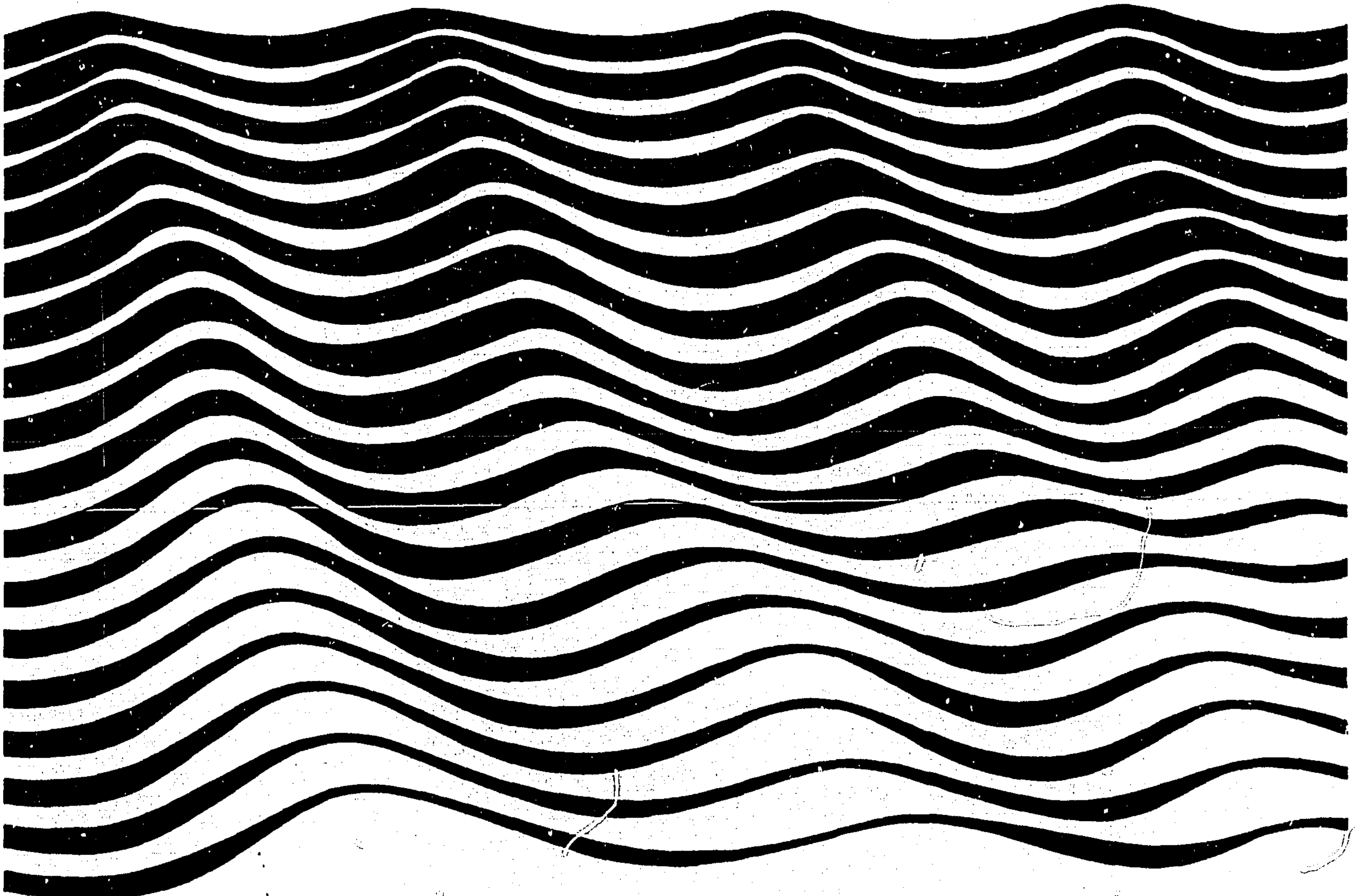
Unesco technical papers
in marine science 26

Marine sciences in the gulf area

Report
of a consultative
meeting
Paris, 11-14 November 1975



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Numbers 2, 3, 5, 6, 7, 10 and 12 are out of stock. For full titles see inside back cover.
Numbers 1, 4, 8 and 14 are incorporated in No. 27.

No.		Year	SCOR WG
9	Report on intercalibration measurements, Leningrad, 24-28 May 1966 and Copenhagen, September 1966; organized by ICES	1969	–
11	An intercomparison of some current meters, report on an experiment at WHOI Mooring Site "D", 16-24 July 1967 by the working group on Continuous Current Velocity Measurements. Sponsored by SCOR, IAPSO and Unesco	1969	WG 21
13	Technical report of sea trials conducted by the working group on photo-synthetic radiant energy, Gulf of California, May 1968; sponsored by SCOR, IAPSO, Unesco	1969	WG 15
15	Monitoring life in the ocean; sponsored by SCOR, ACMRR, Unesco, IBP/PM	1973	WG 29
16	Sixth report of the joint panel on oceanographic tables ans standards, Kiel, 24-26 January 1973; sponsored by Unesco, ICES, SCOR, IAPSO	1974	WG 10
17	An intercomparison of some current meters, report on an experiment of Research Vessel Akademic Kurchatov, March-April 1970, by the working group on Current Velocity Measurements; sponsored by SCOR, IAPSO, Unesco	1974	WG 21
18	A review of methods used for quantitative phytoplankton studies; sponsored by SCOR, Unesco	1974	WG 33
19	Marine Science Teaching at the University Level. Report of the Unesco Workshop on University Curricula – *Also published in French and Spanish*	1974	–
20	Ichthyoplankton. Report of the CICAR. Ichthyoplankton Workshop *Also published in Spanish*	1975	–
21	An intercomparison of open sea tidal pressure sensors. Report of SCOR Working Group 27: "Tides of the open sea"	1975	WG 27
22	European sub-regional co-operation in oceanography. Report of a working group sponsored by the Unesco Scientific Co-operation Bureau for Europe and the Division of Marine Sciences	1975	–
23	An intercomparison of some current meters, III. Report on an experiment carried out from the Research Vessel Atlantis II, August-September 1972, by the Working Group on Continuous Velocity Measurements: sponsored by SCOR, IAPSO and Unesco	1975	WG 21
24	Seventh report of the joint panel on oceanographic tables and standards, Grenoble, 2-5 September 1975; sponsored by Unesco, ICES, SCOR, IAPSO.	1976	WG 10
25	Marine science programme for the Red Sea: Recommendations of the workshop held in Bremerhaven, FRG, 22-23 October 1974; sponsored by the Deutsche Forschungsgemeinschaft and Unesco	1976	–
26	Marine sciences in the Gulf area - Report of a consultative meeting, Paris, 11-14 November 1975	1976	–
27	Collected reports of the joint panel on oceanographic tables and standards, 1964-1969	1976	WG 10

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PREFACE

This series, the Unesco Technical Papers in Marine Science, is produced by the Unesco Division of Marine Sciences as a means of informing the scientific community of recent developments in oceanographic research and marine science affairs.

Many of the texts published within the series result from research activities of the Scientific Committee on Oceanic Research (SCOR) and are submitted to Unesco for printing following final approval by SCOR of the relevant working group report.

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75700-Paris, France

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1. INTRODUCTION

During the period 1973 to 1975, a number of missions to the Arab States of the Gulf and to Iran were carried out by Unesco staff and consultants in order to assess the status and future prospects of, and to prepare recommendations for the development of marine sciences in this important area. In all of the Gulf States, there exists a nucleus of marine-oriented research around which a future programme could be built. Unesco's initiative has evoked considerable enthusiasm from scientists working in local institutions and has been followed by affirmative action on the part of national authorities.

The moment was opportune therefore to bring together representatives of the universities and scientific institutions of the countries concerned, and marine scientists and advisers who have had experience in this region, for the purpose of planning a programme of interdisciplinary marine research relevant to the problems of the area. Consequently, a meeting was organized by Unesco in Paris from 11 to 14 November 1975. Representatives of institutions currently engaged in, or planning to start educational or research programmes in marine science were invited from all of the Gulf States. A list of participants is found in Appendix I. Although Bahrain, Saudi Arabia and the United Arab Emirates could not send nationals from their own institutes, their contributions were not overlooked since experts who had visited these countries were able to report on the work going on there. All the component disciplines - physical, chemical and geological oceanography, ocean engineering, marine biology and fisheries - were represented at the meeting. Related activities within the United Nations system were referred to where appropriate (Unesco and its Intergovernmental Oceanographic Commission, United Nations, United Nations Development Programme, United Nations Environment Programme, Food and Agriculture Organization of the United Nations, World Meteorological Organization, Inter-governmental Maritime Consultative Organization, International Atomic Energy Agency, etc.).

The aim of the meeting was to identify the particular needs of the various States and the most appropriate contributions that could be made by each of the institutes of the region. The meeting expressed the hope that the institutes would co-ordinate their work programmes so as to reinforce each other by sharing facilities and experience, and also to avoid, as far as possible, uneconomic duplication of effort. The long-term aim of the marine science programme is to build up a comprehensive foundation of knowledge of all the natural processes going on in the waters of the Gulf, on the basis of which the many practical problems of coastal area development can be examined rationally. Not only must this knowledge be acquired, but it must also be disseminated and interpreted. Hence it is also necessary to plan for the establishment and growth of centres of advanced scientific and technical training, and for the general education of the community with respect to the marine sciences.

The meeting took the form of a workshop consisting of four working groups. The first two groups considered the programmes of basic research in the two main divisions of oceanography respectively: the Physical Group comprising physical, chemical and geological oceanography, and the Biological Group dealing with marine biology and fisheries. The views of these two working groups were discussed jointly in plenary session and were made available in draft form as a basis for the remaining two working groups. Working Group 3 dealt with applied marine science and technology, including subjects such as pollution, conservation, ocean engineering and mariculture. Working Group 4, dealing with marine science research and educational infrastructure, was set up to recommend ways and means of achieving the developments in marine science put forward by the three disciplinary working groups.

It was felt that, since there was some overlapping between the working groups, the convenor and rapporteur should prepare a shortened summary of the main recommendations. This summary appears as section 2 of this report. The reports and detailed recommendations of each working group follow in section 3.

The recommendations represent a marine science action plan for consideration by the States of the Gulf area. Furthermore, the recommendations are intentionally comprehensive so that they embrace the competence of several UN Agencies, demonstrating not only the interdisciplinary nature of marine science but also the need for a multi-based approach.

A study prepared by the convenor, Professor D.J. Crisp, was used as the background paper for the meeting. This paper, together with a review by Professor K. Grasshoff of present knowledge of the hydrographical conditions and productivity of the Gulf, are included in this report.

Unesco wishes to thank Professor D.J. Crisp, who acted as the convenor, Dr. D. Jones, the rapporteur of the meeting, and the chairmen and rapporteurs of the working groups. The success of the meeting is in large measure due to their efforts.

2. SUMMARY OF THE RECOMMENDATIONS OF THE WORKING GROUPS

2.1 MARINE SCIENCE RESEARCH

Physical oceanography

(i) The interaction between the atmosphere and the sea should be studied in different regions of the entire Gulf over a period of at least three years, and field studies should be made of the vertical structure of the water column. These investigations should lead to a mathematical predictive model of the principal currents, water exchange, and diffusion coefficients.

Chemical oceanography

(i) The distribution of nutrients in the water column and their seasonal variation should be investigated throughout the entire Gulf region in association with plankton and primary production studies.

(ii) With regard to the special environmental conditions in the Gulf, studies of nutrient uptake and regeneration should include the role of nitrogen fixation, as well as the interaction between the sea water and sediments with respect to nutrients.

Geological oceanography

(i) The existing knowledge of the bottom topography and the geophysical structure of the Gulf should be collated, and field work should be undertaken to fill identified gaps, especially in the Straits of Hormoz and the Sea of Oman.

(ii) Investigations should include determination of the mechanical properties, the origin and the distribution of the sea floor deposits. The erosion, transportation and deposition of sediments by nearshore currents and wave action should be especially studied.

(iii)The study of the geochemistry, diagenesis and petrology of marine sediments is of particular interest because of the conditions of high temperature and salinity in the Gulf.

Marine biology

(i) The prerequisite of all the biological programmes is that urgent attention be paid to the listing of local species and the development of taxonomic expertise in the region.

(ii) Monitoring and base-line studies are required on the seasonal and long-term changes, both of the organisms comprising the food chain present in the water column and of the shallow water and shore species.

(iii)The biology, population dynamics and migration patterns of commercially important species should be investigated to supply background science to government fishery agencies. Included as priorities are the shrimp and fish species, both demersal and pelagic, which form the existing commercial resources.

(iv) Much more basic information is required on the ecology of the coastal zone, including its lagoon, estuary, mangrove and reef ecosystems, particularly in regard to their vulnerability to coastal development and pollution.

Pollution

(i) The potential impact of a large accidental oil spill is so great that high priority must be given to the development of the scientific capacity sufficient to predict the effects and minimize the damage of such an event. Attention should be paid to the probable effects on marine organisms of measures adopted for the control of oil spillage.

(ii) Base-lines must be established for the levels of airborne and landbased major pollutants, which are present in sea water, in the organisms and in sediments. These include petroleum hydrocarbons, chlorinated hydrocarbons and pesticides, and the metals mercury, cadmium, lead, zinc and copper. Such investigations need only be carried out in one or two institutes, but the results should be disseminated to all States.

(iii) Information from different parts of the Gulf should be assembled in order to predict the influence of industrial and urban pollution on the coastal zone, preferably before industrial plants are established. Base-line studies should also be initiated wherever new discharges are planned.

Conservation

(i) A research base is required on the present population size, distribution, migrations and population dynamics of the species which are in need of conservation, particularly endangered species such as the dugong, certain sea birds and turtles.

(ii) The impact of various developments on coastal zone processes and ecosystems should be evaluated by national or regional bodies prior to further modification of the environment.

Systems planning and management

(i) A systems engineering or operational research approach to marine planning and development is urged for the Gulf region.

(ii) Suitable zones for potential development as industrial sites, resorts, marine parks and wetland reserves should be located through an evaluation of the coastal area. Surface sediments should be mapped to assess the occurrence of minerals of economic importance, mainly construction materials.

(iii) Manpower and budgetary constraints emphasize the need for a "case study" approach to marine research-related engineering problems. The approach involves problem definition, classification of problem types and dissemination of details to all interested parties in the region.

Mariculture

(i) Research should be directed towards choosing species suitable for cultivation under artificially managed or semi-natural conditions and towards optimizing the factors controlling their growth and utilization. The Gulf should be surveyed to locate areas suitable for mariculture.

2.2 INFRASTRUCTURE FOR MARINE SCIENCE RESEARCH AND EDUCATION

Integration and co-operation

(i) All tne Gulf States were strongly urged to establish national committees of oceanography representing all institutions involved in basic and applied marine science.

(ii) Regional cooperation should be developed through the exchange of scientists, the formal exchange of reports and reprints, thereby facilitating the free flow of information, the sharing of research vessel accommodation and other scientific facilities, and the standardization and intercalibration of methods. Periodic meetings of scientists in the region were strongly recommended.

Establishment of marine institutes

(i) Though each country will have its specific needs, marine science is best conducted by universities or by institutions closely linked with universities. It was stressed that any marine institution needs a station by the sea, especially for the study of marine biology where live material must be kept in frequently-changed clean sea water. Each institution should have or share a vessel of at least 15 meters in length equipped for a variety of disciplines.

Dissemination of information

(i) Each institution should have a library containing periodicals and reference material on basic marine science, and should partake in a regional exchange system in order to build up a complete set of current literature. There was felt to be no need for a regional library centre since the existing information systems (ASFIS and other sources) would be more appropriate in identifying and locating more specialized literature.

(ii) Regional or national oceanographic data centres are not thought to be immediately necessary; scientists in the Gulf should, however, make use of the existing World Data Centre System.

Fauna and Flora Collection

(i) Since the fauna and flora of the Gulf is of interest to all states, a regional reference collection is strongly recommended. Such a collection should be managed by an active group of taxonomists and could be established by strengthening an existing museum. It should be located in the Gulf area in a place with good communications.

Training

(i) Stress is laid on the need for technic l training, ideally in the home country but if necessary in overseas marine research institutions.

(ii) The training of highly qualified professional staff should be explored through national fellowship programmes, bilateral agreements, training components in the UNDP country programmes, and through the various countries' Funds-in-Trust programmes with Unesco. As there is a particular need for persons educated in basic engineering disciplines to have also a fundamental knowledge of marine science, the training of graduates as ocean engineers is recommended.

(iii) It is also strongly recommended that the Unesco fellowship programme, which provides for the short-term training of marine scientists from developing countries, be strengthened.

(iv) It was the consensus of the group that countries of the region should utilise foreign expertise in the planning and initial development of their marine science and technology programmes. Unesco's competence could be used in the selection of experts.

3. DETAILED RECOMMENDATIONS OF THE WORKING GROUPS

3.1 WORKING GROUPS

Working Group 1. Physical, Chemical and Geological Oceanography
Prof. K. Grasshoff (Chairman), Prof. A. Richards (Rapporteur),
Dr. B. Al-Timimi, Dr. M. Amini, Dr. J. Forati, Dr. F. Hosseinie,
Dr. S. Morcos, Dr. M. Shahinpoor, Prof. U. Stefansson.

Working Group 2. Marine Biology
Prof. S. Saila (Chairman), Dr. D. Jones (Rapporteur),
Prof. A. Ar-Rushdi, Dr. K. Behbehani, Mr. E. Carp, Dr. M. Saoud,
Dr. J. Wickstead.

Working Group 3. Applied Marine Science and Technology
Prof. A. Richards (Chairman), Mr. E. Carp (Rapporteur),
Dr. M. Amini, Dr. J. Forati, Prof. K. Grasshoff, Dr. D. Krause,
Prof. S. Saila, Dr. M. Shahinpoor, Dr. J. Wickstead.

Working Group 4. Marine Science Research and Educational Infrastructure
Prof. U. Stefansson (Chairman), Dr. U. Lie (Rapporteur),
Dr. B. Al-Timimi, Prof. A. Ar-Rushdi, Dr. K. Behbehani, Mr. R. Cuzon du Rest,
Dr. F. Hosseinie, Dr. D. Jones, Dr. S. Morcos, Dr. M. Saoud.

3.2 PHYSICAL, CHEMICAL AND GEOLOGICAL OCEANOGRAPHY

Physical oceanography

From the practical point of view, the knowledge of the large-scale, meso-scale and small-scale processes of water circulation is essential for prediction of such vital factors as dispersion of waste products, movements of drifting oil spills, transport of material along the shore, coastal erosion, usefulness of harbour protection measures, and influence of changes of the bottom topography.

Studies of physical processes are also important for the understanding of the nutrient dynamics in relation to primary and secondary production, the behaviour of pollutants in the sea, and the behaviour and migration of fish.

It is obvious that the study of physical processes is also necessary for wave and current forecasting for naval purposes and for any kind of offshore and underwater operations. Other marine science aspects of naval defence may also be considered.

Recommendations

(i) Action should be taken to determine what relevant meteorological observations are made within the Gulf, where such measurements are made, by whom and their frequency. It should also be established if data are communicated to the World Meteorological Organization and to national authorities or only to customers.

(ii) Infra-red remote sensing data should be acquired (a) by satellites for large-scale studies, and (b) by low-flying aircraft for meso- and small-scale studies; the frequency of the latter measurements should be once per month.

(iii) One or two institutions should use meteorological data to study air-sea interaction in the Gulf in order to establish a physical model and to verify the correctness of the model through the use of relevant physical oceanographic data, principally currents. A minimum of three years' continuous data will be needed to define and delineate adequately air-sea interaction, principal currents, water exchange, and their variability.

(iv) Field studies should be carried out to determine vertical and horizontal exchange and diffusion coefficients, with special reference to the water structure in different regions in the Gulf during different seasons.

Chemical oceanography

From the practical point of view, the fertility should be assessed of the waters of the Gulf and its specially important regions, including their potential in terms of commercial fisheries. Evaluation of the state of health of the Gulf, the influence of sewage and waste discharge on the marine environment, the pathways and fate of pollutants and their reaction with sea water is possible only through the application of marine chemistry.

Recommendations

(i) Regular investigations should be carried out into the distribution of nutrients and their variations in the entire Gulf region, including the transition area of the Strait of Hormoz and the Gulf of Oman, in close association with plankton and primary production studies.

(ii) The dynamic processes of nutrient uptake and regeneration with respect to the special environmental conditions in the Gulf should be studied.

(iii) The interaction of sea water and sediment in the intertidal zone, with respect to nutrients, should be studied.

(iv) The chemical aspects of the impact of nitrogen fixation on the primary production should be studied.

(v) Base-lines should be established for the major and important pollutants, i.e., petroleum hydrocarbons, chlorinated hydrocarbons and metals, including mercury, cadmium, lead, zinc, and copper.

(vi) The influence of both domestic and industrial sewage on the local and regional environment with respect to nutrients and pollutants should be studied.

(vii) Intercalibration exercises must be carried out.

Geological oceanography

Studies in geological oceanography, which is taken to include geochemistry and geophysics, are required to understand the following parameters and processes vital to the industrial development and scientific knowledge of the Gulf: the areal and vertical distribution of the different kinds of sediments, their sources, and their age relationships throughout the Gulf and the Straits of Hormoz; the dynamic processes of sedimentary transportation, deposition and erosion, with particular emphasis on how movements of sediments (i) affect the epifauna and infauna and (ii) affect engineering works; the engineering or geotechnical properties of the sediments and rocks; the structural and tectonic relationships, with particular respect to quantifying seismicity and its effects. An essential collaboration is required between the engineer and the marine scientist in determining the system interaction between an offshore engineering structure, the environmental loads (wind, waves and currents) on the structure, its foundation and the underlying sediments. Also the types and availability of mineral resources (mostly for the construction industry) in the Gulf, Straits of Hormoz, and Sea of Oman should be assessed. The geological and geochemical processes of diagenesis (i.e., transformation of sediments into rock) in carbonate and non-carbonate sediments, including evaporites, should be examined under the interesting conditions of high temperature and salinity which occur in the Gulf.

