongly recommended (e.g. STDs, expendable BTs, under-water cables, or buoys with continuously recording sensors).

Project 1.9 Studies of coastal and oceanic upwellings and their relation to the general ocean circulation, large-scale ocean-atmosphere interaction, and local atmosphere and oceanic conditions.

Programme Outline - Studies of the immediate mechanisms of upwelling could be correlated with large-scale oceanic and atmospheric phenomena, i.e. zonal sub-tropical flows in the ocean and sub-tropical anticyclones. In addition, it seems probable that variations in sea surface temperature produced by changes in upwelling have important effects on the weather conditions in the littoral areas. Studies of such effects would be a valuable by-product of research on the upwelling process. There is also considerable geological interest in the sedimentology of such regions of high organic productivity and of the accumulation of organic matter and phosphorites. Great benefit to fisheries would result from an improved understanding, leading to prediction techniques, of the intensity and fluctuations of upwellings. Theoretical models can be developed to arrive eventually at prediction methods.

Project 1.10 Investigation of frontal systems and convergence zones, their formation and variation, and their effect on living organisms.

Programme Outline - The same approach as in 1.9 should be followed and studies conducted in close correlation with the studies of large-scale atmospheric phenomena through detailed field surveys and theoretical models. Permanent or semi-permanent monitoring systems would be instrumental in following time variations.

Project 1.11 Investigation of the vertical structure of oceanic currents.

Programme Outline - Velocity structure in some of the major oceanic currents has been examined but much still remains to be learned. The structure of slower and less regular currents has received less attention and should be examined, as should particulars of deep flows near the bottom, including the velocity structure between the bottom frictional layer.

Project 1.12 Investigation of the chemical composition of sea water and use of chemical knowledge for studying the ocean circulation.

Programme Outline - Further studies on the composition of sea water and its variability in time and in space may reveal additional information on the formation, mixing, circulation, and "residence time" of water masses at the surface or in the depths of the ocean. Knowledge of distribution of nutrient salts is indispensable for biological studies. There is still much to be learned from studies of salinity, dissolved oxygen, carbon dioxide, phosphorus, nitrogen, and silicone. More recently, deuterium, tritium, oxygen isotopes, and Carbon 14, as well as other radio nucleides and some trace elements, less affected by biological processes, have become recognised as having prospective roles as tracers of circulation.

Project 1.13 Studies of special problems of coastlines and estuaries: runoff, exchange with land, sediment transport, wave erosion, etc.

Programme Outline - Coastal interactions with the marine environment are of growing concern to many nations since they have both direct and indirect effects on many coastal residents. These studies, because of their nature, will require complex multi-disciplinary teams of scientists, including physicists, chemists, sedimentologists, coastal engineers and sanitary engineers. The results of these studies will have practical application in coastal protection, harbour construction, pollution prevention, etc.

Project 1.14 Prediction of physical processes in the sea by means of hydrodynamic-numerical methods.

Programme Outline - These studies are aimed at the determination of currents, water levels, mass transports, density distribution in ocean basins or whole oceans under the influence of external and internal forces. Sufficient computer capacity and information on initial or marginal data are needed as well as the possibility of verification by a suitable network of ocean stations.

C. Variability, Tsunami and Tides

Project 1.15 Investigation of variability of environmental characteristics in time and in space at all scales.

Programme Outline - It was traditional in the past to think of the ocean as being in a quasi-steady stage, considering even the seasonal variations as minor and limited to surface water. Now we find that we cannot progress in our study of the ocean without taking into account the variations which take place in it as a result of static and dynamic instabilities and a generally transient state of oceanic processes. Understanding of short period and long period variability of the oceanic characteristics,

particularly the temperature, is important for estimating and forecasting thermal conditions of the ocean. Large-scale variations of oceanic conditions (particularly thermal) lead often to disastrous effects on living organisms, to their mass mortality or migration. The well-known El Nino near the Peruvian coast can serve as an example of such natural disasters. The total area of sea ice cover which radically reduces the heat exchange through the ocean atmosphere interface is subject to large scale variation from year to year. The following topics may be chosen when planning research in variability:

- (a) Large-scale and long-term changes in surface conditions that take place in such areas as the North Pacific and the North Atlantic require more detailed and longer series of observations in order to be understood.
- (b) Significant seasonal changes, such as those occurring under the influence of monsoons, as well as less-pronounced seasonal changes in other regions, should be studied.
- (c) Small-scale and short-term variations, such as internal waves, should be investigated.
- (d) Seasonal and annual changes of sea-ice cover should be monitored.

Project 1.16 Further studies of Tsunami.

Programme Outline - A different kind of variability is involved in natural disasters which occur as a result of underwater earthquakes. The latter produce a wave or a series of waves travelling great distances and producing rapid changes of sea level which in turn result in floods and destruction. This phenomenon is called tsunami. The disastrous effects of tsunamis on many coastal areas of the world have directed the attention of many people to the study of this phenomenon. The International Tsunami Warning System was established in the Pacific Ocean recently with the assistance of IOC. Further studies of the dynamics of the formation and propagation of tsunami waves are necessary. International exchange of all tsunami data is desirable.

Project 1.17 Further expansion and improvement of the global tide station network and its extension into the open ocean.

Programme Outline - More sea level recordings over longer periods of time and in many additional localities are needed in order to improve tidal prediction and tsunami warnings (cf. also Project 1.15). International cooperation can be instrumental in extending the global network of the tide gauges into the open ocean where recordings are particularly needed, through cooperative development, production and maintenance of deep sea tide gauges to be placed on the ocean floor.

