

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

SPECIAL COMMITTEE ON OCEANIC RESEARCH

(SCOR)

Indian Ocean Working Group¹

Chairman: Dr. G.E.R. Deacon

Report of Meeting at Copenhagen, July 16-17, 1960.

Helsinki - 1 August 1960

The group met from 0900 to 1100 on 16 July and from 0900 to 0930 and 1500 to 1800 on 17 July. The working-groups on Physical and Chemical Oceanography and on Marine Meteorology, Biological Oceanography, and Marine Geology and Geophysics, met from 1100 to 1800 on 16 July and 0930 to 1500 on 17 July. The following numbers refer to the Agenda circulated from the coordinator's office on 6 May 1960.

1. The chairmen of the three working-groups outlined their main conclusions and common issues were discussed. It was agreed that the chairmen and two or three members of each group should meet during the next few days to prepare statements as detailed as possible for further discussion at Helsinki.
2. National representatives gave brief accounts of the contributions their countries would try to make, and agreed to send details to the coordinator. It is evident that cooperation between countries will greatly increase the effectiveness of the Expedition. For example Australia has two Frigates available for a total of 2-1/2 Ship years and scientists for only half this time, whereas Germany, although not expecting to have a ship before late 1963, can provide five to ten scientists and nine technicians. Moreover, two ships are needed for some geophysical work and spare ship time can be used in this way. It was agreed that a new statement should be drawn up for national committees in such a way that it will appeal to working scientists and to emphasize these possibilities of cooperation. This statement should ask individual scientists to describe special problems they are interested in and, if possible prepared to contribute to.
3. After long discussion the committee agreed that the effort being made by U.S.A., USSR, Australia and other countries before the middle of 1962 would provide a reconnaissance of the main physical, biological, topographical and geological features. It was considered that the activity beginning in the middle of 1962 should take the greatest possible advantage of cooperation between ships that could work together to cover some of the important problems in as much detail as possible. For example, UK, US, and German ships might form a nucleus of work in the Arabian Sea, and Japan and Australia in the eastern part of the ocean.

Note: The list of the members of the Indian Ocean Working Group is given in Appendix A in the report of the coordinator.

It is hoped that others, particularly ships from the USSR, would join them as well as providing related information from other regions. Meetings of the scientists who will lead the work at sea in these cooperative programs should be held as soon as possible and supported in so far as necessary by SCOR.

4. It was agreed that a laboratory-meeting should be arranged at which all the chemists who would estimate oxygen and nutrient salts in the Indian Ocean should make comparative analyses and agree on common procedures. It was agreed that it might be advantageous to extend this laboratory-meeting idea to standardization of biological methods. It was considered desirable, that ships working in the same area should meet to check their methods and exchange samples.
5. It was generally recognized that no ocean-wide navigational aid was likely to be available in the Indian Ocean by 1962-63, though it might be possible for groups of ships doing intensive work in special coastal regions to arrange for local cover, for example by portable Decca systems. It was, nevertheless, agreed that the International Council of Scientific Unions be asked to use its influence to try to hasten development and installation in the Indian Ocean area of longer range navigational systems.
6. It was agreed that it would be an advantage to have measurements of seasonal and shorter period changes in mean sea level at as many points as possible, and that a reasoned appeal for operation of tide gauges during the entire period of the Expedition should be made to national committees, and other authorities in the neighbouring countries, after the matter has been discussed with the International Association of Physical Oceanography's Committee on Mean Sea Level. It was agreed that ships fitted with wave reading equipment should take representative samples of the wave conditions.
7. It was agreed that countries sending ships ought to be prepared to purchase equipment, if such equipment will make a considerable contribution to the joint programme, and if they can fit the observations into their own programme and purchase or make the equipment at reasonable cost. It was agreed that all echo-sounders ought to have precise control of transmission intervals and record speed. The accuracy should be about 1 in 5000. It was noted that UNESCO might be able to help in procuring equipment and that everyone would try to keep prices down.
8. The question of the biological centre was referred to the biology working-group for further consideration. It was also suggested that each working-group should give some idea of the sort of working facilities that even well-provided ships would be glad to use in shore laboratories of the neighbouring countries, and of the special things, rather outside the ordinary run of commerce, that the scientists might want to buy; some chemicals and preservatives might not be readily obtainable unless the small stocks usually held in seaports and neighbouring towns were increased a little.