Recommendations

(i) Existing depth, seismic reflection, seismic refraction and other geophysical data for the Gulf, Straits of Hormoz and Sea of Oman, should be obtained from the oil companies and governmental agencies. This information should be compiled on a common scale. Then, maps should be prepared showing stratigraphic and structural relationships, kinds of sediments and rocks, and distribution of inactive and active areas of slumping or sliding on the sea floor and of faulting. It may be necessary to supplement the existing data for the Straits of Hormoz and the adjacent ports of the Sea of Oman by further surveys.

(ii) Studies should be made of the dynamic processes governing sediment transportation, deposition, and erosion, particularly of the clastic sediments in the Gulf, and adjacent regions. Emphasis should be placed on understanding coastal erosional-transportational-depositional systems (including nearshore currents), especially those affecting harbours and important beaches.

(iii) Geotechnical properties and the behaviour of sea-floor sediments should be investigated with emphasis on reducing the presently conservative "safety factor" used for the design of structures placed on the sea-floor, which should result in significant cost savings. This is because the less that is known about a given situation, the greater is the "safety factor" that is generally used.

(iv) Investigations should be made of the geology, biogenesis, and geochemistry of the processes of carbonate and non-carbonate sedimentary deposition, consolidation (compaction) and diagenesis. These studies should include the sedimentary petrology and petrogenesis of carbonate rocks which are of particular interest because of the conditions of high temperature and salinity in the Gulf.

(v) The surface sediment deposits in the Gulf should be investigated with the object of mapping these materials at a common scale and assessing the occurrence of minerals of economic importance, mainly construction materials.

(vi) The coastal area should be investigated in order to identify suitable zones for potential development as industrial sites, resorts, marine parks and wetland reserves.

3.3 MARINE BIOLOGY

If the fishery resources of the Gulf are to be utilized efficiently and production maintained at a maximum level, fundamental studies on marine biology must be initiated. Such studies are a necessity and are required urgently since certain stocks (e.g., shrimps) are already showing signs of depletion.

Recommendations

(i) Current literature on the biology of marine organisms in the Gulf should be collected together and made available to all marine science institutions.

(ii) Monitoring and base-line study programmes should be initiated. Water column monitoring, benthos and intertidal sampling, together with ship surveys, are required to assess productivity of Gulf food chains. However, such studies must be related to defined problems in order to economize on manpower. *

(iii) Taxonomic studies must be carried out before many research programmes can be initiated, and a supply of expertise is required. This need could be met by visitors to universities in the region. This should be on a cooperative basis.

(iv) In view of the present stress on fish and shrimp resources, a marine science programme is urgently required to supply information to government fishery agencies. The importance of the free interchange of all fishery data between bodies at national and international levels is emphasized.

(v) The potential impact of accidents such as oil spills is so great that regional planning and co-ordination should be directed towards minimizing such an event. Gulf States must evolve the scientific capability to predict the effect such an accident would have on marine organisms and be able to provide appropriate controls.

(vi) In summary, it is stressed that marine biological research programmes are urgently needed in the following areas:

a) Collection of available information
b) Studies of productivity and food chains supporting important fisheries
c) Monitoring of selected variables to identify seasonal changes in fauna and flora of Gulf waters, to detect pollution effects, etc.
d) Biology, population dynamics, and migration patterns of important commercial species
e) Ecology and biology of coastal zones, including lagoons, estuaries, mangrove lagoons and coral reefs. These ecosystems constitute a basis for coastal planning and development
f) Effects of pollutants such as oil, sewage, and other chemicals upon Gulf marine systems.

3.4 APPLIED MARINE SCIENCE AND TECHNOLOGY

Pollution

Oil pollution represents a serious threat to the total marine environment in the Gulf area. It is recognized that marine pollution may be generated by airborne pollutants such as persistent chlorinated hydrocarbons (DDT, metabolites, PCB's), certain heavy metals (mercury, lead, cadmium) and land-based pollutants such as industrial waste and urban sewage. Specific attention is drawn to background work and recommendations contained in the several reports of the IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP).

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* Attention is drawn to the FAO manual on fishery survey design (IOFC/Dev/75/41, by S.R. Banarje, "Improvement of National Fishery Statistics").

Recommendations

(i) Oil pollution. Research programmes should be initiated, funded and conducted by all the regional States with the goal of eliminating, or when this is not possible, minimizing the environmental damage caused by oil pollution. This may be effected by the physical, chemical, biological, or combined treatment of ballast or other residual oil, or by providing means for containment or inland discharge. With this in mind, it is recommended that a meeting be held in the near future, with the participation of all Gulf States, which would be oriented towards the solution of oil pollution problems peculiar to the Gulf area. From this, a list of specific oil pollution research projects could be formulated.

(ii) Industrial and urban pollutants. It is recommended that a uniform legislation be adopted to deal with industrial pollution prevention in all Gulf States.

The effects of industrial effluents on the marine environment should be monitored wherever possible and base-line studies should be made before industries, especially oil production installations, refineries, and related chemical plants, including those producing halogenated hydrocarbons, are set up in coastal areas. Results of all such studies should be made available to all Gulf States.

Measures should be considered to prevent the release of untreated or only mechanically treated urban sewage into the Gulf. The influence of existing sewage outlets on the marine environment, including biological effects, pollution and the reduction of amenities, should be investigated as special "case studies" in different regions in the Gulf.

(iii) Airborne pollution. Research and monitoring studies of airborne pollutants reaching the sea through atmospheric transport, and their impact on the environment of the Gulf, should be supported by all States in the Gulf area. However, these studies need be carried out only by a limited number of designated institutes which would provide the necessary information for eventual action. The recommendations for protection of semi-enclosed seas such as the Baltic may be studied and adopted where this would be relevant for the reduction of pollution in the Gulf.

Conservation

Recommendations

(i) A strong programme of research is required to determine the population dynamics of endangered species of this region such as dugongs and turtles. This research should be carried out both by the universities as well as the resource management and environmental protection agencies of the region.

With reference to the establishment of wetland reserves and marine parks, it is recommended that the criteria be adopted for the identification of wetlands of international importance as specified by the International Conference on the Conservation of Wetlands and Waterfowl, Heiligenhafen, Federal Republic of Germany, December 1974, as well as the agreed principles and general recommendations of the Working Group of the Regional Meeting on Promotion of the Establishment of Marine Parks and Reserves in the Northern Indian Ocean, including the Red Sea and the Persian-Arabian Gulf, Teheran, Iran, March 1975.

(ii) The importance of setting up a system of wetland reserves incorporating sites of international importance as a habitat of migrating and breeding waterfowl should be recognized, and attention is drawn to the "Convention on Wetlands of International Importance, especially as Waterfowl Habitat". which came into force on 21 December 1975 (Iran is already a signatory).

Systems planning and management

A systems engineering or operational research approach to marine planning and development is urged for the Gulf region.

Recommendations

(i) It is recommended that the above approach be adopted. This will call for suitably trained engineers with a knowledge of various aspects of marine science, who will consult colleagues in the related disciplines. Ocean engineering encompasses several disciplines, and the training of adequate numbers of ocean engineers is also strongly recommended for the Gulf region.

Industrial and governmental organizations need advice on the applicability, suitability, and cost of engineering projects, such as the design and construction of harbours and outfalls and of structures placed in the Gulf by outside contractors. The optimization of such projects, based on a knowledge of marine science and the Gulf environment, can be expected to lead to lower costs, improved construction quality, and reduced damage to the environment. As the training and utilization of ocean engineers progresses in the Gulf States, more projects can be undertaken by companies based in the Gulf States, rather than by companies from outside the region.

(ii) Environmental impact assessment: Since the rate and extent of various forms of environmental modification in the Gulf region are likely to increase for some time, and as this modification may involve large structures which imply interactions and effects upon the marine environment, it is recommended that detailed environmental impact assessments be made available prior to further environmental modification. These should be carefully evaluated by suitable national and/or regional bodies with respect to their overall impact on the environment.

(iii) Case study approach: Whilst there are both manpower and budgetary constraints on marine research related to engineering projects in the Gulf Region, it is recommended that every effort be made to utilize a case study approach to such problems. This would involve problem definitions, classification and rapid dissemination of details to all interested parties. A regional approach should be taken by defining the type of engineering project and its potential significance for the marine environment. Priorities should be assigned to these projects, and research efforts partitioned into several so-called case studies which are typical of the problem type and its consequences. One example would be the use of secondary treated urban sewage as a fertilizer through agricultural irrigation.

The results of these case studies should be compiled regionally and disseminated rapidly and efficiently to all interested parties in the Gulf Region, by means of regional workshops or published compilations.

Mariculture

With a view to its potential as a resource for future local consumption as well as for industrial purposes, the following recommendations are made concerning mariculture.

(i) National surveys should be carried out to identify areas suitable for mariculture, or areas that could be modified for such purposes without interfering with the long-term balance of the ecosystem.

(ii) Gulf States should study and identify species that would be particularly suitable for cultivation under artificial or semi-artificial conditions.

(iii) Investigations should be undertaken into mariculture methods which will provide the optimum utilization of areas at both an industrial and an artisanal level.

3.5 INFRASTRUCTURE FOR MARINE SCIENCE RESEARCH AND EDUCATION

Organization and co-ordination of marine science activities

It is emphasized that, ideally, marine science centres should encompass all major disciplines of marine science, although first priority has been given to marine biology or fisheries biology in most countries.

Recommendations

(i) Marine science activities are best handled by university departments or by separate marine science institutions closely linked with the universities in order to achieve the broad scientific foundation that is required for continued innovation and for investigation of the complex marine environment.

(ii) To ensure a rational use of existing facilities within each State, and to avoid unnecessary duplication of efforts, a "national committee of oceanography" should be established in each country. The committee will serve a particularly useful purpose as an advisory body with respect to priorities in the development of marine sciences, and in ensuring exchange of information among institutions. The national committee of oceanography must represent all basic and applied disciplines related to the marine environment.

(iii) Since the marine sciences in the States of the region are largely at an initial stage of development, an integrated approach to the study of the Gulf can only be achieved by regional cooperation. Through such cooperation, duplication of efforts will be avoided and the research activities of different countries could become complementary to each other. As initial steps in regional cooperation, the following measures are emphasized :

a) exchange of scientists among institutions,
b) sharing of research vessels and other facilities,
c) facilitating the free flow of information between institutions,
d) standardization of methods and intercalibration of instruments.

Cooperation will be enhanced through personal contacts, and therefore periodic meetings of scientists in the region should be organized with participation from international agencies. In the future, integrated cooperative research programmes on significant topics of common concern to the countries of the region should be considered for action.

Institutional facilities

It is suggested that simple, reliable, robust equipment which has stood the test of time should be acquired at the initial stage of implementation. As the development of marine sciences progresses within an institution, increasingly sophisticated equipment will be required. Laboratories planning their marine science programmes should be encouraged to seek expert advice from Unesco in the selection of instruments. The importance of calibration, maintenance and repair services is strongly emphasized.

Recommendations

(i) It is stressed that any marine institution needs a station on the sea. In marine biology, there is a definite need for shore-based facilities which can provide live biological material and clean sea water for experimental research. Each institution engaged in marine research must have a vessel for research and educational purposes. For optimal utilization, however, sharing of the same ship by more than one institution in a country may also be possible, particularly in view of the substantial cost involved in operating a research vessel. The size and type of ships will depend on the kind of research and the extent of the study area, but it is emphasized that a research vessel should not be smaller than 15 meters long. For multipurpose operations, however, a larger vessel in the size range 25-30 meters length is required. On all research ships, provision should be made for interdisciplinary studies. High speed boats (15-20 knots) have distinct advantages for use on a daily basis from shore-based stations. In addition to a research ship, small shallow draft boats will also be required for inshore work. The importance of an accurate positioning system, such as the Decca Navigation System, for the Gulf area is emphasized.

(ii) Each marine science institution should have access to a library with the basic periodicals and reference literature, but there is no need to establish a regional central library. For more specialized information, the use of existing information systems, such as ASFIS and other sources, is recommended; desired information is identified through such systems and then may be obtained from primary sources. Since the literature on marine sciences in the Gulf at the present time is limited, it is recommended that each institute in the region acquire a complete set of the available relevant literature. In order to keep these sets of documentation up to date, scientists in the region should be encouraged to exchange reprints of published reports on marine scientific research. National or regional oceanographic data centres are not immediately needed, but it is recommended that scientists of the Gulf region make use of the existing World Data Centre System.

(iii) Taxonomy and floristics/faunistics are important aspects of the biological oceanography in the initial stage of the development of marine sciences in the Gulf, and it is emphasized that the flora and the fauna must be considered as a whole. Therefore, the establishment of a regional reference collection is strongly recommended, in which type specimens of biological material, as well as complete collections, could be deposited. Such a reference collection, in which scientists of the region could have their identification of biological material verified, could be established by strengthening an existing museum in the area. This should not preclude national efforts in establishing own national collections.

Manpower requirements

Recommendations

(i) Realizing the interdisciplinary nature of marine science, it is recommended that efforts be made to engage research staff representing the major fields of the marine sciences, even at the early stage of development. Moreover, because research scientists in small or newly established institutions in the region will have to cope with a variety of research problems, such professional staff should be marine scientists with broad training, rather than highly specialized personnel.

(ii) There is an urgent need for training of marine technicians, and it is emphasized that a marine science programme to a large extent depends upon the availability of qualified marine technicians. Technicians should ideally be trained in their home country, and some countries of the region have already started such training programmes. Other countries are urged to follow this example. The opportunity for specialized training of technicians in well-known marine science institutions abroad should also be explored, making use of the expertise of Unesco. It is emphasized that in order to make career opportunities more attractive, the countries of the region should take steps to upgrade the status of the marine technicians.

Training programme

Recommendations

(i) The recommendations and the curriculum for the training of professional staff outlined in the Unesco Technical paper in Marine Science No. 19 "Marine Science Teaching at the University Level", Unesco, 1974, are strongly endorsed and a summary of the recommendations of that paper is annexed to this report as Appendix II. This should not however preclude the training in marine science of students with an appropriate degree in agriculture or engineering, as there is a particular need in the Gulf States for persons educated in basic engineering disciplines to have also a fundamental knowledge of marine science. Such graduates are known as ocean engineers.

(ii) To satisfy the need for a highly qualified staff in the region, fellowships for long-term training should be obtained through national fellowship programmes, through bilateral agreements, through training components in the UNDP country programmes, and through the various countries' Funds-in-Trust programmes with Unesco. Unesco's competence can be used for the placing of trainees in institutions abroad.

It is also strongly recommended that the Unesco fellowship programme which provides for the short-term training of marine scientists from developing countries in specific problems, be strengthened.

(iii) It is recommended that countries of the region utilize foreign expertise in the planning of their marine science and technology programmes and in the initial phase of development. Here again, Unesco's competence could be utilized.

4. PROSPECTS OF MARINE SCIENCE IN THE GULF AREA - THE BACKGROUND PAPER

by Professor D.J. Crisp

4.1 STRATEGY AND GENERAL PRINCIPLES

4.1.1 Size and structure of marine laboratories

Marine research is an environmental science. The modus operandi which has been found most effective in other parts of the world is the establishment of a number of locally based stations, preferably sited on the coast, each of which can study in depth its immediate sea area and all of which can take part in joint projects, regional or international as the need arises. To be effective, such institutions need to meet three criteria:

(i) Minimal size. The institutes must have a minimum of science personnel with supporting staff. Since much of the equipment essential to marine science - especially research vessels and sea-going services - involves high capital outlay, it is important that this investment be fully utilized. This in turn implies a minimal corps of active research workers in the institute.* Alternatively, the facilities might be shared by several smaller institutions, though this requires tactful administration and goodwill.

(ii) Amalgamation of disciplines. Marine laboratories should ideally be interdisciplinary. The connection between the physical, geological, chemical and biological processes in the sea is so close that it is essential for scientists engaged primarily in any one of these subjects to have easy access to the literature or to colleagues in related subjects. Moreover, many of the important advances have come from free association of scientists from different disciplines, and this is most likely to be achieved if they work in the same laboratory. There are now very few areas where work can be done in isolation; even animal and plant taxonomy has received an impetus from association with mathematics and biochemistry.

(iii) Location. For obvious reasons, marine laboratories should, if possible, be close to the sea, with access to unpolluted sea water and a variety of environments. This makes it easier to operate research vessels. Both factors are particularly

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* In the writer's experience, one day's work at sea requires the operator to spend between three and twenty days in working up the material and information at his research base. The time required varies with the discipline, but one could approximate to an average of ten days. Hence a research vessel which accommodates 10 scientists and operates for 250 days in the year, allowing 150 days for cruising to and from the research area, would produce enough material for 10,000 man days per annum in the laboratory. Assuming 250 man days work per year by each scientist, this implies that the institution should have at least 40 scientists and skilled technicians.

important to biologists, since they can then obtain and maintain their material much more easily. However, a marine laboratory should also be part of or near to a university or comparable organization. The reason for this is that it is impossible for a marine science institute to be versed in all aspects of science, for its library to cover the whole of science literature, or for it to have more than a limited range of techniques available. Nevertheless, new problems often require the investigator to look into the fundamentals of his discipline, or to apply a method not usually part of marine science methodology. In these circumstances, he will need to have access to colleagues in a broader-based academic environment.

Clearly the two requirements (proximity to unpolluted sea water and to a large academic institute), are frequently incompatible, and it then becomes necessary for a major marine centre that is associated with a larger academic institute to establish remote field stations in an appropriate environment.

There are also other circumstances where these criteria cannot be met, but they should always be borne in mind. Thus the establishment of too many small marine institutions at the expense of larger ones should, if possible be avoided. Highly specialized, single-discipline laboratories are justified only if they can be linked to larger institutes or have support from university centres. Similarly, the co-ordination and sharing of facilities may make several smaller national units viable, which would otherwise be ineffective in isolation.

In order to co-ordinate the work in marine science within individual states and so maximise the efficiency of their efforts, it is recommended that national committees of oceanography be set up.

4.1.2 Expatriate support

Expert advice. In the setting up of national committees or for the purpose of advising on specific marine problems, it is suggested that Unesco be asked to help by providing consultants. These consultants might spend between three and twelve months on such exercises.

Long-term support. It is appreciated that there is a need for experienced marine scientists, not merely to provide advice during a short consultancy, but also to lead the research and teaching activities during the period when the institute is being established. One way of achieving this is through a bilateral arrangement with an overseas laboratory. This latter laboratory would need to be a strong interdisciplinary institution sufficiently well staffed to be able to arrange for some of its own members, or for staff from similar institutions, to be seconded on a relatively long-term basis (e.g., three years) to the national institution. Such arrangements are welcomed by many expatriate scientists, who wish to have experience of assisting developing countries, and by the institutions themselves, given the intrinsic interest in exploring new areas.

4.2 CLIMATE AND HYDROGRAPHY

The summer months are uniformly hot with only weak northerly winds which rarely exceed Beaufort Force 2 and with almost no precipitation. Sea temperatures rise to 31-33°C in the surface waters above the thermocline, and may exceed 35°C in shallow coastal areas. These represent the highest surface temperatures of all seas. Despite the shallowness, a temperature stratification develops in the central Gulf, the bottom water being 10 degrees C cooler than the surface. Conditions in the intertidal zone during the summer are rigorous in the extreme, and little life survives on the sunlit surfaces of rocky outcrops.

During the winter, winds are northerly or variable bringing occasional storms and precipitation, especially to the northern and western regions. Air temperatures fall to about 14°C on average, with occasional near frosts in the northwest. Average water temperatures drop to 20°C, and may fall considerably lower in shallow areas. Vertical mixing is complete in the winter months.

As a result of the arid climate and predominance of evaporation over precipitation, the salinity is very high (over 40‰) except in the extreme northwest near the mouths of the Shatt al Arab. Evaporation causes a lowering of the sea level compared with that of the Arabian Sea and, as a result, a strong surface current of about three knots flows into the Gulf through the Straits of Hormoz. This current generates a weak, counter-clockwise gyre in the surface waters of the Gulf. There is a compensating outflow of high salinity water at deeper levels through the Straits of Hormoz.

The tides are basically semi-diurnal, but the heights reached by the two tides of each day often differ considerably. The tidal range is least in the centre of the Gulf - about 1½ metres between the mean higher high water and the mean lower low water. At the eastern and western ends of the Gulf, the tidal range is greater, the corresponding range at the Shatt al Arab bar in the northwest being 2½ metres and the section between Dubai (United Arab Emirates) and Lengeh (Iran) having a range of 3 to 4 metres. The tides are of intermediate range in the Gulf of Oman; at Muscat, for example, the range is 1.9 metres.

Thus the sea conditions of the Gulf are essentially warm-temperate with a thermocline persisting for only about half the year. The tidal rise and fall is sufficient for the development of an intertidal fauna and flora with a classical zonation pattern.

4.3 COASTAL ECOSYSTEMS

Estuarine marshes. Major freshwater streams are absent from most of the Gulf shores, with the exception of the large deltaic estuary of Shatt al Arab. Within and upstream of this delta are highly productive and largely unexplored marsh areas.

Mangrove lagoons. The lagoons of the central and western parts of the Gulf support *Avicennia* mangroves (species of the oriental group), which modify the environment to produce the typical saline mangrove ecosystem with its accumulation of rich anaerobic mud. The scale of development of the mangrove swamps and the size of the mangroves increases towards the east, with the finest examples in the Straits of Hormoz and the Gulf of Oman. Some of these areas are already designated as marine parks (e.g., Hara Marine Park, Straits of Hormoz, Iran), and others have been strongly recommended for conservation (e.g., the lagoon complex near Kalba, Gulf of Oman, UAE). These mangroves are important feeding grounds of water birds, heron, egret and waders, and probably serve as nursery areas for prawns. The endangered marine mammal, the dugong, also finds sanctuary in the more densely vegetated lagoons.

Coral reefs and islands. Though coral reefs exist in the Gulf, their development in the western half is marginal, and local opinion holds that they have receded in recent years, perhaps due to pollution. This area would therefore be of particular interest for the study of factors limiting coral growth.

The southwestern part of the Gulf (off the coast of the United Arab Emirates) and the shores of the Gulf of Oman have numerous coral reefs and islands, as well as islands of other origins. These islands are often the breeding grounds for large colonies of terns (e.g., great crested tern, lesser crested tern, white cheeked tern, bridled tern and Saunder's little tern) and also support breeding colonies of other sea birds (Socotra cormorant, red-billed tropic bird, herons and osprey). For a good account of the avifauna, see Scott, 1975.