2. LIVING RESOURCES AND THEIR RELATIONS WITH THE MARINE ENVIRONMENT

The Scientific Problems

Life probably originated in the ocean. Study of the immense variety of species now living in it throws light on the evolution of life on earth and its constantly changing composition. Investigation of the complex web of inter-relations between these marine organisms, and between them and the medium in which they live, is a major part of ecological research. Through such research man hopes to understand, to control, and to turn to his own advantage, the general biological processes which give the face of Earth its special character.

Probably man's oldest, and certainly still his most compelling, concern with marine life is, however, as a resource of protein-rich food and food supplements for himself and his domestic animals and also for sport and as providing useful or attractive materials and drugs. He now extracts nearly 60 million tons of such products annually. Each year the food harvest is increased, as is the variety of products. Through the application of science and technology, and sufficient and wise investment, the harvest could be doubled, perhaps quadrupled, in the next few decades. This growth will be limited by the productive capacity of the sea for organisms of the kinds presently harvested. If uses can be found for the even more abundant, but smaller, animals and plants, and means devised for gathering and processing such "unconventional resources" efficiently and cheaply, the useful harvest could be increased many-fold, though by precisely how much more we do not yet know.

Future expansion of fisheries is, however, beset with economic, legal and technical problems, the solution of which will require appreciation and understanding of the population dynamics of the living resources, of their relations with the environment, and of the nature and behaviour of the organisms as individuals and as groups. Catches of many species tend to be highly variable and as yet largely unpredictable. The numbers and movements of young, and of animals of catchable size, are deeply influenced by large and small-scale features of the ocean circulation; these influences must be understood if reliable forecasting systems are to be developed and catching operations made more efficient and sure. To find, aggregate and catch the animals we must understand their behavioural characteristics, and marry biology with engineering for the invention of better methods. Fishing itself affects greatly the size and composition of stocks; management of fisheries for sustained yields requires understanding of the dynamics of the exploited stocks and of the population of organisms which nourish or compete with them. To utilize them more fully we need to know more about their biochemistry.

With the above considerations in mind, projects are outlined dealing with the environmental relationships and assessment of the living resources. The lesser known resources, particularly, would be mapped and measured, and research expanded on the dynamic processes in the ocean involved in the fixation, transfer, concentration and dispersion of organic matter and energy, and which thus determine the degree and nature of its biological productivity (Projects 1 to 5).

With one exception, this document mentions specific ocean areas only as illustrative examples. The Antarctic area is unique in that it contains the largest known unused resources, harvesting of which will require new methods of fishing and processing, as well as oceanographic studies to assist in locating concentrations, and weather and ocean forecasts for safety and efficiency of operation in a harsh environment far distant from centres of consumption. For such reasons the study of Antarctic seas is given special attention in the Expanded Programme (Project 6).

Changes in the marine ecosystem, and geographic exchanges, have special significance. Some of these originate in natural phenomena and others in human activities such as canal digging, dam building and shipping, as well as fishing and waste disposal (considered in another section of this document). More deliberately, man is becoming interested in manipulating the ecosystem to improve it from his point of view, but lasting success in such enterprises as transplantations and mariculture can spring only from scientific studies in depth to complement pilot experiments. Some biological communities need protection from change so that their study can provide a relatively stable basis (Projects 7 to 9).

Uncertainty as to the identity of the animals and plants in the ocean impedes progress in ecological research and can confuse predictions. Only a fraction of these is yet adequately described and classified; the status even of some otherwise quite well-known forms remains in doubt. Taxonomy, which has fallen into relative obscurity, must be revived and supported adequately (Project 10).

Equally important is the need for improved techniques of collecting and observing marine life. To a considerable extent this can be achieved by applying technology developed for other purposes. But, new techniques must be developed especially for biological and ecological research. The biologist must not only be able to go to sea, but to go down into the sea and have adequate instruments for sampling all organisms in, and measuring all parameters of, his object of study. In Project 12 are set out suggestions for some priorities in this respect.

A large general increase is needed in the scale of biological and related physical measurements in the world ocean. Greatest advantage must therefore be taken of existing national laboratories, "ships of opportunity", island observatories, buoys, platforms established for other purposes, aircraft, artificial satellites, submersibles,

underwater habitats and other new devices. At the same time a varied range of experimental work, at sea and ashore, will need to be conducted, and full advantage taken of modern data processing and analysis techniques in the construction and testing of mathematical models of the natural systems being studied.

Project and Programme Outlines

Project 2.1 - Fill gaps in knowledge of distribution in time and space and of abundance of primary and secondary carnivores, and in particular estimate biomass, sizes and availability of exploitable animals and their potential yields in several lesser known areas of potential interest, particularly some of the principal upwelling areas and the continental slopes.

Programme Outline - Conduct systematic exploratory surveys in selected regions to determine the presence and concentration of animals of fishable size. Work should be concentrated on the principal upwelling areas and some of the continental slopes which appear to be highly productive yet remain little known.

Project 2.2 - Determine the abundance of organisms of each size, within each trophic level in the ecosystem, and evaluate the flow of energy and material through the various trophic levels to the pelagic and benthic communities and study the influence of variability in the environment on those processes.

Programme Outline - Investigate the production at each trophic level, and especially the composition of the diets of the animals and the size distributions of organisms and their food at each level. At the same time, determine the seasonal patterns of the ecosystem. Parallel laboratory studies are needed of the reproduction rates of the algae, generation times of herbivores and carnivores and the food intake and growth efficiencies of major consumers. In particular these should be done in one or more areas in which there is little exploitation, such as the Arabian Sea, and areas with higher degrees of exploitation such as the Gulf of Guinea, Peru Current and Gulf of Thailand. Endeavour to trace energy pathways through the benthic-detritus system to the demersal populations.

Project 2.3 - Study

- (a) the global distribution and seasonal variation in primary and secondary production;
- (b) those herbivores and small carnivores that are found in large and dense concentrations and thus may eventually be harvested.