It was agreed that each ship should let the coordinator know its radio call sign and times of radio operation so that a list could be prepared and the need and availability of shore or ship radio stations willing to pass messages

looked into. It was agreed that a small sub-committee of Dr. Bruun, Dr. Heezen, Professor Uda, Dr. Fisher and Dr. Humphrey should consider what special arrangements might be made about shore facilities and hospitality for the ships of the expedition.

9. It was considered that training of oceanographers and technicians from the bordering countries should start as soon as possible in the laboratories of the main contributors. It was noted that UNESCO had expressed its readiness to help by providing fellowships, and it was agreed that countries sending fellows should give some guarantee that they would be given employment and be ready to take part in the expedition, either in their own ships and laboratories or in the ships of other countries. It was agreed that SCOR and the national authorities receiving fellows should be asked to approve the appointments.

It was agreed that the aims and objects of the expedition should be given careful publicity through the publications of the International Council of Scientific Unions and through its component scientific bodies.

It was thought that the only practical way to run the expedition was for all contributors to bear their own costs, and for the sums obtained from international sources and scientific foundations to be used to help those who were making determined efforts and although providing basic facilities were short of some essential items.

12. The working-group considered that the main programme should be sufficiently clearly outlined after the Copenhagen and Helsinki meetings to make further general discussion unnecessary except at the annual meeting of SCOR. It was considered that all the funds available should be used to settle questions about the usefulness, accuracy, and intercalibration of methods, and spacing and timing of observations, to obtain the best possible cover in different seasons by ships working in the same areas. Much of the work could be done by correspondence, about which the coordinator should be kept informed. The rest might be done by laboratory-meetings between the individuals and groups most concerned. Such meetings might be financed by SCOR when arranged in consultation with the executive committee. It was agreed that the SCOR budget ought to have a reasonable allocation for this purpose, but that this budget item could be presented to the treasurer of ICSU only in very general terms, since it cannot be foreseen just where and when meetings will be necessary. It was felt that splitting up of meetings would release pressure on the countries that have not yet committed themselves and SCOR might have to urge them to make contributions. The actual times and plans of meetings would have to be a matter for the coordinator and for SCOR.
13. It was agreed that all ships taking part should write frequent cruise reports outlining where they had been and what observations they had made, and giving preliminary information about outstanding features. Ships would send these reports to their parent laboratories which would circulate them to all the national committees taking part in the work, and to a number of laboratories in each participating country, if the list is not too long. Some agreement would have to be reached about what is reasonable. It was agreed that the

Hydrographic data should be circulated in the same way, as soon as they had been checked and reproduced in mimeographed or printed form. Bathythermograph data would be sent to laboratories prepared to bear the cost of reproduction. It was agreed that there should eventually be a central authority ready to produce an atlas, and to issue collected reprints from scientific journals in which different scientists had presented conclusions based on the Indian Ocean observations.

APPENDIX I

REPORT OF THE SUB-COMMITTEE ON FACILITIES FOR SHIPS

The Sub-committee met on 18 July 1960 at the headquarters of the International Council for the Exploration of the Sea, and made the following suggestions for further examination and recommendation.

1. That since the expedition is co-sponsored by SCOR and UNESCO it would be appropriate that the ships carry some emblem, badge or pennant approved by UNESCO for the expedition, and papers establishing their part and purpose in this international enterprise.
2. The States give due recognition to the international nature of the work and give to the participating vessels the assistance and courtesies generally offered to visiting government vessels.
3. That the scientific personnel be regarded as officers of the vessels and that UNESCO might provide a document for each scientist and crew member to indicate that he is taking part in the International Indian Ocean Expedition.
4. That where possible, States provide the following facilities and concessions. Some of these are covered in item 2 and others are made reasonable by the fact that the countries sending ships are thereby already incurring large expenditure for the general good.
 - (a) No canal and harbour dues for the research ships taking part. Port, docking facilities and pilotage at no cost or at the cheapest possible rates.
 - (b) Tax-exempt fuel for ships engaged in the work of the expedition.
 - (c) Special customs facilities for the entry and embarkation of scientific equipment and stores needed for the expedition. It is important that the packaging of delicate scientific equipment is not disturbed and that water samples are not opened.
 - (d) Special customs facilities for trans-shipment from ships to home laboratories of scientific specimens collected by the expedition.
 - (e) Simplification of procedure for gaining permission for ships to make scientific observations in coastal waters and to enter minor ports when necessary.
 - (f) Special communication facilities where necessary, for example, in relaying messages.