Furthermore, islands with sandy beaches, as well as some of the less frequented mainland beaches, offer breeding areas for sea turtles. Again, the most important areas are in the eastern parts of the Gulf and on the shores of the Gulf of Oman. Green, loggerhead, Ridley, occasional hawksbill turtles, and possibly leathery turtles, nest here. Unfortunately, in most States, there are no laws governing the exploitation of turtle eggs, but a few areas (e.g., Shitvars Island, Iran) are marine reserves. Many more of these breeding areas will need to be protected (see Frazier, 1975).

Rocky shores. The northern (Iranian) shores of the Gulf and the eastern shores of the United Arab Emirates are largely rocky. A little is known of the commoner species of the marine fauna and flora, but much taxonomic and ecological research still requires to be done. From Kuwait to Bahrain, there are only occasional rocky promontories, mostly of ancient coral rock, which support an interesting, though limited fauna, essentially of the warm temperate type. The intertidal marine flora is very poorly developed on account of excessive heating and desiccation in the summer. Stone-built harbour works also afford living space for some of the species along this coast, particularly the sessile forms living on the underside of crevices. Unfortunately, in some places the natural rock outcrops have been destroyed to provide building material, a practice which may not only endanger the littoral species but also the permanence of the shore itself. The commoner animal species present are as follows - periwinkles: Nodilittorina milligrava and Planaxis sulcatus; limpets: Siphonaria rosea, S. atra; browsing gastropods: Monila obscura, Turbo coronatus, Thais carinifera; barnacles: Chthamalus challengeri (?), Balanus amphitrite; bivalves: Saccostrea cucullata, Brachydontes variablis, Lithophaga teres; Serpulids: reefs of Pomatoleios krausii.

Sandy and muddy shores. Almost the whole coastline from Kuwait Bay to Qatar consists of stretches of gently shelving sands, interrupted here and there by lagoons. Behind the sand beaches are salt marshes. Towards the low-water mark, softer deposits are found with considerable quantities of silt and soft mud. At the higher levels, these beaches may be populated by fiddler crabs and at the lower levels by clams, cerithids, pagurids and echiuroids. Mud skippers (Periophthalmus species) are abundant in the softer areas. Where there are shallow sublittoral sands, large populations of Strombus sp. and Nassarius pullus are found. The fauna is imperfectly known in detail.

A feature of many of the very flat high-water areas which lead into the salt marshes is the development of mats of blue-green algae. When these mats dry in the hot sun, they form sheets having the appearance of cracked roofing felt, but the algae revive when covered by sea water. In view of the nitrogen fixing capacity of blue-green algae, these areas, which are frequently of enormous extent, may be important to the whole productivity of the coastal region. Their role should therefore be investigated.

Unfortunately, in some places, the natural littoral zone and the salt marsh hinterland are being destroyed by tipping desert sand seaward of the shoreline to extend the coast for the purpose of land speculation. This practice destroys the feeding areas available for shore birds and particularly for wintering water fowl, and may also have a serious impact on the productivity of the nursery grounds of the juvenile shrimp (Crisp, 1975a).

Sea grass beds. In the eastern part of the Gulf and in the Gulf of Oman, sea grass beds have been reported, but the species of sea grasses present have not, to the author's knowledge, been fully identified (Zostera? Thallassia?). Since the rhizomes of these angiosperms have now been shown to fix nitrogen, the sea grasses' composition, distribution and organic nitrogen production should be studied.

4.4 PREVIOUS OCEANOGRAPHIC STUDIES OF THE GULF

4.4.1 Biology and fisheries

The Danish Scientific Expedition to Iran laid the foundation of our knowledge of the biology of the Gulf. Their report, published in several volumes during the 1940s, gives an account of the marine biology, including dredge collections, of the northern and central areas of the Gulf (for example, see Blegvad and Loppenthin, 1944).

A considerable amount of taxonomic information has been accumulated, partly from material sent to museums by collectors, and more recently from the work of the staff of the new universities of the Gulf States. However, only a limited number of faunal groups have as yet been described as to species, or check-listed for the Gulf. (E.g., "Fishes of Kuwait", Kuronuma and Abe, 1972; "Common Sea Fishes of the Arabian Gulf and Gulf of Oman", White and Barwani, 1971; "The Polychaete Fauna of the Gulf" Fauvel, 1911). As a result, identification of most of the groups must be made from works based on the Indian Ocean or on the Indo-Pacific area as a whole, thus seriously limiting the progress of ecological and other biological studies in the area.

In recent years, fishery departments and fishing companies of the Gulf States have made surveys to acquire information useful to fishery development. In Kuwait, for example, a study by USSR experts, comprising several cruises of the research vessel Sabah, has obtained information on plankton production and on the abundance of various species of commercially important fish but, to the author's knowledge, the results have not yet been fully reported. Another survey in December 1968 by the Tokyo University of Fisheries provided information on hydrographic sections, zooplankton, core samples of bottom deposits and experimental fishing. The short period covered by this cruise, however, limits the usefulness of some of the data on physical and biological oceanography.

Apart from experimental fishing surveys, our knowledge of the changes in abundance of commercial fish is dependent on statistical information gathered by the fisheries departments of the various States. This information is not always readily available. However, the more relevant data is critically reviewed from time to time in relation to specific problems in publications of the Indian Ocean Fishery Commission, and circulated through FAO. Of particular interest are the reports by Cushing (1971) on the resources of the Indian Ocean and Indonesian area, which includes the Gulf; by Marr et al (1971) on fishery development in the Indian Ocean area; by Bromiley (1972) on the trawl fishery of the Gulf, which includes some details from the RV Sabah cruises; and a recent study by Ellis (1975) on the changes in shrimp stocks over the past decade.

4.4.2 Physical oceanography

Due to their bearing on navigation, tidal and meteorological data have been collected over a considerable period of time. These form the basis of the UK Admiralty Tide Tables and the atlas published by the US Oceanographic Data Center (Dubach, 1964). Observations on the basic physical and chemical oceanography of the Gulf were made by the German research vessel Meteor and reported in 1965 (see next section by Professor K. Grasshoff). The recent fishery cruises mentioned above have also added to our information on sea surface temperatures, salinities, temperature profiles and hydrographic sections. Fuller details are given in Professor K. Grasshoff's paper in section 5.

No doubt a large amount of information, especially on physical oceanography and geotechnics, is locked away in the archives of the oil companies or issued as reports by consultant organizations, such as the oil companies' consultancy organization (International Meteorological and Oceanographic Services). Some of this material will be confidential, but some may be accessible. There may also be government reports on levels of pollutants, which similarly have not yet become part of the published scientific literature. A characteristic of the present position is that much existing information is difficult to locate and likely to be overlooked. It would therefore be of considerable service if, at this stage, the available information on the oceanography of the Gulf could be drawn together at least in bibliographic form, or better, for the material to be collated and accompanied with critical reviews describing the present state of knowledge in each of the main disciplines.

4.5 MARINE SCIENCE PROGRAMME

4.5.1 Physical oceanography

Physical oceanography includes all studies of the structure, movements and physical properties of water masses and of their interaction with meteorological factors - winds, precipitation, radiation. The understanding of these processes is fundamental to all other branches of marine science, since they influence the chemical changes in the sea, the environment of marine organisms and the productivity chain which determines the yield of commercial fisheries.

Water circulation in the Gulf

Although the main pattern of circulation of the Gulf is known, it is not solidly based on quantitative measurements made at various seasons of the year. In particular, the exchange of water between the Gulf and the Arabian Sea through the Straits of Hormoz at different seasons should be studied. The waters of the Arabian Sea are highly productive during the southwest monsoon (Kabanova, 1968), and their penetration into the Gulf may have a profound effect on the productivity of its southwestern part. To complete this study, more detail of the coastal topography and sea bottom contours in the Straits of Hormoz may become necessary.

The hydrography of the area into which the Shatt al Arab empties should also be investigated, since estuarine waters contain silt and nutrients that increase the productivity of the sea areas into which they flow. This study is doubly important because of the reduction in the amount of water discharged as a result of dam building and increased agricultural use of water. The estuarine circulation of the river system itself should also be studied, especially concerning the increased penetration of salt water into the estuary as a result of the reduction in fresh water flow. This investigation would form a background to the ecological study of the area's creeks and marshes and to the investigation of changes in the silt burden of the water with related modifications in the bottom deposits. Both these investigations require much ship time and might be undertaken as co-operative programmes by the two or three States nearest the regions concerned.

Background hydrographic investigations should also be made in lagoon and mangrove areas of particular ecological or commercial value. Included here are any areas that are being designated for conservation and scientific purposes, any areas that support a considerable population of juvenile prawns or fish, and any areas that are likely to be developed for mariculture. Such investigations would be on a smaller scale than those relating to the water exchange at the eastern and western ends of the Gulf, and would best be carried out as the responsibility of the individual States.

Another aspect of water circulation likely to affect all the Gulf States is the general surface circulation throughout the Gulf and, in particular, the incluence of wind stress on the movement of water at various seasons of the year. Information on such wind stress and circulation would be invaluable in the event of major, or even minor oil spills. The track of oil slicks is highly dependent on the wind, and thus needs to be predicted in relation to weather forecasts. With the help of good prediction, vessels with oil dispersant can be more strategically placed, and an early warning of impending pollution can be given to the coastal areas likely to be affected. The influence of sudden squalls which arise from the north, especially in winter, on the movement of water masses and on the density structure is particularly interesting. Radio buoys are useful in investigations of the foregoing phenomena, with the buoy movements followed by taking co-ordinates from shore stations. The whole process can be made automatic after the initial equipment has been installed and after the body of information so obtained is related to synoptic readings of local winds. Fixed current meters should also be installed to obtain speed and direction of water flow at known depths. Again these can be set up to obtain automatically continuous records over a period of time.

The tidal movements are well known near the major ports, and tidal investigations by overseas organizations on behalf of shipping and oil interests are continuing. However, there are a number of gaps where tidal constants and tidal streams need further investigation. Fixed installations, namely recording tide gauges and recording current meters, will provide the necessary information. Once the capital for the purchase of such an installation has been allocated, funds will be required only for regular servicing. Apart from their navigational importance, tidal and wind stress data are of great significance in the prediction of "surges", i.e., exceptionally large and potentially dangerous rises in sea level brought about by the coincidence of large astronomical tides and of wind stress from a particularly unfavourable quarter.

Heat budget and density structure

The great extremes of temperature in the Gulf make it a very interesting area for the study of air-sea interaction, and particularly the influence of meteorological conditions on evaporation and on the heating and cooling of the water. Temperature and salinity changes lead to the development of density structures which may stabilise the layers of water. Such a stabilized density structure has a profound influence on biological production, fish behaviour and, at the eastern end of the Gulf, on the exchange of water between it and the Indian Ocean. The density structure can be investigated at any one site by boats carrying such simple standard equipment as a small winch with water sampling bottles and sea water thermometers. However, a well equipped oceanographic vessel can obtain continuous records of temperature and salinity during its period of cruising between stations. Another valuable technique is aerial infrared photography from which sea surface temperatures and sometimes other features of the water can be measured over the whole area in view. Such a method would be very useful for investigations of local heating in coastal waters or for locating areas of cold water up-welling.

Meteorological and routine oceanographic data collection

An important foundation for all oceanographic study is the measurement, from a wide scatter of stations and from ships in passage, of the variability of such phenomena as wind, hours of sunshine, precipitation, humidity, water transparency, sea surface temperature and sea conditions, including wave height. Present oceanographic institutes cannot optimally cover an area as large as the Gulf, but small land- or island-based units can be established quite cheaply to reinforce existing stations so as to give a good coverage of the whole area. Furthermore, some of the above measurements can be made and fed into the system without special training, for example by officers of ships. Also, recording equipment (e.g., wave height recorders, sea surface temperature recorders) can sometimes be installed on ships plying regular routes. As long as these supplementary observations fall into a standard pattern (e.g., the methods and scales of the World Meteorological Organization) and are organized into an accessible form, they can be of great value for weather and navigational forecasting, for the production of climatology maps, and for use in individual research problems. Any organization responsible for the collection of such material, banking the data and making it readily available would have to be established on a regional basis and supported by all the Gulf States. An 'Oceanographical Data Centre' would be a suitable name for it, and it could also be responsible for keeping chemical and some biological data.

4.5.2. Geological oceanography

The geological structure of much of the Gulf and the constitution of the sediments below the sea bed have been thoroughly investigated by commercial companies and their consultants in the course of oil exploration. However, it is recognized that this work, although extensive, is limited both in its availability and also in its scope of coverage of the geological oceanography in the Gulf area. An important synthesis of available research in geological oceanography was edited by Purser (1973), which provides a sound basis for future research. The marine geology of the Gulf is strongly conditioned by the unique climatic régime and by the basin's previous history. The main features of the basin's topography (35 metres average depth, 100 metres maximum depth at the Hormoz Strait) reflect the underlying geologic structure: the shallow, stable continental structure in the southern and western Gulf, deepening to the northeast. Most of the islands and many of the shoals are due to salt domes. During the glacial ages (Pleistocene time) ending about 15,000 years ago, sea level fell and emptied the Gulf - river valleys were eroded down the slopes. Modern marine sediments reflect topographic and climatic influences: the shallow southern and western Gulf floor is covered by biogenic and evaporitic deposits, mainly derived by biologic and chemical extraction from sea water; the northeastern Gulf sediments are mainly derived from the neighbouring land, carried to the Gulf by streams and rivers. The Tigris-Euphrates-Karun delta (the Shatt al Arab) dominates the northwestern end of the Gulf. Tidal and wind-driven currents and waves are locally strong and are effective in both moving the bottom sediments and also giving them specific properties. Finally, the large variations of temperature and salinity of the Gulf, together with the water movements, provide character to the sediments of the southwestern Gulf not found in other major carbonate areas of the world. Enough is now known about the geological oceanography of the Gulf for future research to concentrate on the significant and interesting scientific problems already identified. Nevertheless, the Gulf is large (226,000 square kilometres) and many important geological parameters still need to be mapped, both locally and regionally.

The marine geology of the Gulf furthermore affects the biological resources and industrial development of the region. Important marine organisms such as shrimp, demersal fish and bivalves are associated with certain sediment properties, and predictions of relative abundance can be made from studies of the mechanical properties and chemical composition of surface sediments of the Gulf region. It is recognized that the coastal regions of the entire Gulf region will be subject to increased activities of man, including such coastal modifications as harbour and channel dredging, groyne and jetty construction, as well as other forms of coastal modification. Knowledge of beach profiles, long shore transects and erosion and sedimentation processes are essential for the planning and effective execution of such coastal modifications, as well as of analogous processes for engineering needs further offshore.

Therefore the study of the movement, composition, granulometry and mechanical properties of the deposits forming the sea bed itself is essential in connection with all forms of underwater engineering and coastal development. Although such properties may not be of immediate importance to oil exploration, studies of the modern geological oceanography of the Gulf are of significant application in the interpretation of older marine sediments found in oil wells. Geological oceanographers should therefore be included in at least some of the proposed oceanographic institutes. They should work in close association with, and provide training for, the organizations responsible for the engineering operations referred to above. The study of recent sediments will require vessels to be equipped with core sampling gear and special sonar apparatus to identify the small-scale texture of the sea floor. The latter apparatus should include echo-sounders, sediment profilers and side-looking sonars. The sediment cores will be of interest not only for their physical structure, but also for the animal and plant remains from which a picture of the past climate, the changes in sea level, and the biological history of the Gulf can be built up.

4.5.3 Chemical oceanography

Dissolved oxygen and nutrient salts

The rate of photosynthetic activity in the surface waters is the key to the potential productivity of the sea. Plant production is dependent on a supply of nitrate, phosphate and, to a lesser degree, silicate. The rate of depletion of these salts during the growing season gives a measure of organic production. Hence one of the most important routine functions of an oceanographic laboratory is to make regular measurements of the concentration of nutrient salts throughout the water column. Priority should be given to those stations where associated biological work is being conducted on the succession of plant and animal plankton. Oxygen measurements are also usually made; high levels of oxygen indicate active plant production, while low levels are generally associated with concentrations of animal plankton or decaying organic matter.

Although the general pattern of seasonal changes, once known, is likely to be repeated each year, it is desirable to carry out at least a skeleton programme of measurements in three or four representative areas of the Gulf over a long period of time. These measurements will form the background information against which evaluation can be made regarding possible causes of variations in fishery yields or the results of man-made changes, such as the reduction of the efflux of the Shatt al Arab. Of particular importance are measurements of nutrient levels during winter, when the water column is well mixed.

It is most important that standard chemical methods are used by workers in the different States. Ideally, arrangements should be made for occasional inter-comparison trials to ensure that the methodology of various laboratories gives reproducible and comparable results.

Pollution monitoring

In critical areas, notably near large industrial complexes or where pesticides are being used, regular pollution monitoring should be carried out. As it is possible to measure some pollutants, such as the heavy metals, in water samples, a survey by oceanographic vessels mapping concentrations of such components over the whole Gulf is most desirable. Other pollutants, notably the persistent insecticides, are best measured in the bodies of animals where they accumulate. Monitoring of fish and shellfish for mercury and cadmium should also be regularly carried out, most appropriately by chemists working in the fishery departments. The coastal environment near some large towns and industrial estates is likely to suffer from excessive organic enrichment, due either to sewage outfalls or to discharges of dissolved nutrients such as ammonia, especially if the water movement is restricted. When measures are taken to abate such conditions - such as the building of a long pipeline for offshore discharge - a team including marine chemists and hydrographers will be needed to advise on the projects and to conduct tests on their effectiveness.

Oil pollution is a very serious problem in some parts of the Gulf, and can be monitored through marine organisms. Recently it has been shown that mineral oil is taken up by the lipid fraction of planktonic organisms. Thus, by analysing the composition of their tissues, it is possible to assess the level of chronic oil pollution in the area. Organisms from representative ecosystems and their associated sediments should be surveyed regularly using a standard development of this method. The Integrated Global Ocean Station System (IGOSS) plan for the pilot project on marine pollution monitoring (IOC/WMO, 1974) provides a framework within which such studies can be carried out.

Marine biochemistry

There is an increasing trend in developing countries towards the study of the biochemical constituents and processes in marine organisms. Some obvious applications arise from this work, e.g., in the nutritional and fishery fields, in mariculture, and in the study of the accumulation of pollutants by marine organisms.

However, the more exciting possibilities lie in the development of new technologies based on free-ranging biochemical research. In the sea there are many groups of organisms, entirely different from terrestrial forms, whose biochemical processes have evolved along quite different lines. They synthesize novel substances with physiological properties which may have medical or other uses. Another feature of the biochemistry of marine organisms is their capacity to accumulate some elements to a concentration several million times that of sea water. This phenomenon suggests the possibility of imitating these processes commercially for the extraction of rare elements from the sea. Extraction of some common elements, such as bromine and magnesium, is already undertaken on a large scale. With so much energy, financial resources and access to highly saline water, the Gulf States are in an excellent position to do research into new extractive processes based on sea water. These are long term aims suitable for universities and institutes with a brief to study innovative science.

Gene polymorphism

A protein of specific function, such as an enzyme or blood pigment, which is needed by all individuals of a given species, may exist in two or more forms with only minor structural differences between them. Which form or forms are manufactured by the organism depends on its genetic constitution. The phenomenon is known as "genetic polymorphism" and, when the proteins are enzymes, the alternative forms are called "isozymes". A well-known example of genetic polymorphism is afforded by the human blood groups. Fairly routine methods now exist for identifying which isozyme or pairs of isozymes are carried by a particular individual. These methods are based on "electrophoresis", which is the forced movement of the protein in an electric field. A drop of fluid derived from the animal is put on a sheet of paper or gel in an electric field, and the isozymes move from the point of origin at different speeds. Hence, one or two bands appear in the "electrophoretogram" at positions characteristic of the isozyme present.

Not only is this technique sometimes useful in taxonomy, since the electrophoretograms differ between species, but they have been widely used in fishery investigations. A stock of fish will have a certain proportion of isozymes present in the population, and this proportion may differ from that of a neighbouring population, just as the ratio of human blood factors varies between different ethnic groups. Indeed, in some fish, blood groups similar to the human blood groups can be used. The isozyme or blood group ratio thus characterises a particular breeding stock in such fish. Since the demarcation of the geographical limits of stocks of fish or prawns is very important to their conservation and maximum exploitation (see below), there should be at least one Gulf centre versed in these techniques.

4.5.4 Marine biology and ecology

Taxonomy and distribution of the marine fauna and flora of the Gulf

Correct identification of plant and animal species is clearly a first priority to all biological investigations. Furthermore, the teaching of zoology and botany in developing countries should not rely on foreign material and text books (Crisp, 1975b), but it is only when the local fauna and flora have become known that it is possible to teach the subject in a way relevant to the students' own environment.

In the developed countries, well over a century has passed since the long and painstaking process of determining and describing the numerous species making up the marine fauna and flora was begun. All the commoner and most of the rarer species have now been described, as a result of which taxonomy no longer occupies so important a place as it did in the past. However, in the developing countries the situation is entirely different, and a long-term, internationally-based programme will be required to achieve the desired result.

First priority should be given to the production of lists of animal and plant species, giving the habitats and geographical locations where each is found, with notes on breeding seasons and other relevant details. Many species will be identical to those described elsewhere in the Indo-Pacific region, but others may be new and require a description. It will frequently be necessary to refer specimens to the world authority on the group, in whatever country he or she happens to live. Secondly, it will be necessary to produce, as early as possible, illustrated regional keys for the easy identification of species by non-taxonomists, e.g., physiologists and students in training. Thirdly, illustrated guides to the commoner species of the marine fauna and flora should be prepared in Arabic and Farsi for use in schools, in order to develop an interest in the sea and to encourage conservation. Finally, and in the longer term, text books for use in schools and universities should be written in which the principles of the subjects are exemplified as far as possible by reference to locally occurring species and ecosystems.

The expertise necessary for taxonomy should not be underestimated. Specialists dealing with the worldwide range of species can only expect to be able to recognize with certainty those from a very limited grouping of the animal and plant kingdom. Hence, not even developed countries can support a sufficiently large body of specialists to deal with every group. The Gulf States can expect to build up only gradually over the next decade a group of taxonomic experts able to undertake the bulk of this work for themselves.