Programme Outline - Measure the radiant energy available for photosynthesis and the rate of carbon fixation throughout the world ocean, at various seasons and with accompanying environmental information. Concurrently herbivore and small carnivore biomass and production should be measured.

Project 2.4 - Investigate the effects of different levels of fishing and of changes in the environment on recruitment into stocks of fish and other useful species.

Programme Outline - Studies of the stock and recruitment problem, including: construction of models of processes determining year-class strength; laboratory experiments for improving these models; estimation of density-dependent mortality at sea. Studies on long-term variability have to be accompanied by environmental monitoring. Special and interacting lines of investigation include (a) the construction of models of processes which might influence year-class strength, (b) laboratory experiments concerning e.g. growth, behaviour, density and mobility of the fish larvae, and (c) estimation of density-dependent mortality at sea.

Project 2.5 - Identify and investigate the physical, including the optical characteristics of the water, and biotic factors of the environment which affect the behaviour and availability of fish and other useful marine organisms.

Programme Outline - Exploit information coming from the physical, biological and chemical studies under various Projects with the aim of developing time/space forecasts of occurrence of concentrations of useful organisms; and to improving efficiency of harvesting (searching, aggregating, capture). This will require the employment in the field of instruments to be developed under Project 12 (a), (c) and (d) and parallel observations and experiments on behaviour and reactions of organisms confined in tanks or enclosures.

Project 2.6 - Determine abundance, distribution and interrelations of the principal organisms of the Southern Ocean, together with their life histories, aggregation and migration characteristics, particularly as related to the environment; lay the scientific basis for efficient and rational harvesting of such organisms.

Programme Outline - Conduct a cooperative survey of the living resources of the Antarctic seas and study their environment. This work will involve basic research on the distribution of the principal organisms, their life histories and their aggregation and migration characteristics, particularly as related to the environmental conditions. Consideration should be given to the planning and initiating of broadly based international efforts in support of existing interdisciplinary programmes in the fields of meteorology, hydrography, biology, geology and other sciences.

Project 2.7 - Study the impact upon ecosystems of natural and man-made faunistic and floristic exchanges between one sea area and another.

Programme Outline - Establish biological collecting and sampling schemes at stations strategically located in relation to regions a) of natural exchanges and b) where man is affecting or may soon significantly affect the environment through engineering works, transportations or transplantation, e.g. at both ends of important straits and sea canals and off mouths of major rivers, the outflows from which are modified by dam systems.

Project 2.8 - Study the high biological production of coastal waters, estuaries, lagoons, mangrove areas and coral reefs, particularly in view of their potential for mariculture and algal harvesting.

Programme Outline - Identify on the basis of environmental characteristics and survey, potential coastal aquaculture areas on a world-wide basis and select suitable species for culture, with a view to optimum utilization and improvement of the living resources, such as fish, molluscs, crustaceans and algae. Investigation should be made of the optimum conditions for culture of these organisms.

Project 2.9 - Study the desirability and feasibility of establishing marine reserves for protection and study of natural marine communities.

Programme Outline - Examine the scientific criteria and practical problems of selecting marine areas which contain representative communities and within which human activities would be restricted to observation and research.

Project 2.10 - It is essential that there be no uncertainty about the identity of the organisms to be exploited or investigated, and it is necessary therefore to improve capabilities for classifying, identifying and cataloguing them.

Programme Outline - Take steps to encourage the pursuit of taxonomic studies which are essential as support for ecologically oriented biological projects. Encourage biologists to engage in this field and facilitate world-wide collaboration between specialists and pooling of their efforts in using both conventional and modern techniques. Extend also the network of biological sorting centres and establish regional international collections. Improve and apply rearing techniques for identification of eggs and larvae. Assist through providing adequate means for publication of taxonomic and systematic work.

Project 2.11 - Identify those marine plants and animals which are aggregated in sufficient abundance for commercial exploitation in order to use a wider range of marine organisms as sources of a greater variety of useful products.

Programme Outline - Determine for each of those species its chemical composition (with special reference to toxicological and pharmacological components), its seasonal and regional variability and its ecological determinants.

Project 2.12 - Investigations of dissolved organic matters and detritus and the remineralization of organic substances in the water and sediment.

Programme Outline - The concentration of different organic substances in the sea waters and in the sediment must be measured. The quantity of suspended detrital organic matters must be examined to evaluate its possible usefulness as a food supply for the pelagic and demersal organisms including fish. Studies of heterotrophic organisms and their metabolic activities are needed, and these studies must be carried out not only in the sea, but also in the laboratory to clarify the reactions involved in the different decomposition processes.

Project 2.13 - Develop new or improved, and preferably standardized methods, instruments and facilities for various purposes. Such developments are required in almost every aspect of marine biology. The following may serve as examples:-

Programme Outline -

- (a) To increase the ability of scientists to make direct observations, in all parts of the marine environment by providing guidelines in technology through formulation of the specific requirements of biologists for underwater study by using habitats and submersibles and by diving;
- (b) To measure the input of organic material to the sea-bed;
- (c) To detect and assess fish and other organisms. In particular devise methods for the detection and estimation of (a) flatfish, shrimps and other animals living on the sea-bed, and (b) pelagic fish and squid, and perhaps also shrimps, living over continental slopes;
- (d) To observe the behaviour of individuals and groups of fishes and other organisms, including their reactions to instruments and equipment operating in the marine environment; study possible adaptation and application of new techniques and the use of large observation tanks.

- (e) To improve methods of sampling and measurement of the biomass and rate of production of marine organisms by application and adaptation of the most recent methods and techniques.
- (f) To improve the processing and exchange of biological data by identifying those data which can be exchanged through data centres and by developing methods for handling data which at present do not lend themselves to routine exchange.