- (g) Information and as much help as possible in connection with storage and handling of the explosive charges needed for seismic studies.
5. That the National Oceanographic committees and the National Commissions for UNESCO do everything possible to promote cooperation between their scientific institutions and the scientists in visiting ships.

APPENDIX II

Report of working-group on physical and chemical oceanography and marine meteorology

The working-group met on 16 to 17 July in the Parliament Building in Copenhagen. Those present were Messrs. Böhnecke, Deacon, Dietrich, Fedorov, Fuglister, Hidaka, Iselin, Ketchum, Knauss, Laevastu, Tchernia and Uda.

The working-group felt that by 1962-63 there would be enough hydrographical and biological stations in the Indian Ocean to give a reasonably good overall network. Although the detailed study planned for 1962-63 ought to cover as much of the Ocean as possible in both summer and winter, the present estimate of ships and men likely to be available during 1962-63 suggests that they will be used most effectively by concentrating on special problems, in several major regions.

The characteristic of the Indian Ocean which distinguishes it most from other oceans and makes it a particularly useful region for physical studies, is the marked change in circulation with season caused by the change of winds with winter and summer monsoons. Most of the work in 1962-63 will be concentrated in studying these changes. The Arabian Sea will be fairly intensively covered by US and UK ships with enough lines of full hydrographic and biological stations during the NE and SW monsoons to give good maps, useful information about changes in slope of the density layers right down to the bottom, and enough data for geostrophic calculations and identification of the different water masses in winter and summer.

There will be another large area of intensive study northwest of Australia, extending at least as far as 90° east in which Japan and Australia will cooperate. It is hoped that the Japanese contribution will cover the period of the northern summer as well as the winter at home. SCAR will be asked to arrange as much oceanography as possible south of 40°S.

These surveys will include observations along lines of latitude and longitude arranged to give as nearly as possible synoptic cover. The spacing of stations with observations down to the bottom will not be more than a hundred miles, and the network will be strengthened by intermediate observations to lesser depths, by bathythermograph observations, and by use of such other salinity-temperature-depth recording equipment as is ready in time. The spacing of observations at the full stations will not be greater than the usual standard depth intervals. It is expected that ships taking part will use electric "salinometers" for "salinity" measurements.

In addition to these repeated lines there will be multiple ship studies of special problems in smaller regions. These might be joint physical and biological studies of a coastal area which at one time is dominated by upwelling water and at another by piling up of surface water by the wind. Another problem of interest to both physicists and biologists is that of the surface and sub-surface currents near the equator and their effects on the plankton and fish.

It is recognized that direct current measurements cannot be made on a routine basis, but all ships are asked to make measurements whenever they can. No recommendations were made except to emphasize the need for good reference points, such as anchored buoys, to see what the ships or floats are really doing.

The working-group recognized the need for work in the Red Sea and Persian Gulf in both winter and summer with special emphasis on the heat budget and water budget problems, and the supply of highly saline water to the northern part of the Indian Ocean. It was considered essential that there should be current measurements for at least two weeks in both winter and summer in the straits of Bab El Mandeb and Hormuz, and for a longer time, if possible. It was considered that the German anchored current meter is the most suitable for the purpose.

Among other areas not adequately provided for is the Bay of Bengal. The southern part of the ocean is partly covered by the Australian and South-African contributions, but it is hoped that some joint ship studies in physics and biology as well as geophysics can be arranged in the region of the Agulhas current and of the ocean between Madagascar and Mauritius.