Since the taxonomic programme should cover the Gulf as a whole and will be of benefit to all Gulf States, a co-ordinating centre is very necessary. To this centre - which might be developed in an existing museum and be called "The Gulf Marine Fauna and Flora Reference Collection" - specimens and collections would be sent for identification and kept for reference. It would hold the master copy of the growing Gulf faunal and floral list and have a library of the necessary Indo-Pacific and other works needed for the taxonomic investigations. In addition, working space for its own staff and provision for visitors from the region and elsewhere should be made. It will need to have close links with other taxonomic institutions such as the British Museum (London, U.K.), the Smithsonian Institution (Washington, DC, USA), and the Indian Ocean Plankton Sorting Centre (Cochin, India).

There are two ways in which help could be provided to accelerate a programme on marine taxonomy. The first would be to encourage student expeditions from universities either in developed countries or from neighbouring areas where the fauna is similar (e.g., India and Pakistan). The students could collect and sort material from a variety of habitats and locations, and experienced staff in the universities could check the identifications. The second form of co-operation would be for specialists in taxonomy to spend between three and twelve months at the sorting centre to identify collections and describe species from particular groups.

<u>Productivity</u>

In those areas where it is recommended that measurements of dissolved nutrient salts should be made, biological work on productivity should also be carried out. In the first instance, direct measurements of the rate of carbon fixation should be made, using either the light or dark bottle method, which requires no specialized equipment or, better, the Steeman Nielsen C^{14} method should be used, if the equipment is available. Measurements should also be made on water transparency, suspended matter (seston) and chlorophyll content as a rough measure of plant material present. The animal plankton can be measured with quantitative sampling nets, and the main component organisms, both animal and plant, should be identified in order to follow the seasonal succession. Automatic plankton samplers that can be towed behind ships are available, and these could be extremely useful in covering large areas of the Gulf, providing arrangements could be made for towing them over regular routes.

Because of the shallowness of the Gulf water, the zooplankton contains a high proportion of the larvae of bottom living invertebrates. The larvae therefore play an important role in the productivity cycle. Many of these larval stages need investigation, because at present they cannot be linked to the parent organism.

The Gulf is a shallow productive area with seasonal diatom blooms and has rather low water transparency. It is in many ways the antithesis of the Red Sea. A comparison of its productivity with that of the Red Sea would therefore be of considerable interest.

The shallow coastal areas of the Gulf should also be studied from another standpoint, by which special attention is given to nitrogen fixation by blue-green algae and the rhizomes of marine grasses. The meiofauna (interstitial fauna) of the shallow sands is well represented (author's own investigations). The meiofauna's role in recycling organic matter, its reaction to the very high temperatures reached by intertidal sands, and its symbiotic relationships merit detailed study.

Ecology, conservation and pollution

Many of the marine ecosystems of the Gulf are seriously threatened by oil pollution and by industrial and organic effluents. Speculative coastal development, rather than tourism, is at present the main threat to the intertidal ecosystem. However, the impact of tourism is likely to increase. Therefore, it is prudent to introduce conservation measures before malpractices become the established custom.

The priorities of marine ecological research should therefore be directed towards understanding the effects of pollution and studying the ecosystems and species which it is thought necessary to protect.

Coral reefs. The chief interest of the reefs of the Gulf is that they represent an extreme northerly extension of such ecosystems and survive winter temperatures considerably lower than elsewhere. A quantitative or semi-quantitative survey of coral species and a classification of reef types in the Gulf and Gulf of Oman should be made, perhaps with the help of an initial aerial survey. Information on the loads of suspended matter in the water and its transparency should be obtained, since corals are believed to be susceptible to sedimentation, and this is a factor likely to change as a result of man's activities. The results should be compared with those of a similar survey proposed for the Red Sea. Further surveys of critical reef areas should be made from time to time to find out whether they are increasing or decreasing in extent. *Acanthaster* ('Crown of Thorns' starfish) should be reported if and where it occurs.

Mangrove areas. Only a few typical mangrove areas should be studied, but they should be studied in depth. Preferably, one should be in an area designated as a marine park, and therefore unlikely to be modified, and one should be in an area known to be important as a nursery for juvenile prawns. The study should include the inter-tidal vegetation (including *Avicennia*), the inter-tidal fauna, the salt marsh vegetation, the benthic fauna of the creeks, and the avifauna. The study should seek to establish their trophic relationships.

Birds, turtles and dugongs. These groups contain some of the most endangered species of the Gulf. Their distribution, abundance, breeding sites and the factors to which they are most sensitive need to be studied as a basis for conservation. However, some species (in particular turtles) are in such urgent need of protection that legislation should not be delayed pending definitive research (see Frazier, 1975). Research may help to reinforce the effectiveness of conservation measures.

Pollution ecology. Studies of the marine biology of polluted regions are just as important as studies of virgin habitats. Methods now exist which use such data to classify species into those which are pollution-sensitive and those which are pollution-tolerant, so that changes in the quality of the marine environment can be demonstrated objectively using the data from all the species studied. Priority should be given to the benthic fauna of the intertidal and shallow sublittoral zones, since generally pollutants are most concentrated in these shallow coastal areas. Some of these studies should be included in inter-disciplinary surveys of the physical, chemical and biological effects of discharges entering the sea. It takes a scientist several years to become familiar with the benthic fauna, as well as with the problems of waste discharge. Thus continuity could be provided by a small team, experienced in such work in the Gulf, carrying out these surveys. This team could act as a focal point for collecting pollution data, and its experience would provide a sound basis for dealing with enquiries about pollution problems.

4.5.5 Fisheries

Background

There are three main fisheries of current economic value in the Gulf: pelagic or midwater fisheries, demersal fisheries and the shrimp or prawn fishery.

The main pelagic fish are the sardines, anchovy, mackerel and barracuda. They are commonest in the southeastern end of the Gulf and in the Gulf of Oman. These fish tend to congregate in shoals and are migratory.

The demersal, or bottom living fish comprise a great variety of species, which can be trawled wherever the sea bed is flat and there are few rocks, reefs or wrecks to tear the nets. At present, probably only some fifty to sixty thousand tons of demersal fish are taken annually (Boerema and Job, 1968, give 40-45,000 tons), whereas the potential yield is considered to be at least 200,000 tons (Bromiley, 1972), or even as high as 600,000 tons per annum (Gulland, 1970). The important species of demersal fish are: Caranx species (Trevally, Hammam); Epinephelus tauvina (brown spotted grouper, Hamoor); Lutjanus coccineus (red snapper, Hamur); Spardus berda (black bream, Mozaizy); Nemipterus japonicus (thread fin bream, Antak); Lethrinus nebulosus (pig-faced bream, Sheiry); Pampus argenteus (silvery pomfret, Zobaidy); Psettodes erumi (Indian halibut, Khofaah); Cynoglossus macrolepidotus (large scaled sole, Lessan Althor).

The shrimp fishery has yielded up to 15,000 tons per annum, but catches in several areas, notably in Kuwait and Saudi Arabia, have fallen dramatically while in others, such as Iran, less so. However, in Bahrain and Qatar the fishery has remained more or less constant. Ellis (1975) concludes that over-fishing and possibly other factors are responsible where stocks have fallen. It has been recommended that some of the effort now employed on shrimping should be transferred to the demersal fishery. The main shrimp species present is Penaeus semisulcatus (Hall, 1966) with small quantities of P. latisulcatus and Metapenaeus affinis. Penaeus merguiensis dominates in the Straits of Hormoz and Gulf of Oman (Cushing, 1971).

Although a considerable amount of exploratory fishing has been done in recent years, there is little or no information on population dynamics and on stock identification and assessment. Projections have been based on yields from corresponding areas in other parts of the world (Marr et al., 1971). In the case of shrimps, however, statistics allow a rough yield assessment from the relationship between fishing effort and catch (Ellis, 1975).

The history of the shrimp fishery bears out the danger inherent in any lucrative fishery, especially where several nations fish the same stock. Formed without regard to optimal yield considerations, expectations of the growth of the industry lead to over-investment, over-fishing, depletion of stocks and finally a waste of resources, both commercial and biological. The history illustrates the need for more basic research on the species to be fished, and for rational management of the fishery on a regional basis, as recommended by the Indian Ocean Fisheries Commission (IOFC). Such research is not immediately profitable; indeed, it may point to restrictions in the short term. Hence, it cannot be left to the fishery companies themselves.

Exploratory fishing

The demersal fishery has been explored both by experts from USSR and Japan operating from Kuwait, and by teams from Bahrain, Iraq and Iran. Greater stress should perhaps now be given to the pelagic fishery in the southeast of the Gulf and in the Gulf of Oman, using acoustic methods for shoaling fish. A number of the species of sardine and anchovy need further taxonomic research (see Kuronuma and Abe, 1972).

An important recommendation by the IOFC is that exploratory fishing should be done with standard equipment or with equipment which has been intercalibrated between manufacturers. The results should also be entered on a standard data sheet. It would then be possible to combine the results of different surveys at a regional centre where the pattern of distribution over the whole Gulf could be built up. For demersal fish, the evidence so far published suggests that catches are greater in the northwest, but they contain a lower proportion of useful fish (Bromiley, 1972).

Stock identification and assessment

Before rational control of fish exploitation is possible, it is essential to know the limits of each inbreeding stock. Stocks frequently cross national boundaries, so that conservation measures should be taken by all the States concerned.

Stock assessment is a major exercise, since ships must operate over a long period of time in order to mark and recapture fish on a large scale. Many of the recaptures however will be made by fishermen, and a system of rewards must be established with good understanding between the scientists and fishermen. Another method of stock identification is through the recognition of small morphological differences between stocks, e.g., in the mean number of vertebrae. Even better is the electrophoretic analysis of polymorphic genetic characters as described above, which offers a less tedious method of delimiting stocks. The method applies especially to penaeid prawns, where the annual crop makes marking and recapture impracticable.

Population dynamics

Some information on the growth and fecundity of shrimp has been obtained for the Saudi Arabia-Bahrain area, but almost nothing is known of the biology of the common demersal fish of the Gulf. There should be little difficulty in obtaining age-growth curves, because the temperature extremes will leave annual marks on the bone and scale structures. Breeding seasons, gonad development, egg production, and the numbers of eggs and larvae later found in the plankton all need to be observed. Enumerating fish eggs and larvae from plankton samples can be a tedious and expensive operation, but it is possible that the plankton sorting centre in Cochin, India, could assist in this. Such studies can be made for each of the common fish in turn, and are ideal subjects for university postgraduate work.

Mariculture

Pilot studies of mariculture of prawns are proceeding in Kuwait and Bahrain. These should be encouraged and extended. Apart from perfecting an industry for entirely artificial breeding, as exists in Japan, there is also the possibility of developing semi-artificially managed fisheries in large lagoon areas of the Gulf. Penaeid prawns, mullet, and possibly some bivalves would be suitable organisms for culture. Careful investigation and control is required however before species are introduced from outside the region to avoid the introduction of potential pests, either deliberately or accidentally.

New fishery resources

It should not be forgotten that new fishing industries may be built up round hitherto unexploited or little exploited material. For example, much of the "trash" fish caught during shrimping is returned to the sea, because it is less profitable than shrimp. This represents a waste of resources that could be used directly, since much of the so-called trash fish is perfectly edible or indirectly edible through conversion to fish meal for animal feed.

Among the edible species which might be exploited by the populations of the Gulf States or prepared for export are the following: large thick-shelled clam, Meretrix meretrix (common on sandy beaches); oyster, Crassostrea sp. (common everywhere); rock oyster, Saccostrea cuculata (common on rocks); rock lobster, Panulirus sp. (these probably occur in the southeast of the Gulf and in the Gulf of Oman); Portunid crabs, Portunus pelagicus (common in all parts of the Gulf).

As the biology programme develops and the distribution of the marine fauna becomes better known, the potential of these and probably of other species will become obvious. As with commercial fish, however, any large scale exploitation should be accompanied by a study of the population dynamics, in order to estimate the optimal yield which the fishery can provide and the best season for cropping the resource.

4.6 LOGISTICAL IMPLICATIONS OF THE PROGRAMME

4.6.1 Scale and duration of the programme

Some of the scientific problems mentioned above could be solved in a relatively short time (e.g., one to two years), especially if they were approached on a co-ordinated international basis. Other projects, by their nature, must be regarded as continuing indefinitely - e.g., the collection of basic oceanographic data for the area. But the time scale ought not to be underestimated, having regard for the long-term interests of the Gulf States and the relative lack in some States of a well-developed educational infrastructure. Moreover, the function of a Unesco programme is not primarily to achieve the desired results of research as quickly as possible, but rather to ensure that the national infrastructure and research capabilities are so developed that, as the programme terminates, the nationally-based institutions can maintain functional efficiency and, within acceptable limits, independence. A ten-year term is therefore probably the minimum required to achieve this result.

It would be difficult to give an overall estimate of the manpower required for the programme. Detailed recommendations have been included in the reports on Iran, Iraq and the United Arab Emirates. Their implementation must be left to the individual States whose resources vary considerably. Scientific and technical training will occupy a large part of the efforts of all Gulf States. Unesco will no doubt be able to use its good offices to suggest appropriate laboratories for overseas training, to recommend experts and advisers to assist with parts of the programme, and to provide a forum for negotiations to set up bilateral projects whereby foreign experts can spend an appreciable time in the region.

4.6.2 National centres of the area

Every encouragement should be given to the establishment of national oceanographic centres, since there is ample scope for co-operation by all States in the programme. It is best, all things being equal, to build on the already existing infrastructure, provided it functions satisfactorily. The rôle of each State will depend on the field in which its strength lies. The strength of the scientific contribution of an institute will depend on (i) the quality of training and experience of existing senior scientific staff, which in turn will be related to the existing facilities and educational infrastructure; (ii) the financial resources that can be assured by governments; here the degree of national integration in sharing and maximizing facilities is most important; (iii) the environmental situation in which the institutes are located.

There follows a list of national initiatives.

Iran (from Richards, 1975)

The major development proposed is the establishment of an Iranian National Centre for Marine Science at Shiraz under the joint sponsorship of the Ministry of Science and Education and the Department of Environmental Conservation. It would be affiliated to Pahlavi University, where a comprehensive plan for a College of Marine Science and Technology has been approved. Within this organization would be a College of Marine Sciences for higher education and basic research in the relevant disciplines and an Institute of Marine Science and Technology for applied research. It is proposed that the centre be developed in co-operation with Unesco. It is recommended that the Centre have a comprehensive library, a computer centre and a calibration centre.

A co-ordinating body would be set up with responsibility for ship facilities, both in the Caspian Sea and in the Gulf, including the Straits of Hormoz and Gulf of Oman. The board of directors responsible for the centre will include representatives of the navy, oil interests, port and shipping interests, and the fishing company Shilat Jonoub, as well as representatives of other universities. Initially it will be strengthened by a board of consultants. If this plan is activated, the board will be in a strong position to advise and co-ordinate the national effort in all fields of oceanography, basic and applied.

Iraq (from Stefansson, 1975)

The main proposal is the establishment of a relatively small marine science centre on the new university campus of the University of Basrah on the banks of the River Garmatali. The development is expected to occupy the period 1975-80. It is recommended that a strong team of highly qualified overseas experts, covering the four main disciplines of marine science, should lead the research and training programme in its initial stages.

There already exists in the department of biology an active research school and an undergraduate curriculum in which either marine biology or a fisheries training scheme can be taken. Some limited interest in oceanography has been expressed by the departments of physics and chemistry, and these departments are certainly capable of giving the necessary background science training. There is no department of geology.

The Iraqi Government's immediate concern is improved fishery yields, and the state fishing company has established, with USSR help, a small group to carry out experimental and exploratory fishing. There is also a national committee for controlling pollution, consisting of the Ministry of Health and university members. One of its priority areas is the investigation of sewage and industrial pollution on the waters of the Shatt al Arab.

Kuwait

Though a small State, the strength of Kuwait lies in its exceptionally well-developed educational infrastructure. The State University is already established and financed on a generous scale, but nevertheless it is shortly to be moved and expanded at a new campus at Shuwaikh on the shore of Kuwait Bay. Plans are being made to include an institute of oceanography, eventually with its own fully equipped research vessel. The university has strong departments of chemistry (with biochemistry), physics and geology and a new department of engineering, so it will be able to provide a background for marine science education. The departments of botany and zoology are already undertaking research on marine biological subjects, and several students now in training abroad will return to join the staff during the next few years. Courses in marine ecology and marine algology have been part of the curriculum at least since 1971 and will be greatly expanded in the direction of more specialized teaching when a new degree course comes into force. There is also a small temporary marine laboratory only a few miles from the university, in juxtaposition to the mariculture unit of the Kuwait Institute for Scientific Research. This Institute, from which the university has received much help and encouragement, was established through the Arabian Oil Company and is now partly government financed. Its marine activities include the production of the very useful booklet on fishes by Japanese scientists (Kuronuma and Abe, 1972), a fisheries and hydrographic survey of the Gulf completed in 1969, and a current programme directed towards mariculture of prawn and mullet.

The Department of Fisheries (under the Ministry of Public Works), is situated in the port area and has under its control a large research vessel (RV Sabah) operated by a group of Soviet scientists. The Institute also plans to build a marine aquarium in the centre of the city. There is a plan to establish a regional fisheries institute in co-operation with FAO.

Saudi Arabia

As a result of a five year agreement with University College (North Wales, Bangor, UK), a fisheries laboratory has been built in Jeddah Port, together with a marine biological laboratory on the coast to the north of Jeddah; also, a 22 metre research vessel was purchased and has been operating in the Red Sea for two years. A small research laboratory operated for two years at Dammam on the Gulf. The biology and population dynamics of Saudi Arabian shrimp stocks have been investigated, in collaboration with UK scientists, and results have been published in the Bulletin of the Marine Research Centre, Saudi Arabia. It is probable that fishery development investigations will continue in the Gulf with the assistance of the UK White Fish Authority. ARAMCO in Dhahran has a small, well-equipped team of marine scientists whose leader advises on marine environmental research and pollution problems. In the same vicinity, there exists the University of Petroleum and Mining Resources, an organization of excellent standing which can offer a sound scientific background for this group of sciences. Marine biological research will in future be undertaken by universities. King Abdul Aziz University in Jeddah is starting marine sciences courses; the marine research programme will initially be concerned largely with the Red Sea.

Bahrain

The Bahrain Government and the UK Ministry of Overseas Development have jointly set up a Fisheries Research Bureau under a six-year project agreement. One function of the bureau is to investigate fishery resources; with the assistance of the fisheries adviser, a fisheries biologist, and a fishing skipper, surveys have concentrated on the Bahrain area of the Gulf over the past three years. A second function of the bureau is to study shrimp culture, and two scientists have been engaged. Trial rearing of P. semisulcatus has met with success and present studies are concentrated on breeding, rearing and the establishment of algal food cultures. The shrimp project is well placed for expansion into a regional facility, since Bahrain is central to the Gulf, has good communications and has easy entrance regulations.

Qatar

Higher education in the State of Qatar was introduced only two years ago. The Faculties of Education were established as a nucleus for a new university at Qatar. The faculty is following the credit system and is offering a Bachelor of Science degree with two majors, one in education and one in a science or arts subject, and one minor. Students whose major is biology are offered a marine biology course as an elective. Interest is also shown in marine sciences by other science departments (e.g., geology, chemistry and physics).

The science departments in the Faculty of Education include: chemistry, physics, mathematics, biology and geology. These departments are manned by staff members with a minimum qualification of a Doctor of Philosophy degree.

A meeting has been scheduled to take place at Doha from 24-30 November 1975, to discuss the promotion of marine sciences (both in teaching and research) in the new university. A number of outside experts (including experts from Egypt, UK and Unesco) have been invited to the meeting, and it is hoped that future plans will be formulated following this meeting. It is hoped that the establishment of a National Committee of Marine Sciences will shortly be discussed with other interested government departments. The Government of Qatar will provide headquarters in Doha for the UNDP Regional Fishery Survey and Development Project.

United Arab Emirates

During September 1975, a Unesco team spent some time in the United Arab Emirates on a mission designed to evaluate the feasibility of a Marine Resources Research Centre in the vicinity of Dubai. The consultants' observations of the coastline of the United Arab Emirates indicate only limited evidence of pollution of any type at present. However, they were impressed by the large amount of coastal development taking place, and they saw ample justification for the establishment of a Centre in the area (see also Gaskell, 1969). The United Arab Emirates are now actively collaborating in the UNDP Regional Fishery Survey and Development Project of the Gulf region. This programme is to last for several years. In addition, it seems likely that active steps will be taken in the near future towards the establishment of the National Marine Resources Research Centre and Aquarium in the United Arab Emirates. The Ministry of Agriculture and Fisheries is the official agency sponsoring the above proposed actions. Recently, a fishery department with its own research vessel was set up. At present, the fisheries advisor is preparing a check list of marine fish of the Gulf of Oman and is responsible for investigations on dugong and turtles in the United Arab Emirates.

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5. REVIEW OF HYDROGRAPHICAL AND PRODUCTIVITY CONDITIONS IN THE GULF REGION

by

Professor K. Grasshoff

Relatively little has been published on hydrographical and hydrochemical conditions in the Gulf region, and even the intensive study of the Indian Ocean during the International Indian Ocean Expedition (IIOE) added little to literature on the subject. Schott (1918) was the first to describe the hydrography of the Gulf, mainly on the basis of ship observations from 1906 until 1914. Emery (1956) published surface charts and also vertical profiles of temperature and salinity. He used the observations from a two-week cruise to the Gulf and the Gulf of Oman in August 1948 where hydrocasts with three standard depths were made at 18 stations.

More extensive data obtained from 199 stations by the USS "Requisite" in February and March 1960 and January to March 1961 were published by Peery (1965). Other data can be found in the work of Sudgen (1963) and of Dubach (1964). Wyrtki (1971) has compiled all relevant data from the I.I.O.E. in an atlas. This atlas and the data analysis it contains reveal the lack of regular observations in the Gulf but also underline the extraordinary variability of the basic hydrographic parameters. The seasonal surface temperature variations may be as high as 17°C, from 18°C in March to 35°C in August and the salinities vary from almost 42‰ in the inner part of the Gulf in August to 37‰ in the transition area of the Straits of Hormuz.

The Gulf is a shallow semi-enclosed sea in a highly arid climatic zone. The strong evaporation exceeds the sum of precipitation and discharge or river water and accounts for the high salinities in the inner part of the Gulf, together with a deep-reaching thermo-haline convection leading to an outgoing current of high saline water in the bottom layers. (Fig. 1). In contrast to the Red Sea, the entire area of the Gulf is shallow, resulting in a much more developed interaction and mixing of deeper waters and surface waters; the total amount of deeper water acting as a nutrient trap is much less than in the Red Sea.