3. MARINE POLLUTION

Nature of the Problem

The world ocean is receiving in increasing amounts and variety waste substances and energy from our civilization, but it does not have an unlimited capacity to absorb them. The levels reached by some pollutants in some parts of the ocean are already a matter of deep public and scientific concern, and dangerously high levels may be imminent with respect to others. Pollution affects many of man's economic and cultural activities in the marine environment. Noxious materials can be transported by physical and biological processes over vast distances from the site of their injection into the environment. Some pollutants stay a long time in the sea water and in marine organisms before they reach the sediments or decompose. Others, instead of being dispersed, may accumulate in certain organisms, including those of economic interest to man. Some pollutants, or certain concentrations of them, have acute and quickly noticeable effects on the biota; others have delayed or sub-lethal effects which are not immediately apparent, but may nevertheless be very important in the longer run.

There is a degree of control over the injection of some pollutants into the ocean but some reach it accidentally and others are released indiscriminately. Many pollutants reach the ocean from many sources: rivers and coasts, particularly urban and industrial effluents; the atmosphere; ships and equipment operating in the marine environment, including underwater operations. Losses or impairment of use through contamination may only be prevented by rational policies based on research and monitoring. An effective monitoring programme could also deter pollution of one ocean area as a result of activities elsewhere. All the sources of pollutants mentioned above need to be monitored and eventually, as far as possible, controlled. At the same time the complex effects of each type of pollutant require detailed investigation. This involves study of their fates in the ocean environment, the selection and investigation of marine test organisms, the development and standardization of techniques of analysis and the establishment of the relevant material budget of the ocean. In some cases, wastes may be treated or disposed of in such a way as to cause benefit rather than harm. Even general scientific benefits can come from the study of pollution; thus, certain contaminants can, in principle, be used to elucidate the routes and rates of energy flow through the ecosystem (see especially living resources project No.2).

In view of the expected growth of the problem of pollution with the rise in human populations and increase in their industrial activities, and because of the broadly interdisciplinary nature of the scientific investigations required, the projects relating to

this question are gathered in this document under a single heading. For the purpose of the Expanded Programme marine pollution should be defined as:

"Introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairing of quality for use of sea water and reduction of amenities.

Scientific studies under the following projects should lead to the preparation of periodic comprehensive Reports on the Health of the Ocean. These would review the state of the ocean and its marine resources as regards pollution, and forecast long-term trends to assist governments individually and collectively to take the steps required to counteract its effect.

Projects

3.1 Study of changes in the marine environment with a view to understanding the effects of known pollutants and identifying presently unrecognized ones.

3.2 Study the impact of such changes on marine life, including studies on toxicity and accumulation of pollutants.

3.3 Investigate the delayed and sub-lethal effects of pollutants on growth, reproduction, and other biological processes. Such effects, unlike for example mass mortalities of fish, are not always immediately apparent. Nevertheless, they are among the most serious results of marine pollution.

3.4 Development of relevant physical, chemical, physico-chemical and radio-chemical methods of analysis with special consideration to the presently known pollutants.

3.5 Identification of a spectrum of species that are affected by pollutants in various ways and hence can be used as sensitive indicators of the level of pollution in a given area.

3.6 Standardization and intercalibration of methods of sampling analysis and of instrumentation.

3.7 Establishment of a world-wide system of monitoring of the constituents of marine pollution including the collection of samples from various environments and biota, their submission and analysis at analytical centres, the transmission of the results of analyses to oceanographic data centres and the evaluation, interpretation and publication of these results on a regular basis. Implementation of the monitoring programme has important legal aspects which are related to the problems of prevention and control of marine pollution; these urgently require study and solution by the competent organizations.

3.8 Review the sources of marine pollution and investigate the mechanism through which the pollutants reach the marine environment.

3.9 Investigate the fate of pollutants in the marine environment. This involves study of the physical, chemical and biological processes of transport, accumulation, dispersion and degradation of pollutant substances and energy.

3.10 Provide the scientific basis for devising methods of removing pollutants from the sea, of countering their deleterious effects or, where possible, of exploiting beneficial effects of these substances.

3.11 Study positive and negative effects on sea organisms by thermal waste water.

4. GEOLOGY, GEOPHYSICS AND MINERAL RESOURCES BENEATH THE SEA

Introduction

An understanding of the character and evolution of the earth's crust beneath the ocean is proving to be the key to global geology and heralds a new approach to the solution of geological problems on the continents as well as below the sea. This understanding can provide a basic scientific framework within which prediction, evaluation and exploitation of material benefits from the sea floor can be made. These benefits will be greatly diminished, if only haphazard exploration and empirical studies guide our programme.

Undoubtedly in the future the rich mineral deposits located on and beneath the sea floor will be exploited as an important source of industrial raw materials for the whole of mankind. Deposits of ferromanganese concretions, also containing cobalt, nickel, copper and other metals, and deposits of rock-phosphate, have already been identified. Judging from preliminary data, oil deposits may also be found deep in the sedimentary formations beyond the limits of the continental shelf. However, our knowledge of the ocean's mineral resources is still far from adequate, and prolonged study both of their geographic distribution and of the concentration of the various mineral resources will be required in order to determine which of them can be profitably exploited for the benefit of mankind.

The sedimentary sequence reflects the ocean's present and its past history. It is here that we can follow the processes of erosion and sedimentation and discover the comparative rate at which deposits have formed in different regions of the ocean. Here, too, we find clues as to the original nature of the material deposited and the transformation it has since undergone. Study of this sequence will reveal the processes of the formation and distribution of many mineral deposits.

There are, in many places on the ocean floor, outcrops of the underlying igneous rock. A knowledge of the relationship between the properties of these rocks and their geological framework and age will enable us to determine the nature of volcanic phenomena, the changes which have taken place through geologic time in the composition of the earth-mantle, the age and composition of the suboceanic earth-crust

and the mechanism of metamorphic processes within the crust. This, in turn, will provide us with a better understanding of the rocks located on and below the ocean floor, their mineral potential such as chromite and nickel, and enable us to answer a number of questions relating to the geological history of our planet.