METEOROLOGY

The working-group considered that the analyses of the oceanographic data would require daily weather maps as good as possible, and monthly climatic summaries for the actual working months and for as many 5° squares, or smaller areas, as possible. All the research ships should therefore take standard meteorological observations at the synoptic hours and send them at once to the authority that makes weather maps in their area. It was considered reasonable to urge meteorologists to join more actively in what should be the geophysical study of an ocean. The presence of the research ships and the great seasonal changes in water conditions will afford good opportunity for studying the energy exchange between atmosphere and ocean; the important observations will be temperature and humidity gradients, and wind profiles, and these have been made fairly successfully from floating buoys. Radiation measurements would be useful in connection with both physical and biological problems. Simple reports on times at which rain falls, and the location of rain by radar, would be possible. Radio sonde and radar wind observations would be valuable if the ships can carry enough special equipment.

CHEMISTRY

The chemical sub-group emphasized that chemical observations will be helpful in interpreting both physical and biological observations, and it recommended that all ships should carry out at least a minimum programme. To ensure comparable results from all observers it strongly recommends that all the analysts should participate in a working laboratory conference where each can conduct the various methods simultaneously and compare the results. This could also serve as a training course for those who need to learn the methods. SCOR should arrange a conference and provide funds.

The following is recommended as a minimum programme:

- I. At all hydrographic stations and at each sampling depth
 - A. Oxygen
 - B₁. Inorganic phosphorus, or
 - B₂. Total phosphorus, or both.
 - C. Silicate (if possible).

Note: Inorganic and total phosphorus appears to be equal at depths below 1000 metres in the Atlantic Ocean, but this is not believed to be true in the Indian Ocean and it is hoped that both will be determined by some vessels.

At biological (Productivity) stations in upper water layers:

- A. Oxygen
- B. Inorganic phosphorus
- C. Total phosphorus
- D. Nitrate, if possible.

At occasional stations:

Requests have been received for water samples for shore laboratories interested in determinations of trace elements. Locations and depths desired and the volume, type of storage, etc. will be established by special request and agreement with each vessel when the cruise plans are known.

The analyses for oxygen, inorganic phosphorus, silicate and nitrate, must be completed in the ship soon after collection. If this is not possible samples for phosphate, silicate and nitrate may be frozen at -10°C in a plastic bottle and delivered to a shore laboratory. Frozen samples remain unchanged for two months, perhaps longer.

Samples for total phosphorus may be stored in glass bottles for periods of up to two years without change. The bottles to be used should, however, be tested to determine whether they leach phosphorus since some have been found to be unsatisfactory. Detailed descriptions of the methods will be provided on request to each scientist interested. The following methods are recommended:

1. Oxygen: Winkler-titration (cf. Barnes, 178-185)
2. Inorganic phosphorus: Molybdate method (cf. Harvey, 1948, Barnes 151-55)
3. Total phosphorus: Harvey method (cf. Harvey, 1948, Barnes 157-161, Ketchum et al., 1955) or perchloric acid digestion (cf. Hansen and Robinson, 1953)
- 4 Nitrate: Reduction, and analyses of nitrite (cf. Mullin and Riley, 1955, Barnes, 118-122).
5. Silicate: Molybdenum method (cf. Barnes 163-166)

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- Ketchum, B.H., N. Corwin and D.J. Keen, 1955. Deep-Sea Res., 2, 142-81.
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APPENDIX III

Report of Geology and Geophysics Working-Group

The geology-geophysics-bathymetry working-group for the Indian Ocean Expedition met on 16-17 July, and made the following recommendations:

1. Since it has been agreed that all ships participating in the Expedition will make certain basic observations regardless of their primary cruise aims, the working-group proposes that all vessels should record soundings continuously, employing echo-sounders with a precision time-base accurate to 1 part in 5000 or better. These soundings, together with navigational plots, should be distributed rapidly to other participants. They should also make routine 900 ft. bathythermograph observations at 2-hourly intervals, and more frequently when crossing convergences and major current boundaries. Also, standard meteorological observations and thermograph recordings of surface temperature.
2. Other operations which require little additional ship time should be encouraged. In the geological-geophysical category these include shallow sub-bottom reflection measurements, by sparker or sonoprobe, cores, bottom-photographs, dredging, magnetic measurements, and gravity observations from the larger and more stable vessels. These are not programmes like those in paragraph 1, to be expected of all ships.
3. Some or all the following types of observation should be carried out by ships making geological and geophysical expeditions. (See also Annex 1 for procedures, and report of second SCOR meeting in New York 1959, for summary of problems.)