The system of surface and bottom currents is rather complex because of the mainly transversal direction of the monsoon in this region, which gives rise to eddies with rather large fluctuations. Furthermore, the development of the monsoon is known to vary in different years.

The following discussion is mainly based on the observations made by R.V. "Meteor" in 1965 at 133 stations. For different reasons, it was only possible to visit the zone along the coast of Iran, but special observations were made in the transition area and in the Gulf of Oman. It can be assumed that these observations are at least partially valid for the environmental conditions in the SW part of the Gulf. (Fig. 2a, b). The salinity distribution in March 1965 shows the typical increase of the surface values from 36.5-36.6‰ in the inner part of the Gulf of Oman to values larger than 40.5‰ in the inner northwest part of the Gulf. In contrast to the observations by Schott (1918) and Emery (1956) it is obvious from Fig. 3 that the isohalines do not follow the longitudinal axis of the Gulf. Already this comparison indicates the probability that the salinity is highly variable and strongly dependent on the prevailing wind conditions.

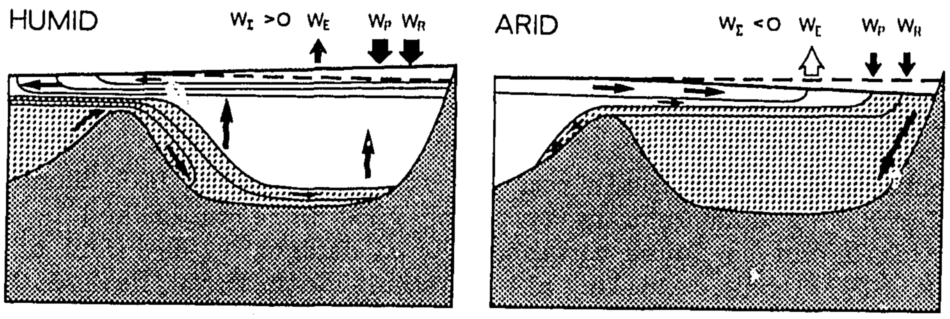

Fig. 1 Schematic section through a semi-enclosed sea in a humid zone (a) with positive water balance and in an arid zone (b) with negative water balance. (Grasshoff, 1975)

W_E Evaporation

W_P Precipitation

W_R River input

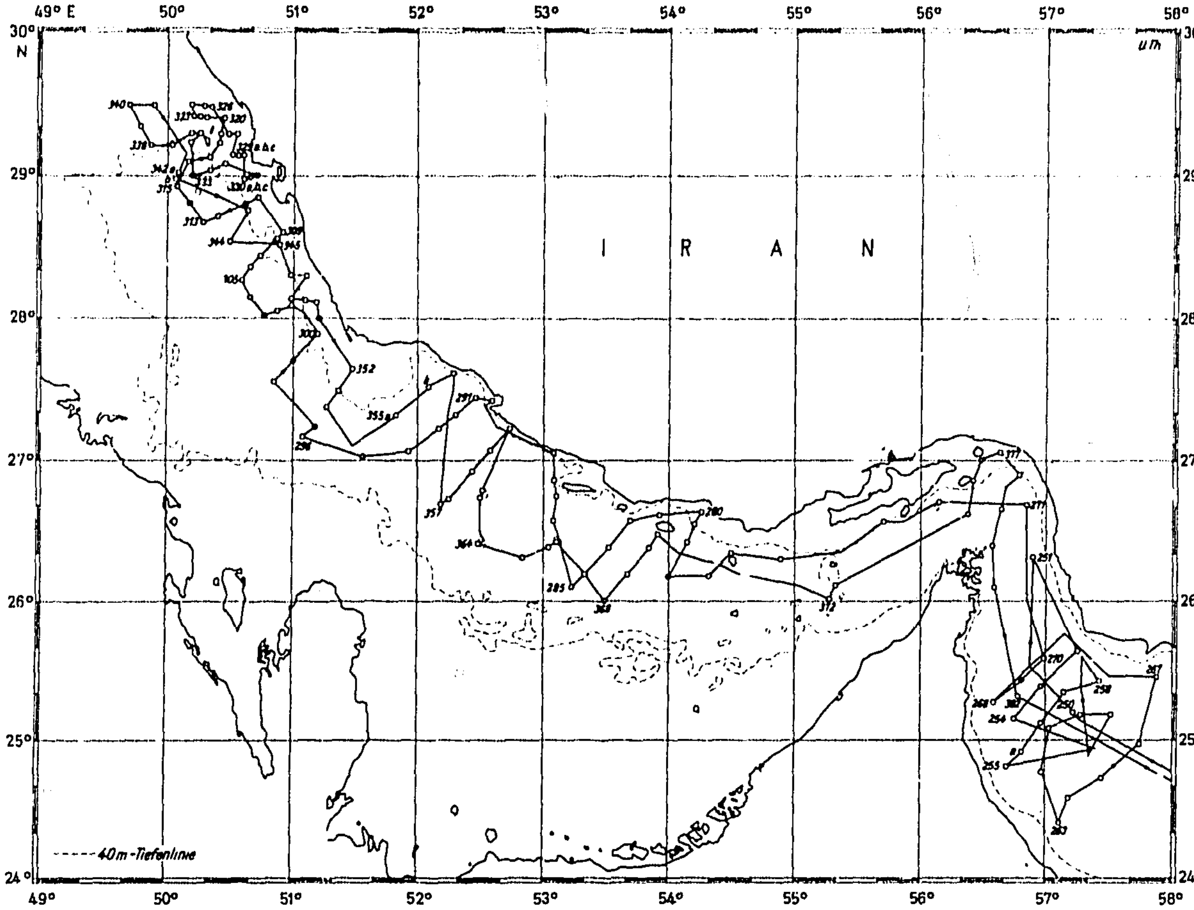

Fig. 2(a) Cruise track and stations in the Gulf and in the Gulf of Oman.
---- 40 m depth contour

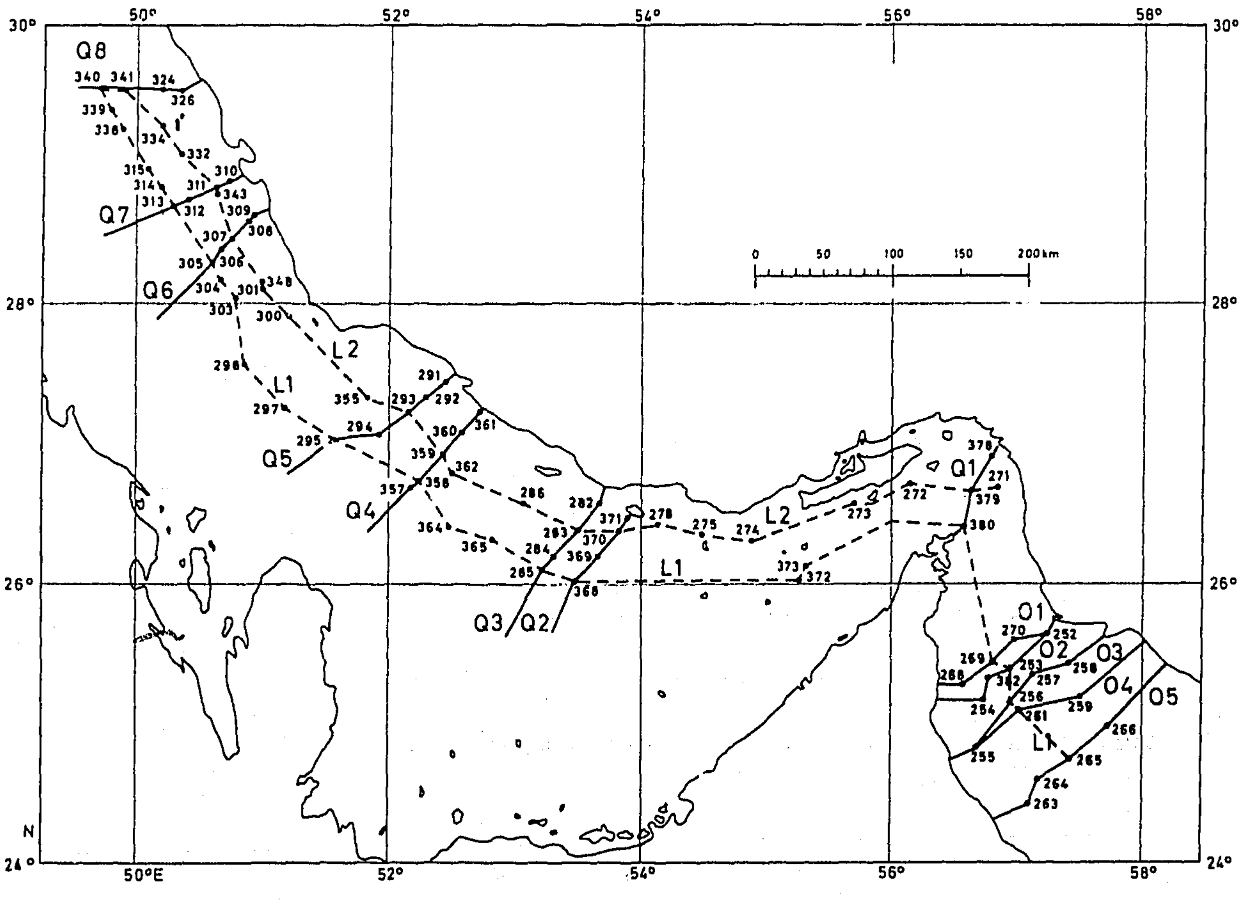

Fig. 2(b) Hydrographic sections.

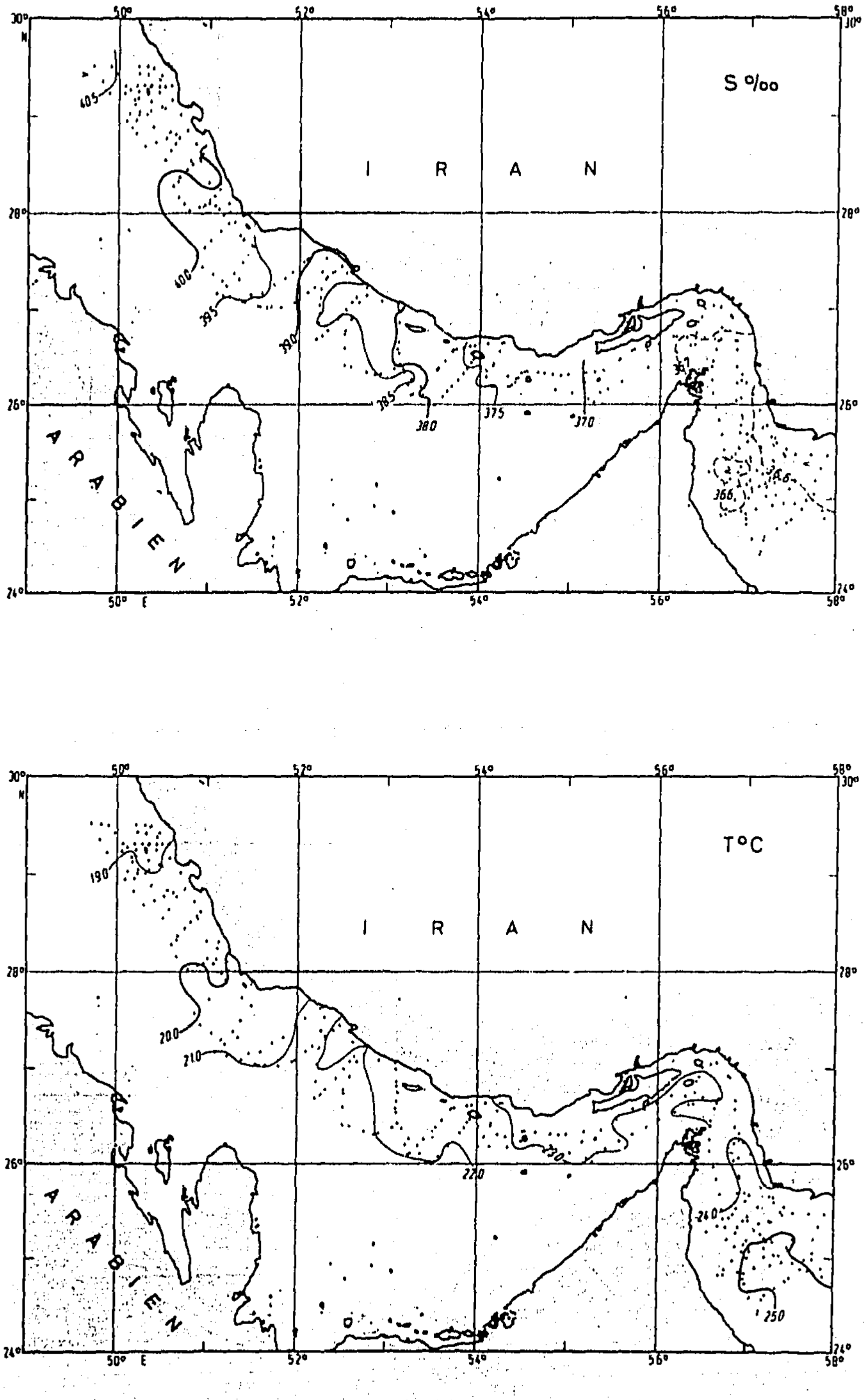

Fig. 3 Distribution of surface salinity and temperature.

Another possible explanation could be the long and short term fluctuations in the water discharge of the Euphrates and Tigris. Schott (1918) reports a total discharge of both rivers of 5,700 m^3/sec in April and 700 m^3/sec in October (corresponding to 180 km^3/year and 22 km^3/year respectively) whereas Hartmann <u>et al.</u> (1971) give a total annual discharge of 5 km^3/year only. Such a drastic reduction of the fresh water discharge could well cause an increase of the surface salinity of 2‰ in an area of 1000 km^3 (Koske, 1972).

Because of strong evaporation, the salinity increases towards the inner part of the Gulf, and during the winter months the temperature decreases from 25°C in the Gulf of Oman to less than 19°C in the innermost part of the Gulf. This results in the formation of extraordinarily high density water with σ_t of 29.0 to 30.0 compared to $\sigma_t = 24.5$ in the surface waters of the Gulf of Oman*. According to Dietrich (1957) the specific gravity of the Gulf water is the highest of all the world's oceans.

The fresh water plume of the Schatt-el-Arab could not be traced even in the inner part of the Gulf.

The water on the shallow shelf in the inner part of the Gulf was almost homogeneous (Fig. 4) at the time of observation in March. In the middle part of the Gulf the isohalines tilt as do the isotherms. The dense bottom-water penetrates through the Straits of Hormuz in a thin layer at the bottom and finally cascades down on the slope of the Gulf of Oman. (See also transversal sections 01, 04, Q2, Q4, Figs. 5 and 6). The evaporation and the cooling in the inner part of the Gulf generate large scale circulation. The water is replenished by a more or less developed ingoing surface current from the Arabian Sea.

Measurements made on a long term station show that both ingoing and outgoing currents are characterized by large variations.

A rough estimate of the water exchange of the Gulf has been made by Koske (1972) on the basis of an estimate of the average total annual evaporation of 144 cm (Privett, 1959) and the salinities of the inflowing and outflowing waters. His conclusion is a total exchange of the Gulf water within three years. The average current velocity of the outflowing bottom water is in the order of 10 cm/sec and is therefore significantly below that of the tidal currents which are in the order of 50 to 100 cm/sec.

It is possible that the stratification in the Straits of Hormuz is not limited to a double layer. Water from just below the thermocline from the Gulf of Oman may also penetrate into the Gulf. This water is rather rich in nutrients.

Grasshoff (1969) has observed similar penetration of nutrient rich water into the Red Sea through the Straits of Bab el Mandeb and the water exchange conditions there have much in common with those in the Straits of Hormuz.

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* If ρ is the density of the sea water at atmospheric pressure and at <u>in situ</u> temperature, then σ_t is defined as $\sigma_t = (\rho - 1)\ 1000$.

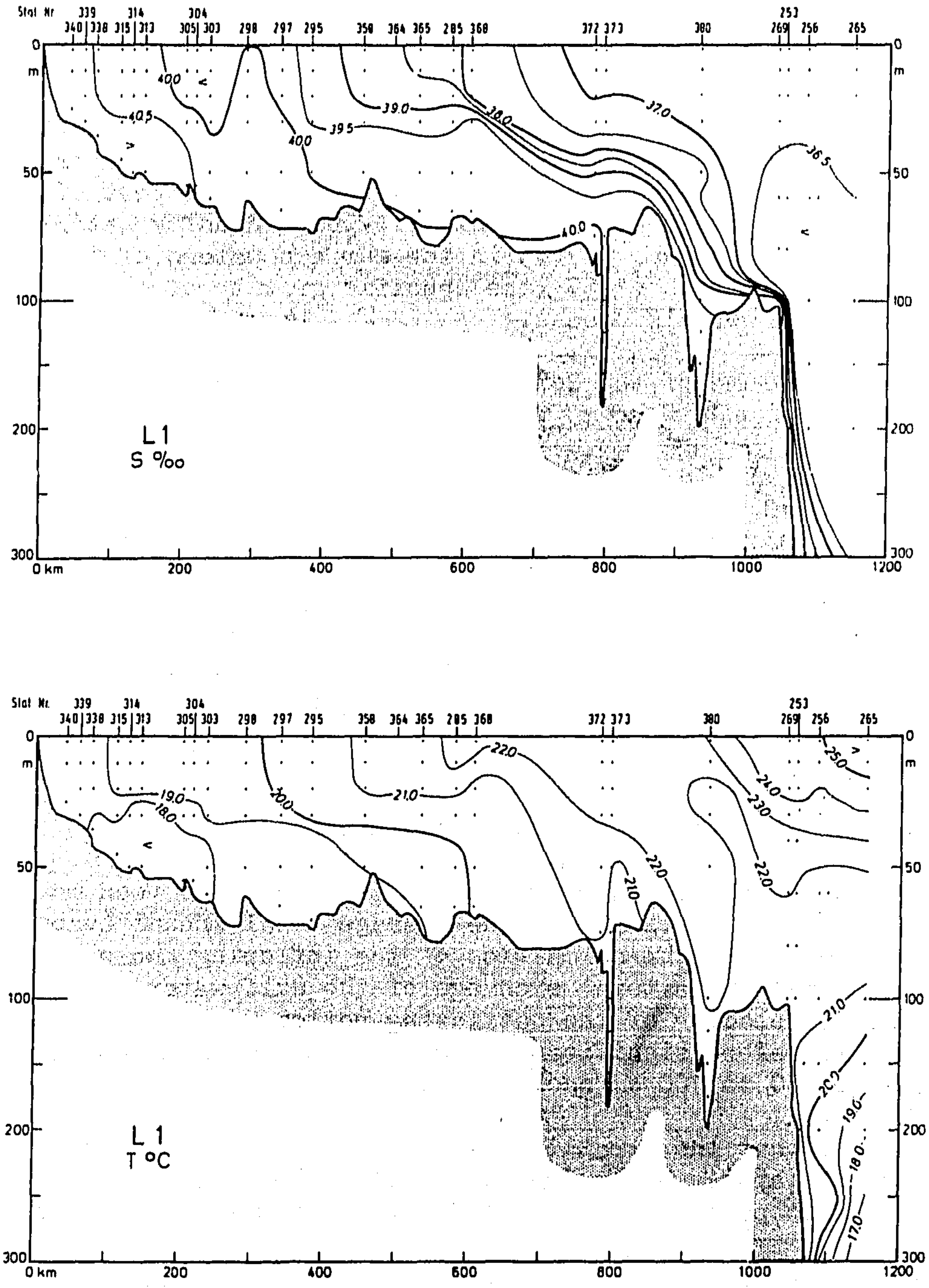

Fig.4 Distribution of salinity and temperature along the hydrographic section L1.

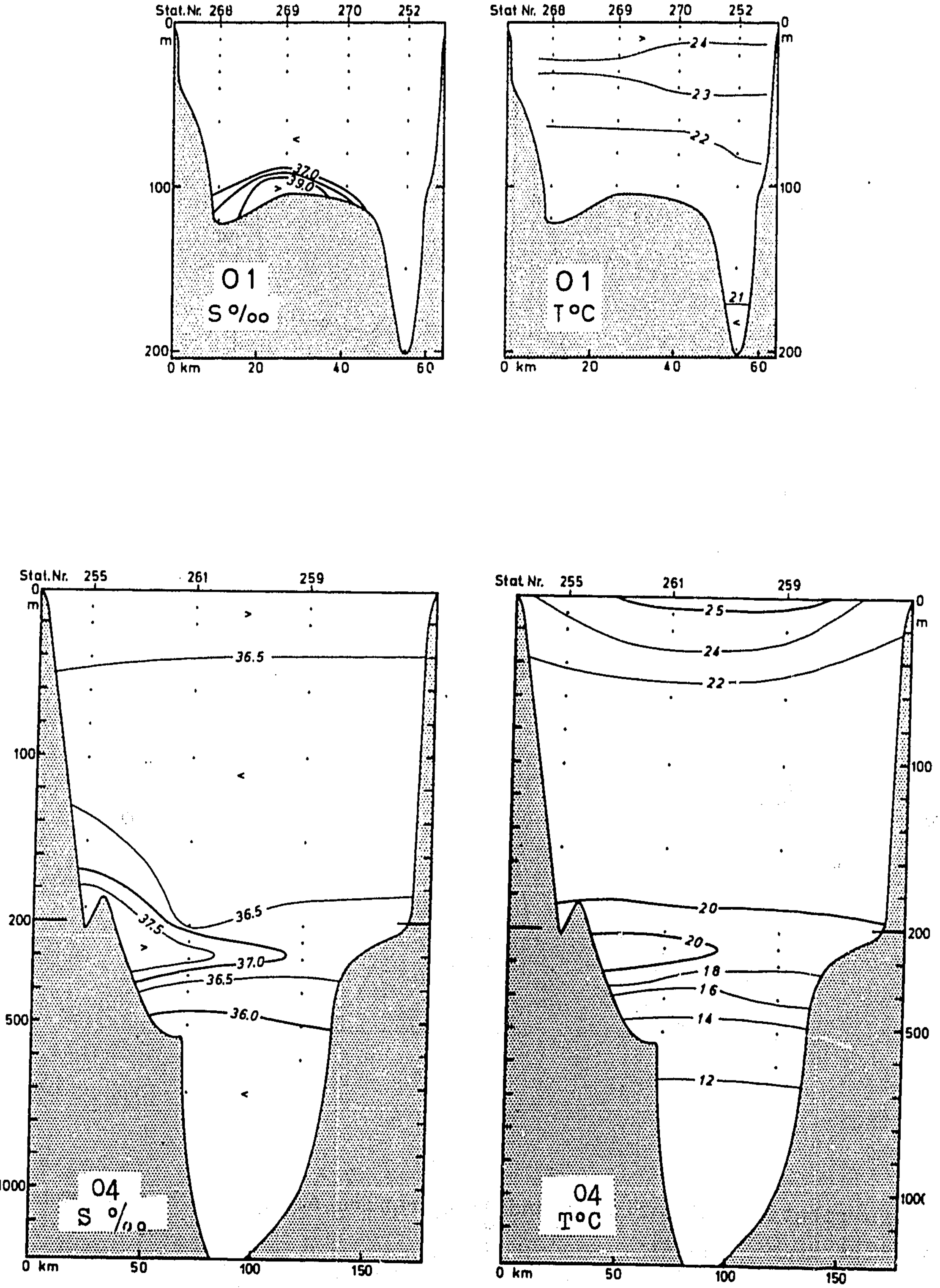

Fig. 5 Distribution of salinity and temperature along the hydrographic sections 01 and 04.