However, new theories require testing, modification and elaboration. The broad divisions of scientific problems listed below do no more than categorize some of the detailed problems to which scientists will turn their attention. The list of research programmes which follows is considered to contain the most important to be pursued in the light of presently available methods and those that can be foreseen to be possible. But as the Expanded Programme proceeds, new developments both in techniques and knowledge will necessarily lead to modified research programmes.

Principal scientific problems:

A. Description, origin and dynamics of the crust and mantle in the oceans, including marginal seas, mediterranean seas and continental margins, and knowledge of the deep sources of material and energy for tectonic processes.

- A.1 Fine structure of the crust and upper mantle of the mid-ocean ridges, both active and ancient, and their associated stress patterns (e.g. related to seismicity).
- A.2 Nature and origin of aseismic ridges and rises (e.g. Wyville Thomson Ridge, Walvis Ridge, Chile Rise).
- A.3 Identification, dating and history of material composing the oceanic crust and the upper mantle beneath the "stable" ocean basins, and their lateral variability.
- A.4 Comparative studies of the structure and history of stable continental margins.
- A.5 The dynamic processes in areas of unstable continental and crustal plate margins (trench, trench-arc and marginal sea systems).
- A.6 The possible transformation between oceanic and continental crust in the marginal and mediterranean seas.
- A.7 Vertical and horizontal movements of the oceanic crust and continental margins.
- A.8 Processes and patterns of vulcanism.

B. Sedimentary processes in coastal regions, on continental margins and in the deep ocean.

- B.1 Description of the nature, history, distribution and thickness of sediments on the sea floor and of the nature and distribution of suspended matter.

- B.2 Sources of sedimentary material.
- B.3 Dynamic processes of erosion, transportation and sedimentation in relation to environmental conditions including quantitative analysis of the energy balance, rates of sedimentation, etc.
- B.4 Physical, chemical and biological interaction between the ocean and the sediments and rocks on the sea floor, a most important interdisciplinary problem.
- B.5 Diagenesis and metamorphism of marine sediments.
- C. Aspects of the sea floor with potential economic value.
 - C.1 Assessment of the mineral and fuel resources of the various types of continental margins.
 - C.2 Coastal and sea floor engineering (e.g. coastal erosion, sediment movement, "soil" mechanical properties, sea floor stability).
 - C.3 Possibilities of mineral and fuel resources of the deep sea floor, in relation to areas of different origin, development and environment.
 - C.4 Identification of geologic hazards in coastal areas and on the sea floor (earthquakes, rupture of sea floor by faults, earthquake-generated sea waves, etc.)

Research Programmes proposed to solve the principal scientific problems

1. Morphological charting of the sea floor.
2. Systematic geological and geophysical surveys of continental margins.
3. Completion of magnetic survey over the world ocean.
4. Deep drilling at key sites.
5. Detailed studies near crests of the ridge-rift systems.
6. Ocean and land studies of trench-arc systems.
7. Investigation of anomalous deep ocean crustal areas.
8. Geological and geophysical studies of mediterranean and marginal seas.
9. Geotraverses across major crustal features and land-sea geologic transects in critical areas.
10. River mouth monitoring with emphasis on the nature of suspended materials and waters.
11. Meridional profiles of deep ocean sediments.
12. Manganese nodule and other mineral resource assays.

These research programmes may be categorized as major elements of five principal programmes.

I. Morphological charting of the sea floor.

Scientific aspects: Geological investigations require bathymetric charts at appropriate scales as base maps. Other marine disciplines use reconnaissance or detailed charts of sea floor morphology in aspects of their research.

Practical aspects: Base maps for offshore exploration for minerals and fuels; for bottom fisheries, or for engineering purposes. Bathymetric charts at appropriate scales are required for all aspects of mineral exploitation, fisheries, engineering construction, and other operations on or above the sea floor.

Scales: 1:1,000,000 for reconnaissance purposes. Preliminary charts for many regions, both shelf and deep ocean, can be made from available data. More precise charts at this scale will be required for deep ocean areas with spacing of 5 - 15 km. between lines depending on complexity of the bottom morphology and on the nature and detail of the geological programme in the area. Scales of 1:250,000 or larger scale will be required in critical areas (where land-sea geological and geophysical transects are to be made).

II. Systematic geological and geophysical surveys of the continental margins.

These surveys include deep drilling and land-sea geologic transects, for the purpose of investigating the sediments, crust, and mantle of both stable and unstable continental margins. Emphasis is placed on comparative study of structure, geologic history, and mineral resources.

Scientific problems include A. 4, part of A. 7, parts of B., C. 1.

Scientific aspects: Better understanding of sedimentary, igneous and metamorphic crustal structures under the sea floor in the transition regions from oceans to continents and the geophysical characteristics of the underlying mantle. Processes of sediment transport from the coast to the deep sea. Distribution of benthic organisms with depth and latitude. Pliopleistocene sea levels and eustatic and tectonic changes in sea level from evidence of relic beaches, terraces and coral reefs.

Practical aspects: Reconnaissance surveys to find location and extent of thick sedimentary basins and structures for possible oil and gas accumulations; discovery of phosphorite deposits on the outer shelf, and placer and beach deposits and other minerals on both the inner and outer shelf; delineation of rock structures with mineral and fuel resources continuing from the continent. Sediment and geochemical maps for fisheries.