- (a) Precise bathymetric exploration, particularly of seamounts, ridges, trenches, and shelf and slope-topography.
 - (b) Continuously recorded magnetic intensity measurements.
 - (c) Continuously recorded gravimeter observations by suitable surface ships and pendulum gravity observations by sub-marines where ever available.
 - (d) Bottom photography, often in conjunction with rock-dredging to determine the abundance and distribution of manganese nodules on the deep-sea floor.
 - (e) Rock-dredgings as frequently as possible. Any biological specimens attached to the rocks collected should be preserved separately.
 - (f) Heat flow measurements in patterns appropriate to structure investigated.
 - (g) Collection of large water samples for radio-isotope dating and trace element analysis.
 - (h) Collection of gravity and piston cores with duplicate cores in areas of special interest. Piston cores with core barrels 30 feet or more in length are recommended.
 - (i) Seismic refraction measurements. Measurements by two ships making continuous profiles across transition zones and major structural features are desirable. Short profiles yielding information on shallow crustal layers may be carried out with small auxiliary shooting boats, or sonobuoy arrays. Since two rather large vessels are required to shoot the long seismic lines needed for measurements to the base of the crust (or the Mohorovicic discontinuity), the working-group recommends that special efforts be made for cooperative two-ship cruises, and that in addition funds be sought by the geophysical expedition to provide shooting ships, available at various times and places, for a total of about one ship year.
4. The working-group recommends that grants and fellowships be sought for travel and training of students, and for exchange of visiting scientists, both at sea and on shore. It suggests that the selection of recipients of such aid be made jointly by the laboratory where the students are to work, and by the agency providing the money.
 5. To avoid duplication of effort, to ensure the widest possible coverage, and to ensure that all regions are adequately covered, means of rapid exchange of information about completed ships tracks, types and positions of operations completed, and programmes of proposed cruises is required. The working-group recommends that this information be distributed to all participants immediately on the completion of each cruise or of each part of a major cruise, either by a central office or by the laboratory actually responsible for the cruise.
 6. Comments and suggestions on sounding techniques and procedures are appended in Annex 1.

The working-group consisted of Messrs. R.L. Fisher, B.C. Heezen, A.S. Laughton, J. Nafe, J.N. Nanda, and E. Seibold. Observers were Professor Hales, Commander Hunt and Dr. Neev, P.L. Bezrukov, A. Zhivago, and H. Niino were unable to attend.

APPENDIX IV =====

----- Report of the Biological Working-Group for the Indian Ocean Expedition -----

The working-group met on 16 and 17 July at the Parliament Building in Copenhagen and on 18 and 19 July at the Headquarters of the International Council for the Exploration of the Sea in Charlottenlund. Those present were: Miss Ray and Messrs. Austin, Bary, Bé, Bruun, Currie (Chairman), Davies, Fedorov, Fraser, Hall, Hansen, Humphrey, Ketchum, Krey, Laevastu, Pannikar, Snider, Steele, Steeman-Nielsen, Steinitz, Sugawara, Vetter, and Zenkevitch.

The primary biological aims of the expedition should be:

1. To study the three dimensional distribution of plants and animals.
2. To investigate the quantitative ecology of the plankton.
3. To collect as much information as possible within the scope of an oceanographical expedition about potential fisheries in the Indian Ocean.