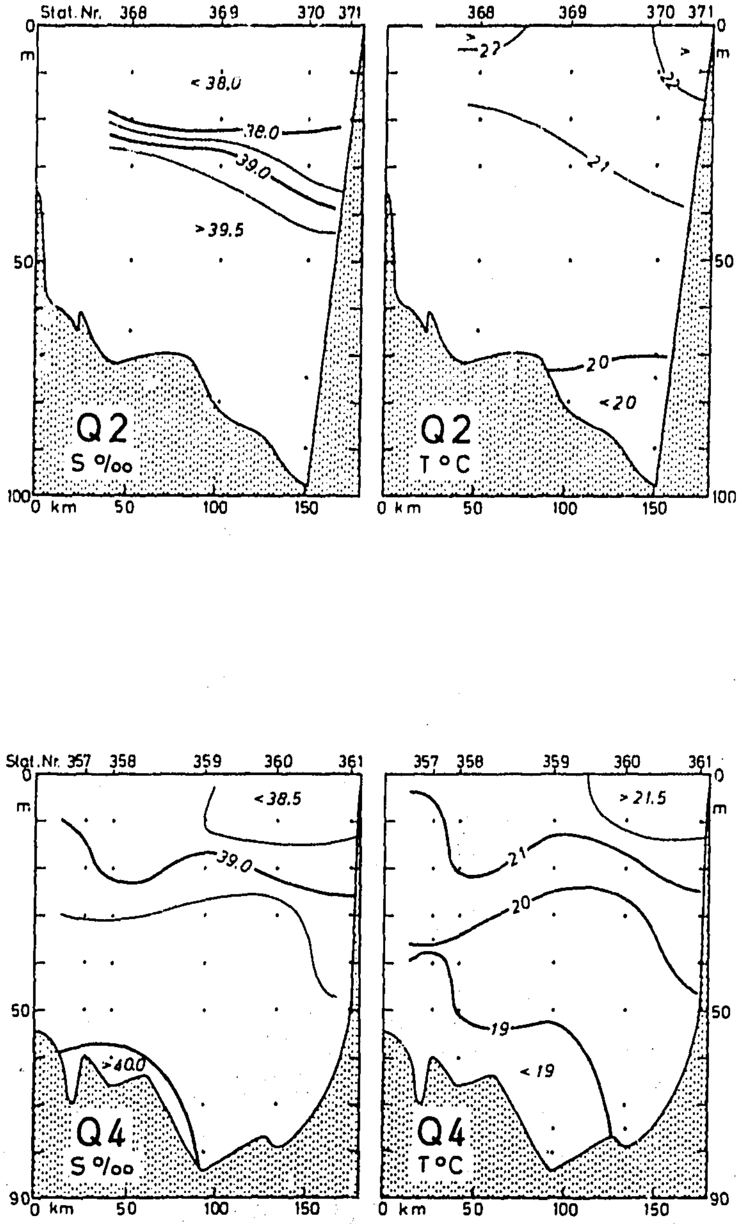

Fig. 6 Distribution of salinity and temperature along the hydrographic sections Q2 and Q4.

Data on the distribution of nutrients and dissolved oxygen in the Gulf are even more scarce than salinity and temperature data. Some observations on nutrients were made during the John Murray expedition in the Gulf of Oman but later observations deal only with salinity and temperature. Rabsch (1972) compiled and evaluated the data from the "Meteor" expedition in 1965. Nutrient, pH and oxygen data were collected at about 100 stations in the Gulf region. Undoubtedly, these data represent the most complete observations to date, but the waters in the south western part have not been covered. Furthermore, the data were collected during one month only (March/April). (The productivity data from the I.I.O.E. do not include the Gulf and the few measurements taken by the "Meteor" are not reliable. Personal communication from secretariat for biological I.I.O.E. Atlas).

It should be possible to establish the general circulation pattern by analyzing the distribution of oxygen and nutrient data, i.e. the water from the Gulf of Oman should mainly flow off the Iranian coast whereas the deeper, outflowing water should move over the Arabian shallow shelf according to the influence of the Coriollis force. Both waters can, however, be observed in the Straits of Hormuz (Section 01, Fig. 5).

Fig. 7 illustrates the distribution of the oxygen saturation along the longitudinal axis of the Gulf. Nowhere in the Gulf does the oxygen seem to act as a hindrance for the development of marine life, at least at the time of the observations. Only in the Gulf of Oman are critically low values obtained in depths below 100 m. The high degrees of saturation in the Gulf indicates clearly the relatively large overturn and the resultant short residence time of water in the Gulf.

The tongue of phosphate-rich water (Fig. 7, 8 and 9) penetrating into the Straits of Hormuz in depths as shallow as 30 m is a strong argument for the inflow of nutrient-rich water at least from time to time. The sources of this water are the layers just below the thermocline in the Gulf of Oman. This nutrient-rich water will gradually mix into the productive layers but inflow and mixing are most certainly highly variable and greatly dependent on the prevailing winds. (Sections Q1, Q2, Fig. 10). Special attention should be given to the dynamics of the silicate circulation, (Fig. 11). It may well be that silicate is the limiting nutrient in the Gulf. Loss of silicate, even in the phosphate-rich water, is due to the fact that silicate debris mineralises more slowly than organic tissues.

It is assumed that a complex system of eddies of different scales with a high degree of variability exists in the Gulf, especially in the part between Qatar and the Straits of Hormuz. The penetration of nutrient-rich water into the Gulf and its further distribution and mixing are a function of the stability of the water column, the system of currents and eddies and the bottom topography (Seibold, et al. 1969, 1970).

Considerable productivity exists, at least in the transition area and in the eastern parts of the Gulf, i.e. off the coast of the United Arab Emirates, but no reliable data, however, is available. However, primary productivity is highly variable and closely linked to the nutrient distribution. This conclusion is supported by the zooplankton data obtained during the International Indian Ocean Expedition (Fig. 12a, b and c).

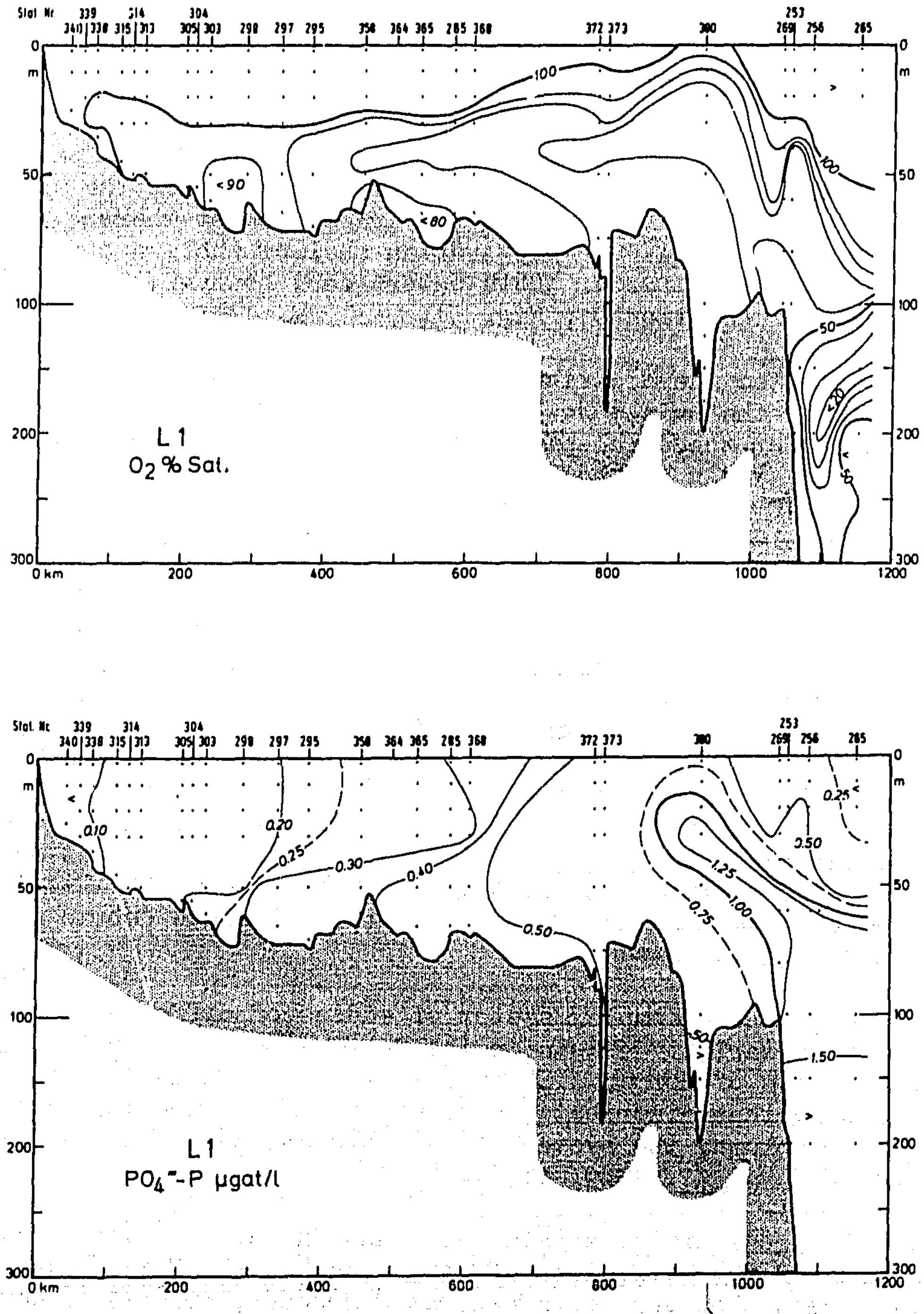

Fig. 7 Distribution of oxygen saturation and phosphate along the hydrographic section L1.

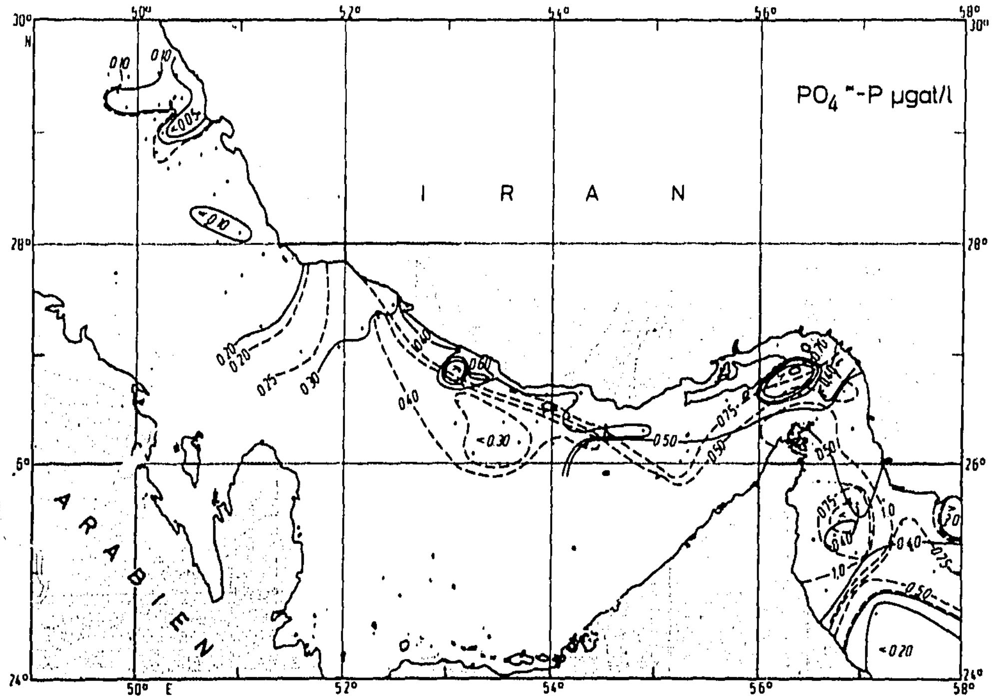

Fig. 8 Distribution of phosphate at the surface and at 30 m depth.
——— surface
- - - - - 30 m

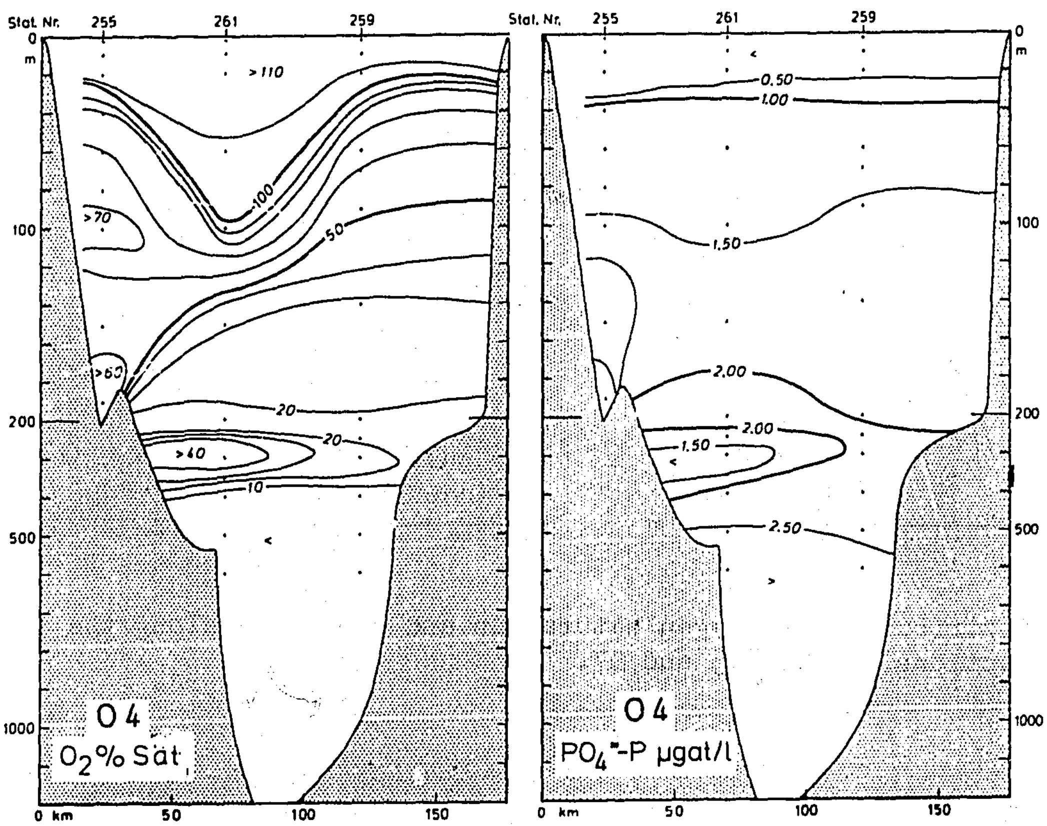

Fig. 9 Distribution of phosphate and of oxygen saturation along the transverse section O4.

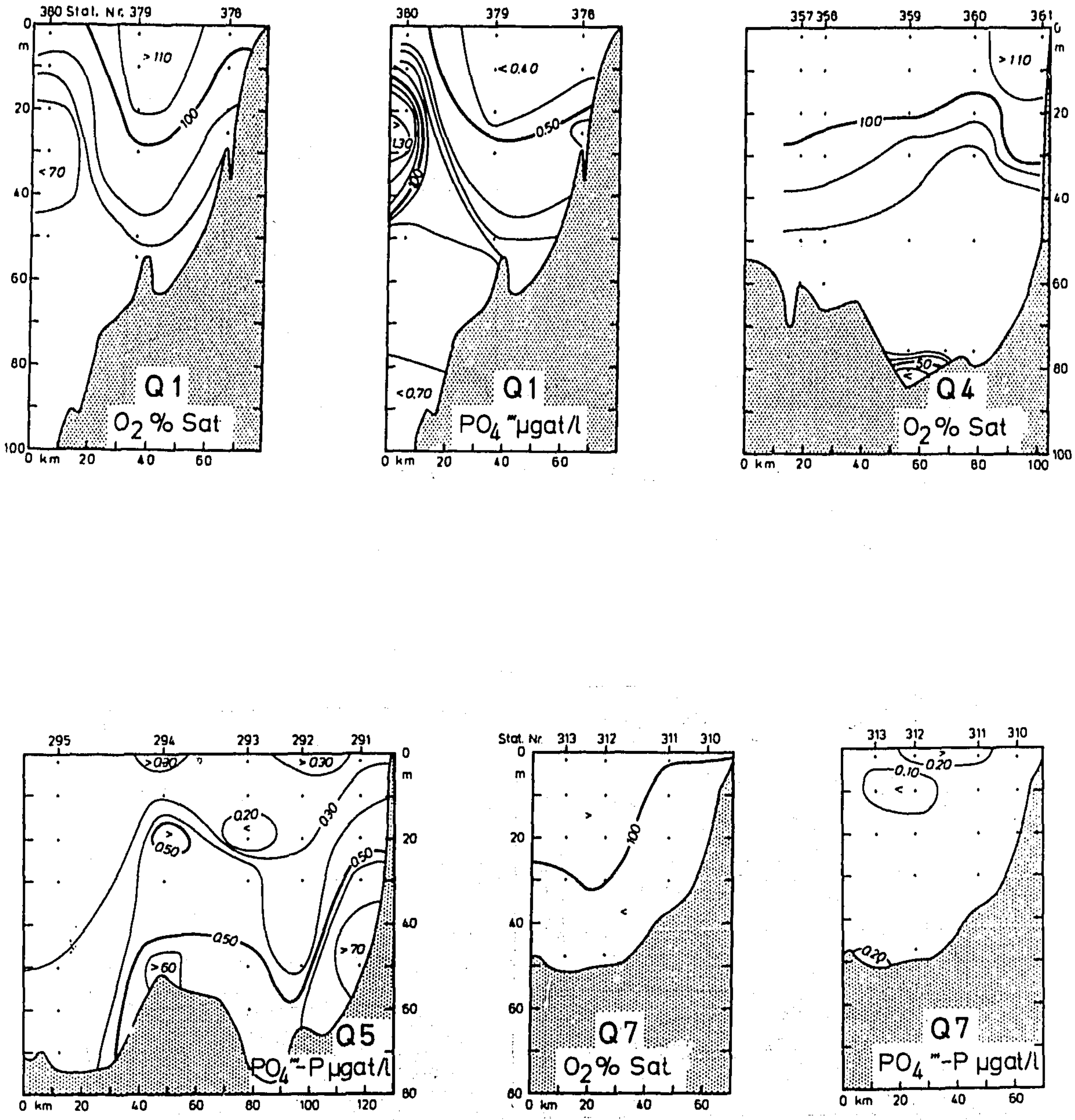

Fig. 10 Distribution of oxygen saturation and phosphate along the transverse sections Q1, Q4, Q5 and Q7.

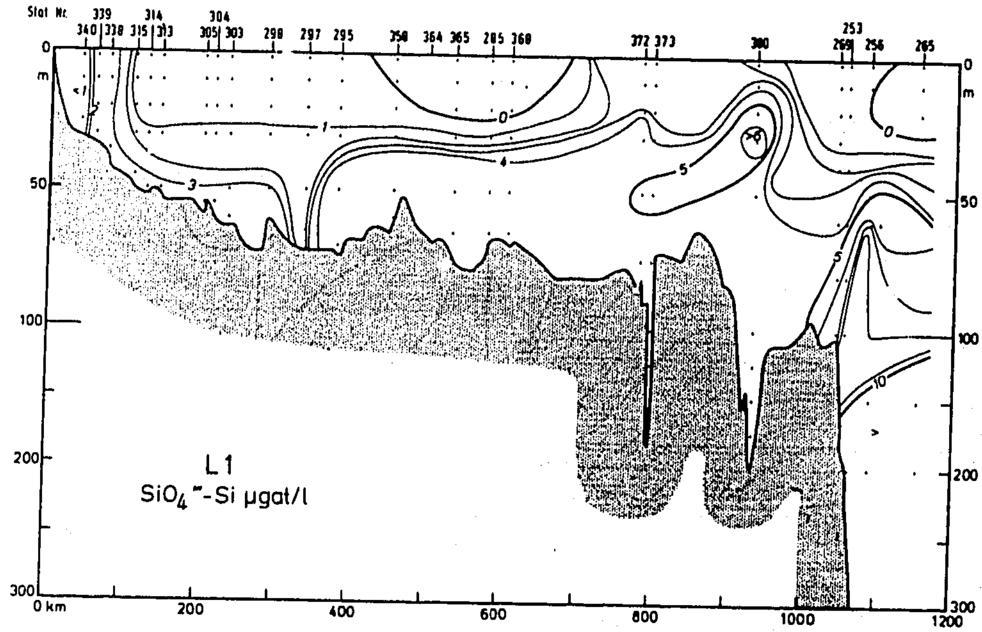

Fig. 11 Distribution of silicate along the hydrographic section L1.