Methods: Reconnaissance survey, using underway and station observations, of the entire marginal area. Additional geological and hydrographic investigations of key areas of high potential for minerals, or areas such as those having arctic, humid, arid or tropical hinterlands with and without high relief, areas off river mouths, and regions where there are prolongations of great tectonic trends from the continent to its margin. Methods should include geological and geophysical land-sea transects and in later phases should be supplemented by drill hole information.

III. Geological and Geophysical Investigations of the Oceans.

Investigations of sediments, crust, and mantle of deep ocean basins, ridge-rift systems, and trench-arc systems. Methods include deep drilling, land-sea transects across trenches and arcs, and related investigations and drilling on adjacent islands.

Emphasis is on history, tectonic processes ("dynamics of ocean floor"), present phenomena of seismicity, volcanism, geomagnetism, gravity and heat flow, and mineral resources.

Scientific problems included in this programme are A. 1, A. 2, A. 3, A. 5, part of A. 7, A. 8, parts of B., C. 3, part of C. 4.

IV. Geological and geophysical investigations of small ocean basins (mediterranean and marginal seas).

Studies of sediments, crust, and mantle with emphasis on history relation to other deep oceans, possible transformation between continental and oceanic crust; and mineral resources.

Methods include land-sea transects and deep drilling.

Scientific problems included in this programme are A. 6, parts of B. and C.

V. Studies of sedimentary and geochemical processes.

Investigations in coastal regions, continental margins, and deep ocean, of the material and energy balance with respect to the coast and atmosphere; physical, chemical, and biological interactions between water column and sea floor; submarine erosion, transportation, sedimentation and diagenesis. Emphasis is on origin of surficial mineral deposits, such as placers, phosphorite and manganese nodules, and on stability of sea floor sediments ("soil" mechanical properties) and evaluation of geologic hazards.

Scientific problems included in this programme are B., and parts of A. and C.

5. THE INTEGRATED GLOBAL OCEAN STATION SYSTEM

(Programme Aspects)

5.1 The system for obtaining oceanographic and meteorological observations from the ocean, available at present, cannot satisfy the current and increasing requirements for scientific knowledge about the ocean and atmosphere and their interactions, nor does the system satisfy the requirements for operational information about the current and future condition of the ocean environment and the atmosphere above it as well.

5.2 Scientific investigations are necessary to determine the interrelations and dynamic development features of the ocean and atmospheric processes. Until these determinations are made, little progress can be made to satisfy the requirements for short-term and long-term meteorological and oceanographic forecasts. Environmental forecast services are required to enhance the efficiency of sea trade and navigation, protection of life and property at sea, successfulness of maritime industries (fishing, petroleum, chemical, etc.).

5.3 IGOSS, in conjunction with the World Weather Watch, will promote the further development of environmental sciences, it will aid in the improvement of ocean and weather forecasts, and will facilitate a better understanding of the ocean and atmosphere interaction processes. It will support countries in their exploitation of new regions in the ocean for the purpose of trade and increase the efficiency of agriculture in all countries from the resultant increased accuracy of weather forecasts and their application to food production.

5.4 IGOSS, which is being developed on the basis of scientific principles, includes the modern technical means for observations, radio-communication and data processing and is intended to provide, together with WWW, the synchronous and undelayed oceanographical and meteorological information from the whole ocean. It will benefit from research proposed for the Expanded Programme, since subsequent design of the system will require understanding of the scales and frequencies of oceanic phenomena and the perfection of models for forecasting oceanic conditions.

5.5 The purpose of IGOSS, in conjunction with the World Weather Watch, guided by the requirements of oceanography, is to provide oceanographic and meteorological information that will support all interested countries in producing forecast services and conducting scientific ocean investigations.

5.6 The main planning question to be resolved during the initial stage of IGOSS is to determine the distribution and content of meteorological and oceanographical observations by fixed and mobile observing stations.

5.7 The Integrated Global Ocean Station System is arranged exclusively for peaceful purposes and is based on the principle of voluntary participation of the interested States. IGOSS is a world system consisting of national facilities and services coordinated by the Intergovernmental Oceanographic Commission, in close collaboration with WMO, with the support of all interested organizations.

6. SPECIFIC INTERNATIONAL REGIONAL INVESTIGATIONS

6.1 International cooperation in studying systematically selected oceanic regions is of great importance. The extreme rapidity of time variations of the oceanic environmental characteristics requires rapid repeated surveys of oceanic conditions, which surveys cannot produce satisfactory data if conducted by a single vessel. In order to understand properly all physical, chemical and biological processes which take place in a particular region, their inter-relation and inter-dependence, regular multi-ship synoptic surveys over the whole area of the region under investigation are necessary. Networks of buoys or other platforms may be indispensable when high degree resolution in space is required.

6.2 No country, however rich or developed economically, can provide the necessary number of research vessels and other means for such investigations. Only through international cooperation is it possible to concentrate in one region of the ocean such number of research vessels and other means as would meet adequately the requirements of synoptic or quasi-synoptic coverage.

6.3 The Intergovernmental Oceanographic Commission has already acquired great experience in organizing and conducting large-scale international expeditions: in the Indian Ocean, in the equatorial part of the Atlantic Ocean, and in the Kuroshio region of the Pacific. The Commission also planned or projected further international investigations in the Northern Atlantic, in the Mediterranean, in the Caribbean Sea and adjacent regions, and in Antarctic waters (Southern Ocean).. The continuation of these cooperative investigations will be the first step of the Long-term and Expanded Programme.

6.4 A great many oceanic regions are still poorly known. Among them are the southern parts of the Atlantic, Pacific and Arctic Oceans, including some regions bordered by developing countries. Regions where more or less satisfactory data have been collected in the past require additional detailed investigations. It is appropriate, therefore, that, during the next five years, the large-scale international expeditions planned or projected by the Commission be complemented by detailed cooperative investigations of regional character aimed at assisting developing countries by studying their adjacent waters for the purpose of national fisheries development. .