As the expedition will be formed of a series of national contributions it is considered that while these nations work on problems of more specific interest to themselves they should also contribute to a general biological (reconnaissance) survey of the ocean. It is realised, however, that some of the ships taking part will neither be equipped nor staffed specifically for biological work and so it is proposed that the biological work requested from all ships should be kept to an absolute minimum. Such a programme must necessarily be confined to a study of the surface layers and to a limited section of the flora and fauna. To supplement this minimum programme, it is proposed that some of the larger ships with suitable biological staffs should make more detailed observations. If these are disposed along three meridional sections and repeated as much as possible in different seasons they should suffice to give a basic picture of the biological structure of the ocean. These two programmes together are considered to be the minimum amount of work which is essential, but for ships unable to participate to this extent in the biological programme a specially abbreviated alternative is proposed.

Besides the general biological survey the ships will have their own special tasks to perform in the area, and these should in most cases supplement the information obtained by the general biological survey. It is considered neither desirable nor necessary to make detailed proposals for work on these special tasks as the methods used will depend very largely on the problems being tackled. For information, however, a number of problems of particular interest in the Indian Ocean are noted in Annex 1 to the biological programme.

The basic biological programme to be undertaken
by all ships taking part in the expedition.

Underway observations

1. Standard meteorological observations.
2. Continuous records of sea surface temperature.
3. Records of
 - (a) Discoloured water and accumulations of plankton
 - (b) Fish mortalities
 - (c) Fish shoals observed on the surface and also on recording echo sounders
 - (d) Depth and intensity of scattering layers shown on the recording echo sounders
 - (e) Occurrence of flying fish, squid, turtles, sea snakes etc. and surface living animals such as Physalia, Velella, Janthina
 - (f) Whales, dolphins, porpoises (sharks, squid, etc.)
 - (g) Seals and Sirenia in coastal waters
 - (h) The occurrence of insects, (especially of locust swarms)
 - (i) Numbers and kinds of oceanic birds, to be recorded at three or four hour intervals
 - (j) Floating material far from land such as land vegetation, drift wood cuttle bones, Spirula shells, pumice, etc. (samples should be collected)

Instructions for the above observations should be prepared and distributed to all ships.

The sub-committee recommends that it would be most desirable to have continuous records of the incident radiation on the sea surface and proposes that the meteorologists should be approached with a view of their cooperation in such a project.

Station observations (to be made if possible at all hydrographic stations).

Daytime Stations (preferably at 1200 local time and in any case between 1000 and 1400).

- (a) Depth of sampling will be determined by measuring optical depths.
- (b) Samples taken from 6 optical depths 100%, 75%, 50%, 25%, 10%, 1% to be measured for chlorophyll content and used for C_{14} determinations of photosynthesis using the simulated "in situ" technique.
- (c) Nutrients to be measured as recommended by chemical working-group.

Night Stations (2200 hrs. local time).

- (a) Vertical net haul 200-0 metres. Displacement volume of catch to be measured on board with apparatus provided.
- (b) Horizontal net haul near surface with a one-metre net towed for 30 mins, and if possible at the same time an oblique haul with similar net from 100-0 metres. Displacement volumes to be measured as in (a).
- (c) Estimations of nutrients.

The extended biological programme to be undertaken by selected ships.

This work should, if possible be performed on three meridional sections in the Indian Ocean, along approximately 62°_E, 78°_E and 95°_E extending from the continent southwards to the southern subtropical convergence. This programme will be as the basic programme but will include also:-

At night stations

Vertical net hauls in the depth intervals 1000-500m, 500-200 m, and 200-0 m.

At day stations

After the station a high speed sampler will be used to sample fish eggs and larvae.

Also at 500 mile intervals on these lines of stations tows with a mid-water trawl (such as the Isaacs-Kidd trawl) will be made between 1000 metres and the surface.

Ships which are neither equipped nor staffed sufficiently to undertake either of these biological programmes should be requested to do an absolute minimum of biological work which would include:

- (a) The underway observations listed on p. 11.
- (b) At night stations only, a single water sample taken with a Van Dorn sampler from one metre depth, filtered through a 0.5 μ filter and preserved for chlorophyll analysis. Also a vertical net haul from 200 metres to the surface and a surface haul with a one-metre net after the station and towed for 30 mins.

Treatment of plankton catches.