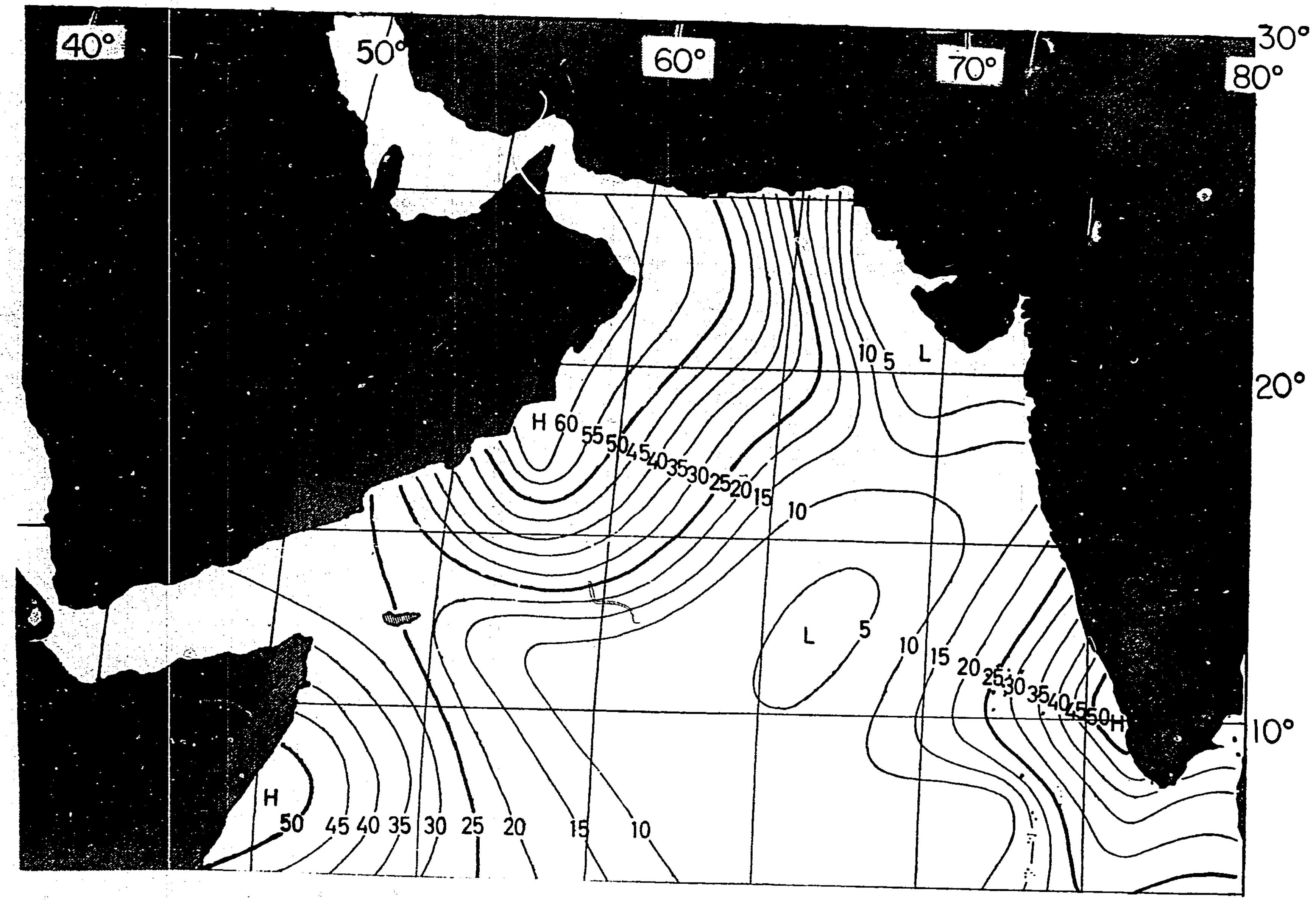

Fig. 12 (a) Total zooplankton displacement in ml, I.I.O.E. Standard Net, SW monsoon, day and night.

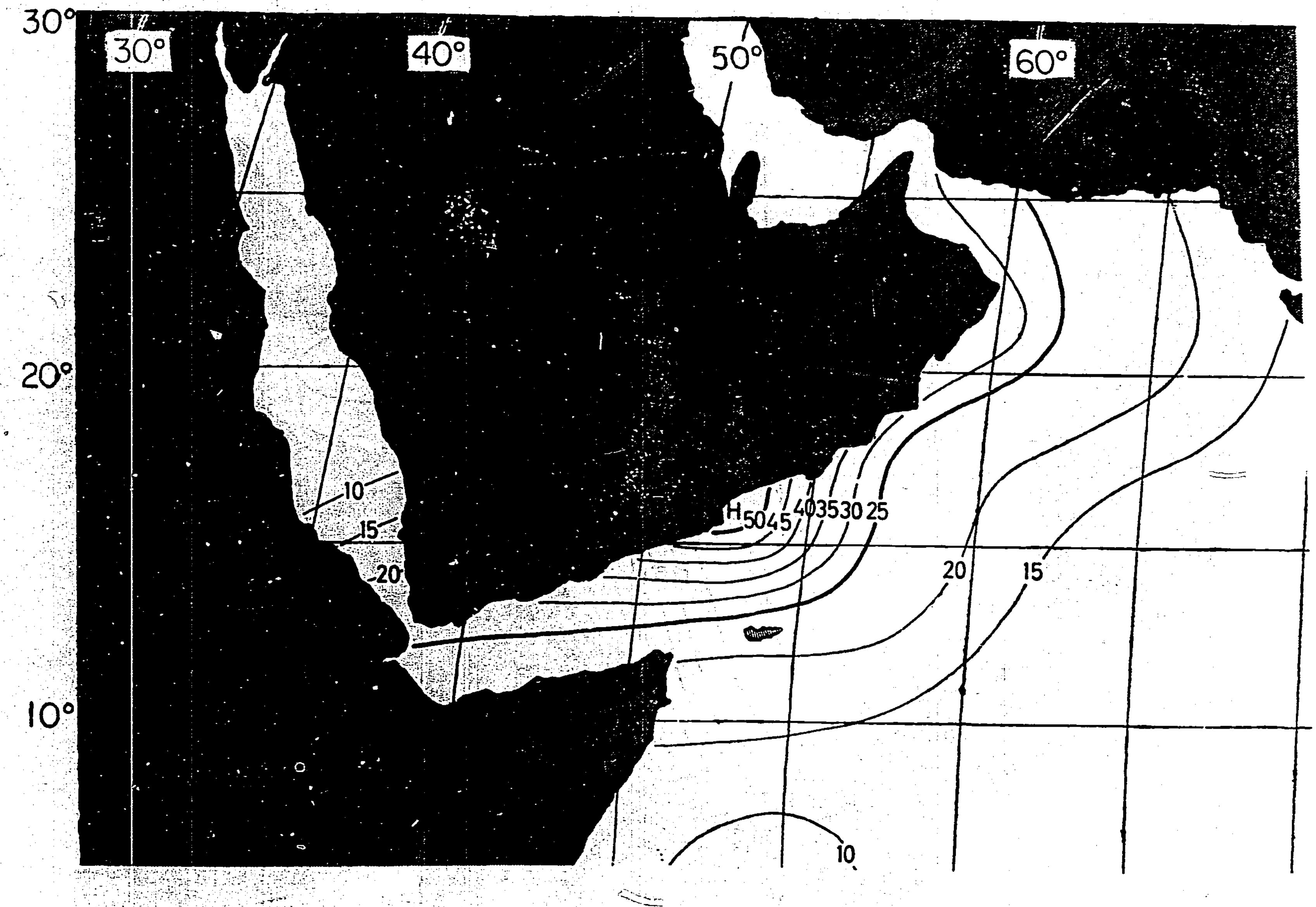

Fig. 12 (b) Total zooplankton displacement in ml, I.I.O.E. Standard Net, NE monsoon, day and night.

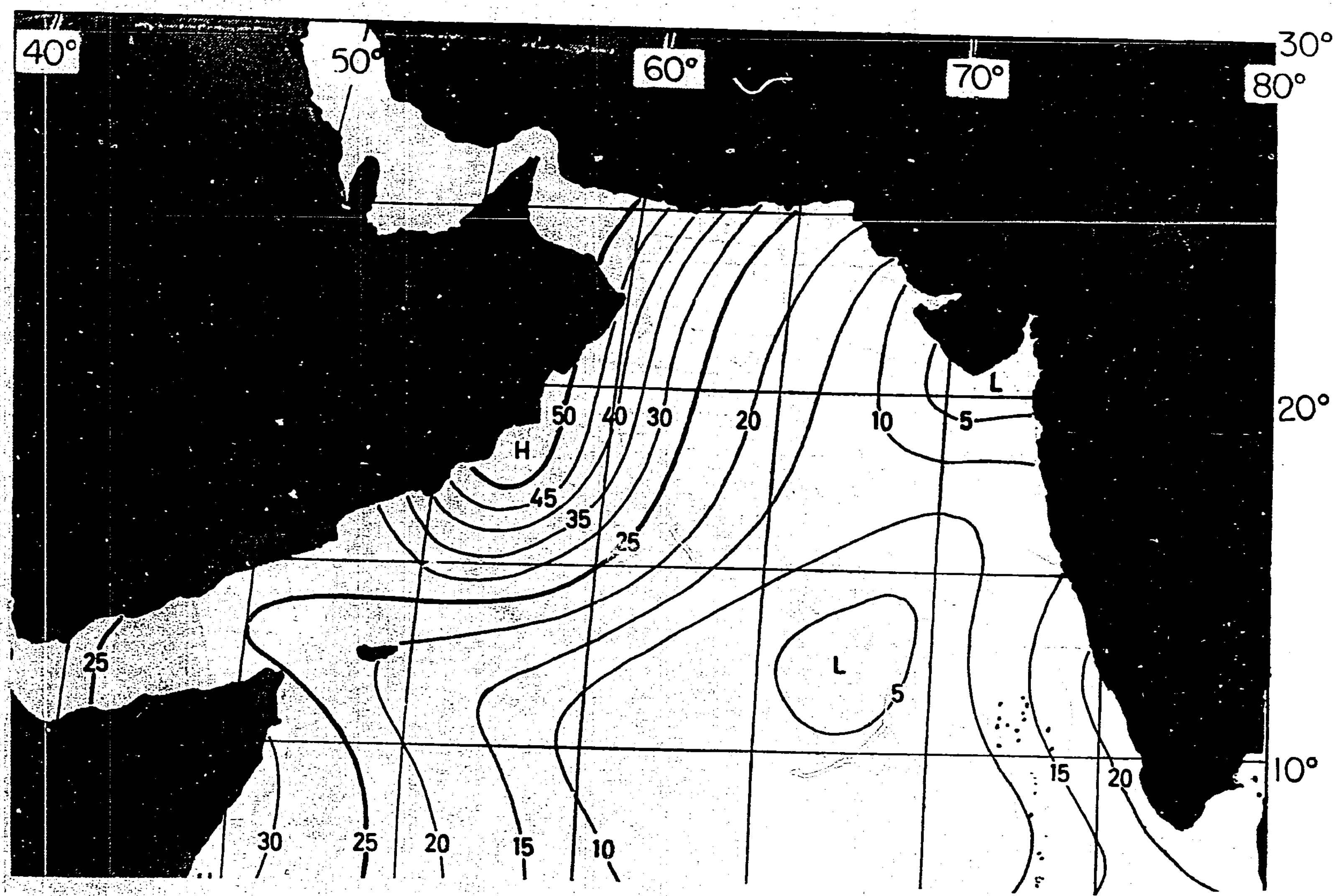

Fig. 12 (c) Total zooplankton displacement in ml, I.I.O.E. Standard Net, full year, day and night. (from I.I.O.E. Plankton Atlas, Vol. 1)

It is suggested that future investigations concentrate on the air-sea interaction, and the response of the current system in the Gulf region to the wind. Furthermore, the general thermohaline circulation must be fully understood, as also its interaction with the wind-system. Fig. 13, a -1, shows the monthly means of wind speed and direction and current speed and direction from pilot charts, illustrating the large variability.

Because of this variability, any evaluation of the productivity of the region and of the presence, recruitment and migration of fish stocks should be based on a complete investigation and understanding of nutrient dynamics and primary and secondary production. Only in this way can a sound forecast be made and rational management of the natural fish resources assured. Such steps are all the more important because of the observed presence of phytoplankton feeding fish (sardines) which may represent the most abundant fish in the region.

Any variation in primary production is mirrored in the abundance of such fish stocks.

It is strongly recommended that the above-mentioned data be taken into consideration in designing the Marine Resources Research Centre.

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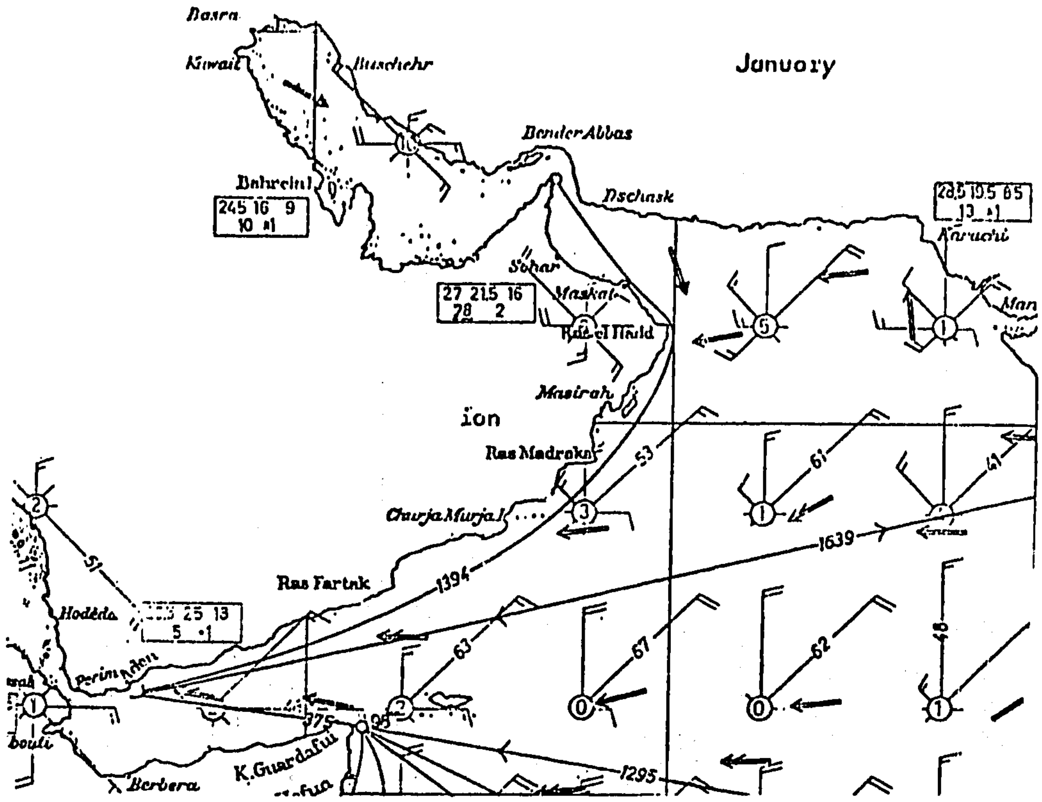

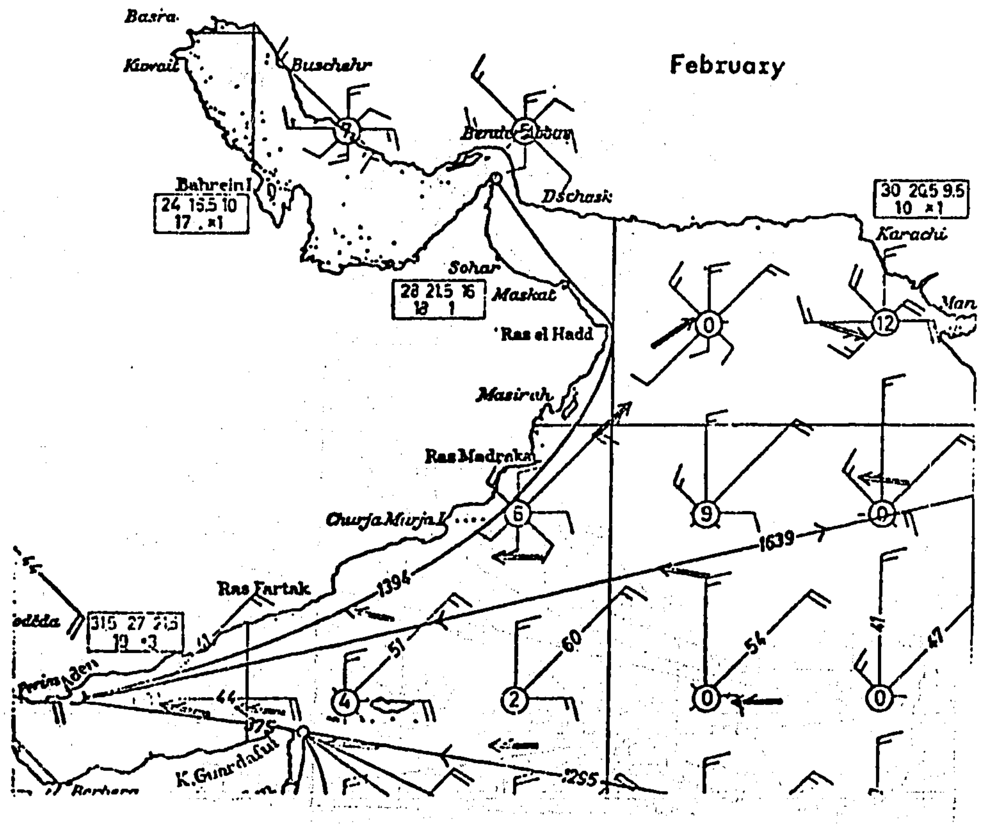

Fig. 13 (a), 13 (b) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - January, February.

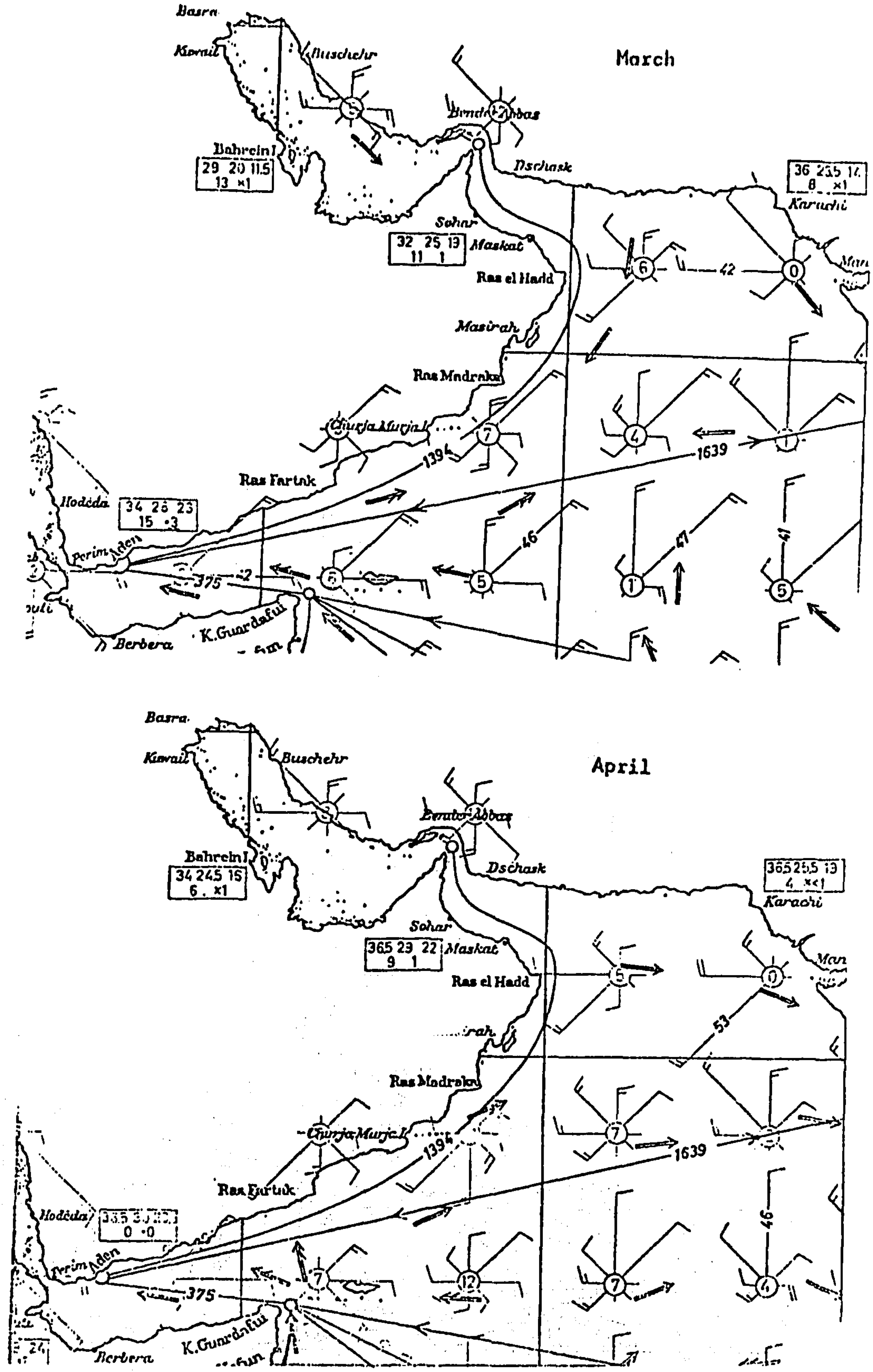

Fig. 13 (c), 13 (d) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - March, April.

