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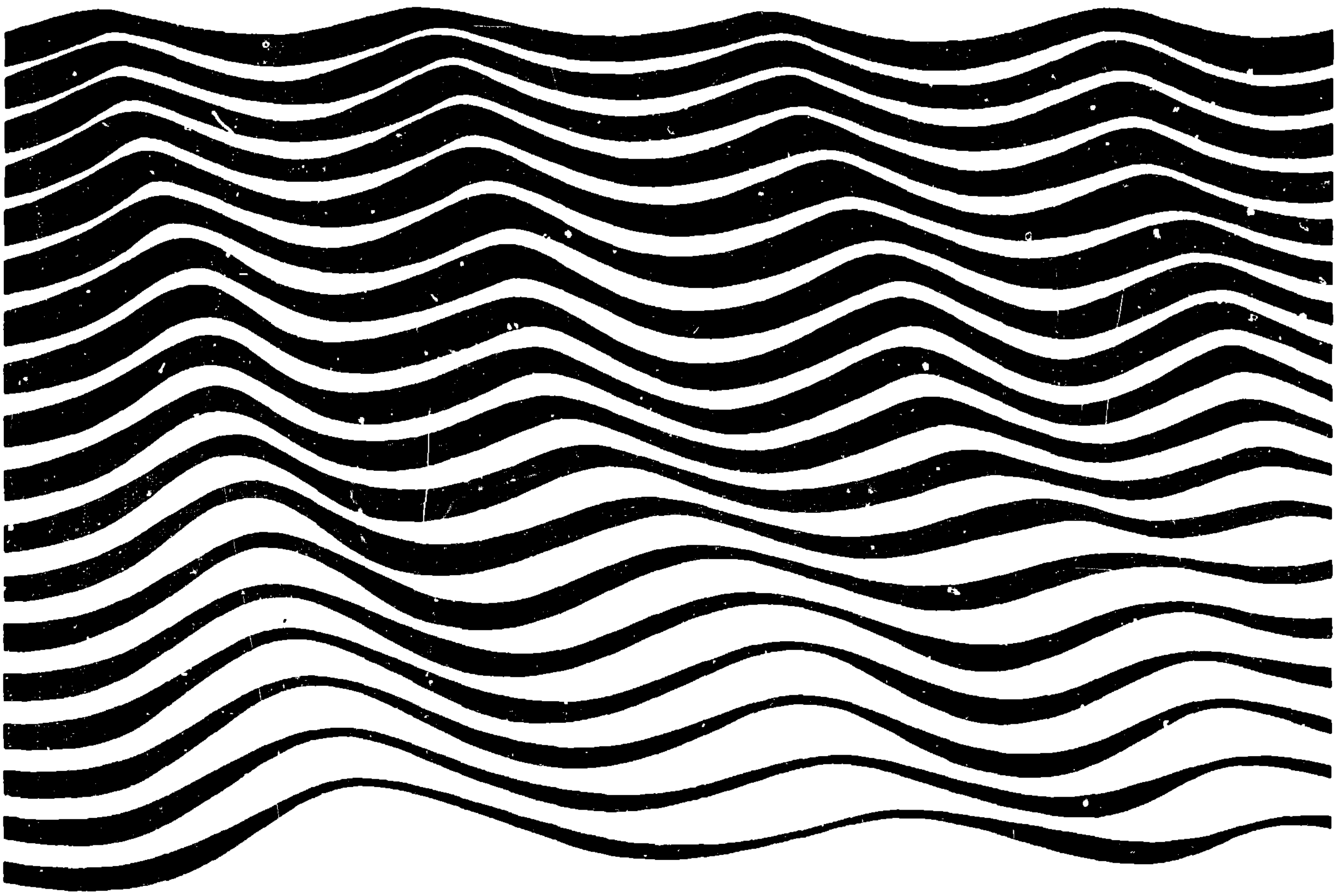
Year 2000 challenges for marine science training and education worldwide



Unesco, 1988

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No		Year
4	Syllabus for training marine technicians Report of an IOC/Unesco workshop held in Miami, Florida, 22-26 May 1978 Available in English, French, Russian and Spanish	1979
5	Marine science syllabus for secondary schools Report of an IOC workshop held at United World College of the Atlantic, United Kingdom, 5-9 June 1978 Available in Arabic, English, French, Russian and Spanish	1979
6	Organization of marine biological reference collections in the Mediterranean Arab countries Expert meeting held in Tunis, 20-23 September 1978 Available in Arabic, English and French	1979
8	The mangrove ecosystem: Human uses and management implications Report of a Unesco regional seminar held in Dacca, Bangladesh, December 1978 English only	1979
9	The mangrove ecosystem: scientific aspects and human impact Report of the seminar organized by Unesco at Cali, Colombia, 27 November-1 December 1978 Available in English and Spanish	1979
10	Development of marine science and technology in Africa Working Group of Experts sponsored by ECA and Unesco, Addis Ababa, 5-9 May 1980 Available in English and French	1980
14	Marine science and technology in Africa: present state and future development Synthesis of Unesco/ECA survey missions to African coastal states, 1980 Available in English and French	1981
15	Fishery science teaching at the university level Report of a Unesco/FAO workshop on university curricula in fishery science, Paris, May 1980 Available in Arabic, English, French, Russian and Spanish	1981
19	Mareas rojas en el Plancton del Pacífico Oriental Informe del Segundo Taller del Programa de Plancton del Pacífico Oriental, Instituto del Mar, Callao, Perú 19-20 de noviembre de 1981 Spanish only	1982
20	Quantitative analysis and simulation of Mediterranean coastal ecosystems: The Gulf of Naples, a case study Report of a workshop on ecosystem modelling Ischia, Naples, Italy, 28 March to 10 April 1981 Organized by the United Nations, Educational, Scientific and Cultural Organization (Unesco) and the Stazione Zoologica, Naples English only	1983
21	Comparing coral reef survey methods. A regional Unesco/UNEP workshop, Phuket Marine Biological Centre, Thailand, December 1982 English only	1983