All plankton should be preserved in 10% neutral formalin and it is proposed that the catches from oblique and horizontal tows should be divided by standard method, one half to be sent to a central handling station for plankton. This plankton station would primarily be a storage and sorting centre, but it is hoped that it might later be developed into a taxonomic centre in connection with the UNESCO training programme.

The committee felt that such a biological centre would most conveniently be stationed in India under the supervision of the Indian Government, but they stress the necessity for the appointment of a suitable director and staff to handle the collections. It is proposed that UNESCO should be requested to assist in the implementation of this as soon as possible.

Methods and equipment.

C₁₄ method.

The recommendations proposed by SCOR working-group III at New York should be followed, but it is noted that these may need to be modified by developments resulting from work now in progress.

Chlorophyll.

The technique of Richards and Thompson should be followed but more precise details of the method will be submitted. Non-biological ships taking samples should preserve them by a prescribed method for later analysis in shore laboratories.

Zooplankton nets.

For vertical hauls a net of about 1/2 m² mouth area having nylon netting with a mesh size of 160-180 μ should be used. The hauling speed should be 1 m/sec. and the net should be fitted with a flow-meter.

For the horizontal and oblique hauls a net with 1 metre diameter mouth area and netting of 30 meshes per inch should be used, towed at a speed of 1-2 knots. This net should also be fitted with a flow-meter.

Decisions on the type of sampler to be used for the high speed towing has been postponed to await the recommendations of the ICES herring committee (and other evaluation).

Biomass.

The displacement volume of catches from the vertical net hauls should be measured by a standard technique to be described in detail later.

Shore laboratory facilities.

Some facilities at selected shore stations will be necessary for the estimation of chlorophyll in samples taken by ships not specially equipped.

Supply of equipment.

At the selected shore laboratories spectrophotometers will have to be available, and also centrifuges.

Dr. Humphrey has suggested that if the Australian method is used for displacement volumes, then his laboratory would probably be able to supply the necessary apparatus.

The plankton nets recommended for the basic programme will have to be prepared for some of the participating ships.

Plastic 5 litre water sampling bottles of the Van Dorn type will be needed for nearly all of the ships.

Submarine and deck photometers may be necessary for some of the ships taking part in the extended biological programme.

Flow-meters will be needed by most ships.

Supplies of glass plankton storage jars of the "Kilner" jar type.

Filters, filtering apparatus and desiccators will be needed for the chlorophyll measurements. Gear which cannot at present be specified will be needed for the C_{14} measurements in selected ships.

If radiation measurements are done, recording thermopiles would be required.

The need for adequate supplies of spares of all this equipment is emphasized.

Observations by merchant ships.

It is suggested that the organisations sponsoring the merchant ships and fisheries surveying ships which send in visual or instrumental reports of, for example, discoloured water, whales, current rips etc. should be made aware of the expedition and requested to cooperate as fully as possible, as their observatories would be a valuable supplement to the work of the expedition.

ANNEX 1 to the Biological Programme

Special problems in the Indian Ocean.

The sub-committee is aware of the importance of many special problems in the Indian Ocean and believes that some of these can be the subject of special investigations. It is essential that the organisation of these special investigations be left to the specialists undertaking the work, and it is proposed that facilities should be available for specialists cooperating on such problems to meet together to plan their programmes. In much of this research close cooperation with the physical and chemical programmes will be essential and the work planned must depend on agreement between the biologists and the specialists in the other disciplines. Some possible subjects for special investigations are:

1. Upwelling and piling up of water along coasts.

It is hoped that when surveys of areas of upwelling and "anstaun" are made attention will be paid to questions of the development and succession of phyto and zooplankton populations and of decomposition and nutrient regeneration in the coastal regions.

2. Equatorial divergence.

Since the problem will be studied intensively by the physical oceanographers, if possible the programme should be extended to include the effects on productivity.

3. Coral reefs.

It has been suggested that the productivity of coral reefs might be studied in the region of the Red Sea and it is possible that some countries in the area may be able to undertake this work. (For comparison similar studies should be made of central Indian Ocean reefs.)