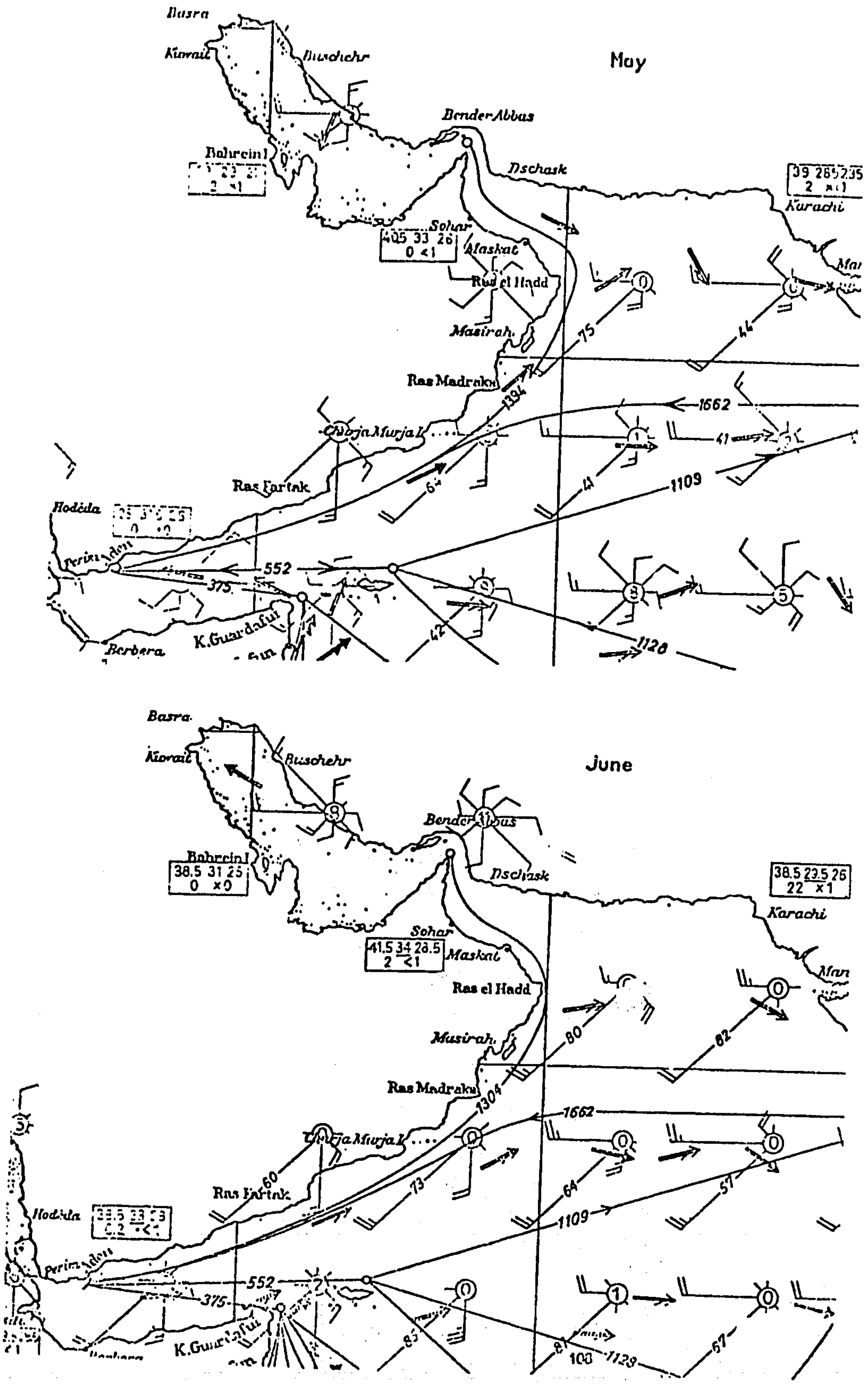

Fig. 13 (e), 13 (f) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - May, June.

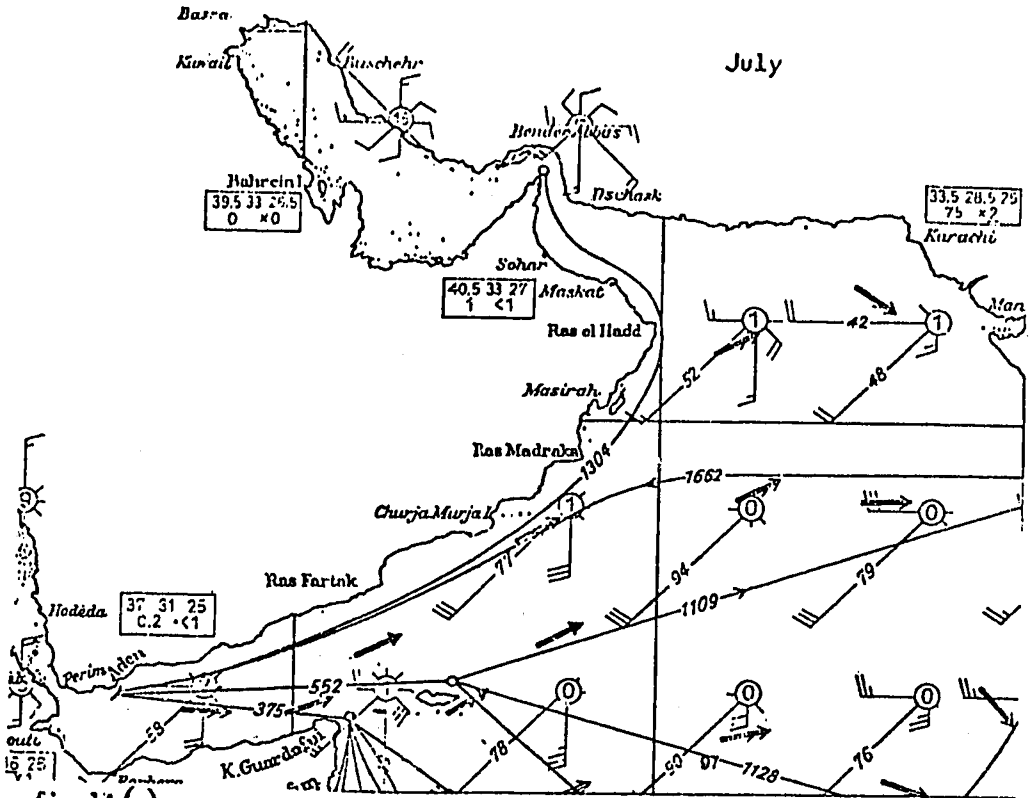

fig.14 (g)

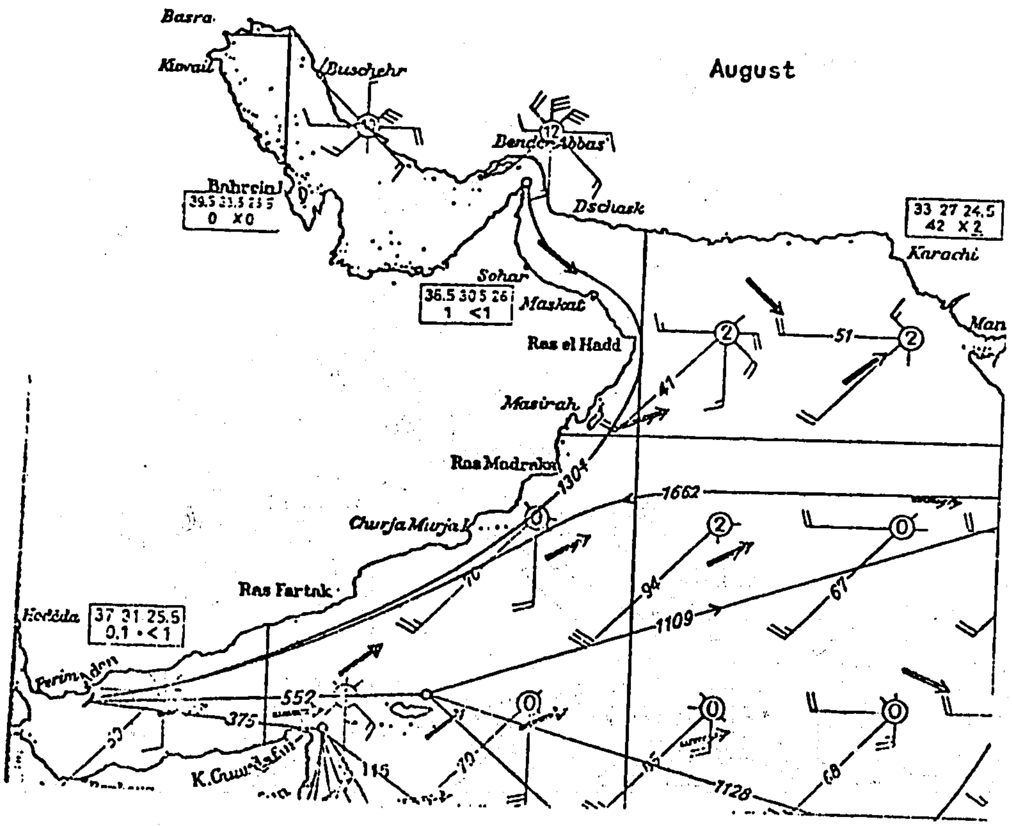

Fig. 13 (g), 13 (h) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - July, August.

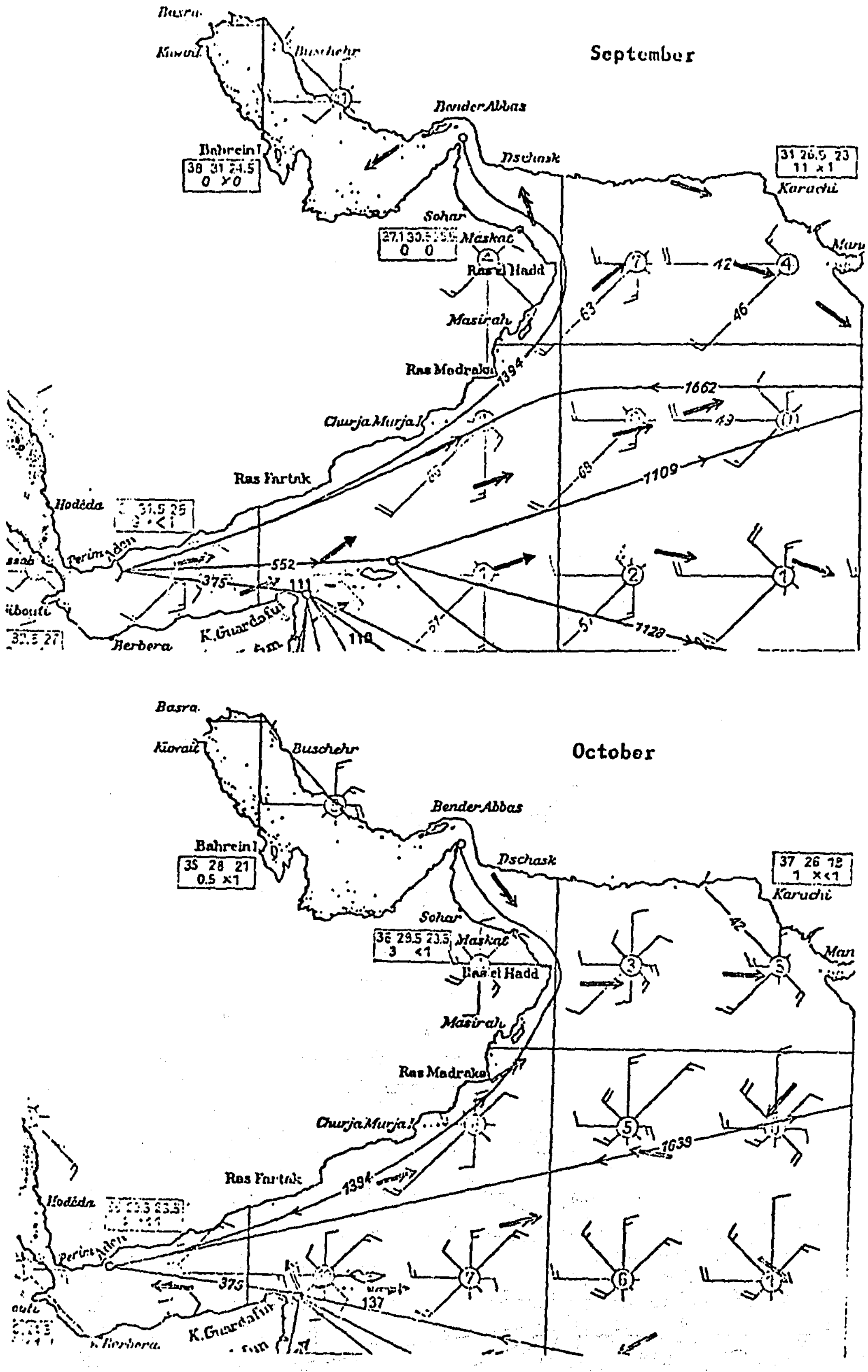

Fig. 13 (i), 13 (j) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - September, October.

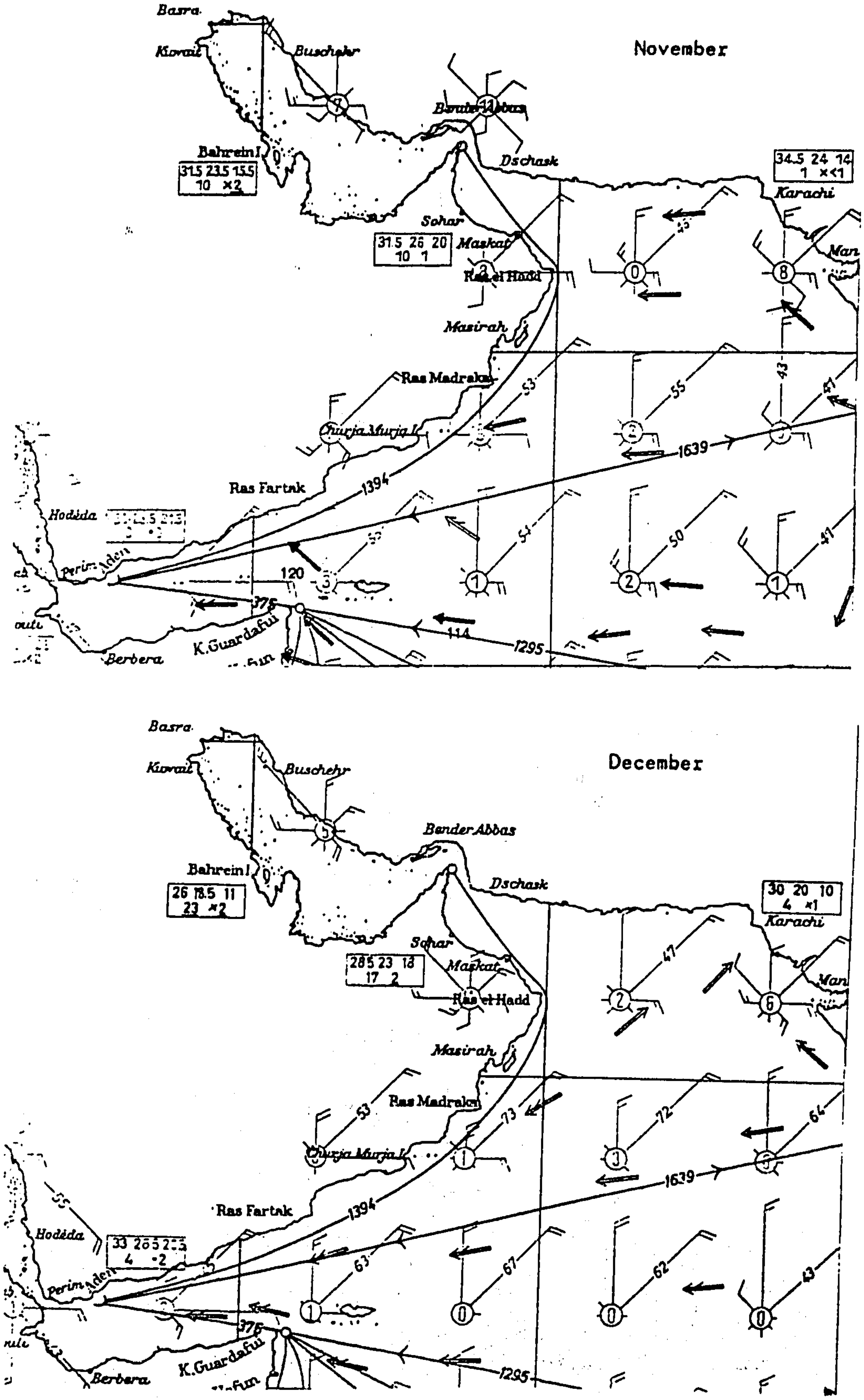

Fig. 13 (k), 13 (l) Monthly means of wind speed and direction and current speed and direction (Deutsches Hydrographisches Institut pilot charts 1960) - November, December.

APPENDIX I

LIST OF PARTICIPANTS

Consultative Meeting on Marine Sciences in the Gulf Area
Unesco, Paris, 11-14 November 1975

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APPENDIX II

SUMMARY OF RECOMMENDATIONS ON MARINE SCIENCE TEACHING AT THE UNIVERSITY LEVEL

Report of the Unesco Workshop on University Curricula*

1. The increasing demands by man on the marine environment require intensive and systematic studies as a prerequisite for a rational utilization. The acquisition of relevant knowledge in any local situation requires the availability of properly trained marine scientists, preferably of the local country or region. Training in marine sciences, including its broad requisites in basic sciences, is costly, since it necessitates not only competent teaching personnel, but also expensive equipment and facilities. Therefore, it is recommended that full-scale training only be established within countries or regions that have the potential of employing and effectively utilizing students graduating in marine sciences.

2. Where marine science training is conducted, a full department or institution should be established wherever possible, to provide identity and undertake the training of marine scientists in the four basic disciplines, i.e. physical oceanography, chemical oceanography, biological oceanography (including fisheries biology), and geological oceanography. If financial or other constraints do not make this possible initially, several alternatives are suggested :

(a) formation of a marine science department or institute consisting of a critical nucleus of scholars representing one or more fields of marine science, and at least one scientist in each of the other fields;

(b) provision of marine science education at an existing science department within the university, with participation in the teaching by scholars of other departments. In this case, one qualified marine scientist should be charged with the responsibility for the marine science curriculum within the department and the development of a broader marine science curriculum within the university;

(c) co-ordination of the academic programme in marine science through an inter-disciplinary committee, consisting of scholars teaching or concerned with marine science in the various departments.

A close liaison by means of frequent communication, consultation, and provision of facilities between governmental or other institutions in marine sciences and universities providing such education should be established wherever possible.

3. Training of professional marine scientists should begin in graduate schools and be given to students holding at least a B. Sc. degree or equivalent in one of the natural sciences. An elementary undergraduate course in marine science might be offered as an elective to both science and non-science students to demonstrate the interdisciplinary aspects of oceanography and help to create awareness of marine science and its relevancy to global environmental problems. The first graduate instruction in marine sciences should be a multidisciplinary course including physical, chemical, biological and geological oceanography. Although introductory it should be comprehensive and of sufficient substance to provide basic knowledge of these fields and emphasize interdisciplinary aspects. Specific curricula for the four basic marine science fields leading to an M. Sc. degree or equivalent are recommended and proposals are given in the report.

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*from "Marine Science Teaching at the University Level", Unesco Technical Papers in Marine Science 19, Unesco, Paris, 1974

4. Only well educated and experienced marine scientists are qualified to undertake training in the marine sciences, and only those who are themselves active in research are likely to be effective and stimulating teachers and research supervisors. The workshop therefore recommends that scientists employed as professors in marine sciences should hold a Ph. D. degree or equivalent, have research experience and teaching proficiency. The professors must not be overloaded with teaching, and facilities should be provided to enable them to participate in research cruises and to carry out research in their respective fields.

5. Marine science training of an appropriate standard requires a basic library, laboratory, equipment and ship facilities. The workshop therefore recommends that at any university conducting marine science training, provision should be made for :

(a) access to a research ship or boat equipped for training and research;

(b) laboratory space and standard equipment for conducting research in the basic oceanographic disciplines as well as means for maintenance of laboratory and shipboard equipment;

(c) a technical marine science library containing basic reference works in physical, chemical, biological and geological oceanography, and a core collection of international oceanographic journals, annual reviews, as well as abstracting and information sources.

6. The workshop found that there is a need for an introductory textbook in general oceanography stressing the interdisciplinary aspects and aimed at an appreciation of the importance of oceanography for the better use of the oceans by man. A textbook of this kind would find particularly wide acceptance as an introductory text for graduate students, if its editor and authors are recognized scientists of different countries and if it be published by Unesco. The workshop therefore recommends that Unesco, possibly in consultation with SCOR, investigates the possibility to publish such a textbook containing the following major subject matters:

(a) physical oceanography, including synoptic and dynamic oceanography and air-sea interaction;

(b) chemical oceanography, including pollution and chemical processes at the sea-bed;

(c) biological oceanography, including fisheries biology;

(d) geological and geophysical oceanography, including practical applications.

Although introductory, the textbook should be comprehensive and of sufficient substance to provide a basic knowledge of the major fields of marine science. Particular attention should be given to the selection of an outstanding editor who would ensure conformity and appropriate coverage. Furthermore, publication in other languages than English should be envisaged.

Titles of numbers which are out of stock

No.		Year	SCOR WG
1	Incorporated with Nos. 4, 8 and 14 in No. 27	1965	WG 10
2	Report of the first meeting of the joint group of experts on photosynthetic radiant energy held at Moscow, 5-9 October 1964. Sponsored by Unesco, SCOR, IAPO	1965	WG 15
3	Report on the intercalibration measurements in Copenhagen, 9-13 June 1965. Organized by ICES	1966	–
4	Incorporated with Nos. 1, 8 and 14 in No. 27	1966	WG 10
5	Report of the second meeting of the joint group of experts on photosynthetic radiant energy held at Kauizawa, 15-19 August 1966. Sponsored by Unesco, SCOR, IAPO	1966	WG 15
6	Report of a meeting of the joint group of experts on radiocarbon estimation of primary production held at Copenhagen, 24-26 October 1966. Sponsored by Unesco, SCOR, ICES	1967	WG 20
7	Report of the second meeting of the Committee for the Check-List of the Fished of the North Eastern Atlantic and of the Mediterranean, London, 20-22 April 1967	1968	–
	Procès-verbal de la 2e réunion du Comité pour le catalogue des poissons du Nord-est atlantique et de la Méditerranée, Londres, 20-22 avril 1967		
8	Incorporated with Nos. 1, 4 and 14 in No. 27	1968	WG 10
10	Guide to the Indian Ocean Biological Centre (IOBC), Cochin (India), by the Unesco Curator 1967-1969 (Dr. J. Tranter)	1969	–
12	Check-List of the fishes of the North-Eastern Atlantic and of the Mediterranean (report of the third meeting of the Committee, Hamburg, 8-11 April 1969)	1969	–
14	Incorporated with Nos. 1, 4 and 8 in No. 27	1970	WG 10