6.5 Plans for these regional investigations should be developed in close collaboration with the existing regional organizations, such as ICES, ICNAF²², etc., which have accumulated valuable experience in organizing cooperative investigations in their respective regions with great benefit for fisheries development there.

* ICES - International Council for the Exploration of the Sea.

* ICNAF - International Commission for the North-West Atlantic Fisheries.

PART II

PRACTICAL PROBLEMS OF IMPLEMENTATION

1. Training, Education and Manpower Requirements

Development and implementation of the Expanded Programme will require a considerable strengthening of scientific and technical manpower. Such problems are of considerable importance particularly to the developing countries. Problems and approaches include the following:

- increased reference to marine problems in natural science and engineering curricula;
- development and strengthening of specialized curricula at the university and post-graduate levels;
- more effective exchange of information on educational and training opportunities;
- preparation and distribution of manuals, text books and other teaching materials in various languages;
- organization of training courses for scientific, technical, and auxiliary staff;
- expansion and more effective use of fellowships for professional study;
- arrangements for exchanges of teachers and investigators between countries;
- strengthening of existing centres for training and research and establishment of additional centres.

The following actions should be taken particularly for the benefit of the developing countries.

- (1) The IOC Working Group on Training and Education should develop further plans to meet training, education and manpower requirements for the Expanded Programme.
- (2) Unesco, FAO and other appropriate organizations should further strengthen and coordinate their fellowships and training programmes in marine sciences.
- (3) Member States should improve the opportunities for training and for employment of trained people in marine sciences, and should give increased support to international organizations involved in programmes of education and training, including shipboard training programmes.

2. Data and Information Management

Data and information will be one of the most important products of the Expanded Programme. Existing international systems for information and data management are not adequate to cope with the present flow of information and data. The lack of ready access to pertinent information and data presents particular difficulties to the growth of marine research in developing countries. The significant increase in the level of ocean research activity which will result from implementation of the Expanded Programme will overload these systems from the beginning. Problems that require solving include the following:

- improvement and consolidation of bibliographic and related information services;
- early exchange of plans and preliminary results of observational programmes;
- integration of real-time exchange of oceanographic data with the meteorological system;
- development of methods for storage and retrieval of biological, geological and geophysical data;
- automation of international data banks and improved programmes and methods for making their contents available;
- development of standardized and/or computer-compatible data formats;
- timely establishment or improvement of international inventories of ocean data and samples and provision for centralized cataloguing of sea data available from various private and public sources;
- strengthening system of sorting centres for biological material.

The following actions should be taken:

- (1) The IOC Working Group on Oceanographic Data Exchange in collaboration with WMO, FAO and other interested organizations such as ICES should examine the above problems and take requisite steps to meet the needs of the Expanded Programme. Certain aspects of this work can be assisted by the IOC advisory bodies.
- (2) Unesco, FAO and ICSU in collaboration with other interested organizations such as ICES should devote increased attention to the improvement of scientific information systems in the field of marine sciences.
- (3) Member States should give increased support to national, regional and world data centres as required for the expansion and improvement of their services.

- (4) Specific mechanisms should be sought for accelerating the flow of data through international exchange channels. And, all meaningful data and information resulting from projects and programmes of the Expanded Programme should be considered as Declared National Programmes (DNP) or their equivalent, to be exchanged or available for exchange and subject to inventories.

3. Instrumentation and Methods

The Expanded Programme will require the development and availability of instruments and methods of high precision and reliability. In order for data from various sources to be pooled and processed automatically, the instruments must be intercalibrated or standardized where possible and methods must be compatible.

The following problems require solution:

- there is little effective intercalibration of measurements made by one Member State, with any other Member State;
- information on the performance of instruments and related equipment is not readily available to Member States;
- standards information to ensure high quality data is not available to Member States;
- information on appropriate facilities needed for the calibration of instruments is not available;
- no effective mechanism exists for standardizing on those instruments which are worthy of such a designation.

The following actions should be taken:

- (1) IOC, Unesco, FAO, WMO, SCOR, ACMRR, ICES, and other interested bodies should jointly intensify their support for methodological work and for the improvement, intercalibration, and standardization of instruments and methods.
- (2) Member States should provide increased assistance in the conduct and publication of pertinent methodological investigations and encourage the production and adoption of standardized instrumentation where practical.
- (3) Member States should designate, where possible, an existing laboratory or facility that can act as a Centre for information relative to that state's activities in oceanographic measurement and for the coordination of instrument improvement, calibration, and standardization with other Member States.

4. Technology and Supporting Facilities

The investigation and exploration of the ocean and its resources require significant technological advances as well as the expansion and improvement of facilities. The development of such technology and facilities will require considerable investments at the national level.

The following actions should be taken:

- (1) Member States should encourage the development of advanced technologies for investigation and exploration of the ocean, which should be made generally available. In particular, the development should be encouraged of systems technology at all levels, providing for development of such systems as oceanographic buoys, research submersibles, instrumented spacecraft and aircraft, off-shore structures and undersea habitats.
- (2) IOC and other interested international bodies should facilitate the dissemination of information on advanced technology.
- (3) Member States should increase the availability of adequate facilities of all kinds for investigation and exploration activities in the oceans. In this connection appropriate assistance should also be provided to developing countries through bilateral and multilateral programmes including activities of Unesco, FAO, WHO, UN and other international organizations financed by UNDP and other international sources.

5. Supporting Services

The Expanded Programme will require the wide-spread availability of precise navigational systems, improved communications, more complete and accurate forecasts of the marine environment, and the expansion of programmes of hydrographic surveys, mapping and charting. In particular, in order to solve a large number of oceanographic problems and make possible geological and geophysical research, it is indispensable to carry out world-wide bathymetric surveys as well as more detailed bathymetric investigation of high accuracy of limited specific areas.