4. Fish mortality.

The occurrence of extensive fish mortalities, particularly in the Arabian Sea has been noted. It should certainly be a task of the expedition to try to collect more information about the occurrence, extent and cause of such mortalities. The causative factors most worthy of consideration are sudden changes in water temperature, lack of dissolved oxygen in the water and the presence of blooms of certain micro-plankton organisms which are capable of releasing toxins into the water.

In the past these factors have been observed either together or separately in coincidence with mortalities, but the question of greatest importance is to determine the sequence of events as some of these manifestations may be resultant rather than causative.

5. Other special problems.

It is hoped that the study of the quantitative and qualitative distribution of the benthos (any rocks obtained in biological sampling should be retained for the geologists), and the biomass of the deep sea plankton will be included in a few national programmes. Other questions such as the particulate carbon/chlorophyll and the protein/chlorophyll ratio may be studied on some ships.

6. Regions of convergence.

Japanese experience has shown the importance of regions of convergence to oceanic fisheries and these features should receive special attention in exploratory work for potential fisheries.

Annex 1 to Report on Geology-Geophysics-Bathymetry

1. Base maps.

It is suggested that all soundings from the Indian Ocean available to date be collected and evaluated by one office, agency or laboratory, and copies of the evaluated data, preferably in the form of easily-reproduced plotting sheets, be made available to participants in the Indian Ocean Expedition. Countries taking part in the Expedition should now furnish all data from their files. Several hydrographic offices make such compilations, and a special effort should now be made to ensure that they get all soundings that have been made. Among agencies doing this work are the British Admiralty and the Scripps Institution. The sounding data should then be contoured by

experienced marine scientists, if special areas of interest are involved. The contoured base map should be reviewed by other scientists interested in the area.

A smaller scale version of the contoured data should be prepared and distributed for use in planning cruises. This chart, like the larger sheets a Mercator projection, should show the Indian Ocean and surrounding seas on the same scale as the General Bathymetric Chart of the Ocean (1:10.000.000 at the Equator).

An accompanying index chart to the same scale (1:10.000.000) should show sounding tracks and indicate areas of special interest or where data are most needed.

This compilation and collection of data should be started soon so that the soundings and resulting base charts will be available for planning all the work to be done after the middle of 1962.

2. Preservation of bathymetric materials and data.

All ships in the Expedition should be requested to prepare and preserve navigational plots of the ship's track. These plots or lists should include all fixes, times, course and speed changes and the like. The data should be in graphical or list form, preferably the former. The adjusted plot should be on a scale of 1:1 million or approximately 4 inches to a degree of longitude. Mercator plotting sheets of the scale agreed on should be made available for use at sea.

It is further suggested that navigational plots with soundings be prepared on the 1:1 million scale, in a form such that copies for general distribution can be made inexpensively. On these plots, soundings should be noted at intervals of not greater than 2 miles, and at all significant peaks, troughs and breaks-in-slope along the ship's track. Changes in the degree of roughness (average amplitude and length of bottom irregularities) should be noted. Soundings should be plotted as the nominal depth read from the sounder. On each plot the nominal sounding velocity must be specified. If corrected soundings are plotted, the method of correction must be indicated.

Echo-sounders should be operated continuously on a recording scale sufficiently expanded to allow soundings to be read to 2 m (1 fathom) at all depths. A minimum transmission length (ping-length) adequate to obtain a well-resolved record is required. Ordinarily, a 2-3 millisecond transmission is advisable to permit resolution of sub-bottom echoes. Records must be marked with date, local time, and depth scale at least hourly, and at each course and speed change. Echograms should be preserved either by the laboratory or agency taking them or by a designated office.

It is strongly recommended that echo-sounders with built-in time bases good to 1 part in 5000 or better be employed. Such instruments as the Precision Depth Recorder (made by Times Facsimile Company, Westrex Corporation, New York), the Precision Graphic Recorder (Alden Industries,

Massachusetts), the N.I.O. Precision Echo-sounder, and the special precision sounder made by ELAC (Kiel) are suitable. If other sounders are used, special effort to regulate, calibrate, and monitor the time base is required to obtain comparable soundings. All ships operating outside the continental shelves should be equipped with recording sounders capable of sounding the greatest ocean depths.