The following actions should be taken:

- (1) Member States should strengthen and improve supporting services and integrate them internationally.
- (2) Member States should strengthen their efforts in the hydrographic field and coordinate their programmes in order to improve and increase the production of bathymetric charts at appropriate scales.

(3) The Ocean Station System (Ocean Weather Ships in North Atlantic (NAOS) and North Pacific) should be used in the Expanded Programme of Oceanic Exploration and Research as they provide unique opportunities for continuous observations of oceanographic parameters and may serve as an important step towards an Integrated Global Ocean Station System.

(4) The IOC, WMO, IMCO, IHB, and other appropriate international organizations should work closely together in developing international aspects of the supporting services.

6. Legal Aspects of Scientific Investigation

The Commission should continue its studies pursuant to Resolution V-6.

7. Integrated Global Ocean Station System (implementation aspects)

The Implementation of IGOSS will draw heavily on all the supporting activities related to the implementation of the Expanded Programme listed in this part of the Draft Outline, with particular emphasis on:

- (a) development of appropriate technology and instrumentation, standardization and unification of instruments and methods of observations for the IGOSS programme;
- (b) standardization and unification of the format for the efficient exchange of data (realtime and non-realtime) obtained through IGOSS;
- (c) standardization of procedures for use of the radio-telecommunication channels;
- (d) organization of the oceanographic service in an integrated fashion and patterned after the World Weather Watch.

8. Organization for Implementation of the Expanded Programme

It was agreed that the Expanded Programme, which would consist of certain on-going and proposed activities of IOC as well as those of other organizations, represented a new magnitude of effort and would require a periodic review and coordination by the proposed IOC Executive Council, taking into account the views expressed by the governing bodies of the other organizations involved. For this purpose certain meetings, or portions of meetings, of the Executive Council might be designated for matters pertaining to the Expanded Programme, thus ensuring that suitable scientific and technical competence is available on national delegations for such meetings or portions of meetings.

It was agreed that the International Coordinators and the Chairmen of the relevant subsidiary bodies should report to the Executive Council on these occasions.

In a discussion of the cooperation among international organizations, it was reported that the Unesco Executive Board had authorized the Director-General of Unesco to establish an Inter-Secretariat Committee which would meet with the Chairman of the IOC to further common aspects of the work of the IOC and the participating agencies, to recommend to these agencies appropriate support action for the IOC and to coordinate such action. This Committee has been formed and met in August 1969.

There was general recognition that the United Nations should continue to use the IOC's technical competence in the scientific aspects of ocean affairs. In this connection, the responsibilities given to the IOC in UN Resolution 2467 were welcomed. The IOC should continue, in cooperation with other organizations of the UN System, to assist the General Assembly in its consideration of matters related to the ocean.

In order to guarantee the effective participation of as many countries as possible, the possibility should be considered of bringing a number of their own national programmes within the general framework of the Expanded Programme.

It was agreed that there was a continuing important rôle for the scientific advisory bodies in the review and evaluation of programmes proposed and implemented during the Expanded Programme. The IOC has recognized the need to broaden the field from which scientific advice is drawn beyond that now covered by SCOR and ACMRR. In this connection ICSU bodies are now considering alternative ways to strengthen and consolidate scientific bodies concerned with various aspects of marine science. Some steps are also being taken to establish an ocean engineering association under the World Federation of Engineering Organizations. In response to the request of the IOC Bureau WMO is giving further consideration to its scientific advice to the IOC in the field of meteorology.

9. Assistance to Developing Countries

An important goal of the Expanded Programme is enhanced utilization of the ocean and its resources for the benefit of all mankind. More than 70 developing countries border the oceans. Unused fishery resources and fuel and mineral deposits are known to exist off the coasts of a number of these nations; also, many of them are dependent on maritime transport to link coastal communities and to provide the basis for foreign trade. In the past, the developing countries have had only limited opportunities to make use of the ocean and its resources; they have, therefore, a special interest in fully participating in the Expanded Programme and in applying its results to further their own

development. The developing countries should also have the opportunity to participate in the development of the resources of the deep ocean to the extent possible. To aid them in their efforts to participate and to reap the benefits arising from the Expanded Programme, the developing nations may need scientific, technical and material assistance, especially in training and education, technology and facilities, as indicated in various sections of this document.

The developing countries may also require assistance in the design and organization of scientific programmes as well as in the strengthening and improvement of existing programmes. It is essential that greater attention be given to the needs and interests of these countries to enable them to be meaningful partners in the Expanded Programme.

The following actions should be taken:

- (1) The IOC, through its cooperative activities, and Unesco, FAO, WMO, UN and other interested organizations, with the support of UNDP and other sources, should develop plans to meet the needs of developing countries arising from the Expanded Programme.
- (2) Member States should participate actively in technical assistance programmes for the mutual benefit of those concerned with the ocean.
- (3) The IOC should encourage work on oceanic regions of particular interest to developing countries, with due regard to any national programmes already established, and should encourage the effective association of these countries in studies of this sort. In particular, the IOC should encourage every means of enabling them to embark upon such studies themselves, by the training of specialists, the setting up or the improvement of local teams and local scientific institutes, and the development of an adequate material infrastructure.

These actions should include:

- active participation by developing countries in planning and working out practicable arrangements for the Expanded Programme;
- particular attention to providing developing countries with data and information obtained from ocean research and exploration;
- participation by developing countries in ocean research conducted by vessels of other nations;
- increased opportunities to developing countries to utilize oceanographic research facilities in developed countries;
- increased availability of fellowships to ocean scientists and engineers in developing countries;

- liberal assistance to developing countries in useful technician training programmes;
- liberal provision of management assistance and technical assistance to developing countries in the establishment of marine science and technology facilities and in improved methods.