22	Guidelines for marine biological reference collections Prepared in response to a recommendation by a meeting of experts from the Mediterranean Arab countries Available in English, French and Arabic	1983
23	Coral reefs, seagrass beds and mangroves: their interaction in the coastal zones of the Caribbean Report of a workshop held at West Indies Laboratory, St. Croix, U.S. Virgin Islands, May, 1982 English only	1983
24	Coastal ecosystems of Latin America and the Caribbean The objectives, priorities and activities of Unesco's COMAR project for the Latin America and Caribbean region Caracas, Venezuela, 15-19 November 1982 Available in English and Spanish	1983
25	Ocean engineering teaching at the university level Recommended guidelines from the Unesco/IOC/ECOR workshop on advanced university curricula in ocean engineering and related fields, Paris, October 1982 Available in English, French, Spanish, Russian, Arabic and Chinese	1983
26	Global survey and analysis of post-graduate curricula in ocean engineering English only	1984
27	Productivity and processes in island marine ecosystems. Recommendations and scientific papers from the Unesco/IOC sessions on marine science co-operation in the Pacific, at the XVth Pacific Science Congress, Dunedin, New Zealand, February 1983 English only	1984
28	Oceanographic modelling of the Kuwait Action Plan (KAP) Region. Report of simposium/workshop. University of Petroleum and Minerals, Dhahran, Kingdom of Saudi Arabia 15-18 October 1983 English only	1984
29	Eutrophication in coastal marine areas and lagoons: a case study of 'Lac de Tunis' Report prepared by Dr M. Kelly and Dr M. Naguib English only	1984
30	Physical oceanography of the Eastern Mediterranean: an overview and research plan Report of a workshop held in Lerici, La Spezia (Italy), September 1983 English only	1984
31	MABAHISS/John Murray 50th anniversary: Marine science of the North West Indian Ocean and adjacent waters Report of a symposium on the occasion of the 50th anniversary of the MABAHISS/ John Murray Expedition (1933/34), University of Alexandria, Egypt, 3 to 7 September 1983 English only	1985
32	L'estuaire et la mangrove du Sine Saloum Résultats d'un Atelier régional Unesco-COMAR tenu à Dakar (Sénégal) du 28 février au 5 mars 1983 French only	1985
33	Coral taxonomy Results and recommendations of a regional Unesco (COMAR)/ UNEP Workshop with advanced training Phuket Marine Biological Centre Thailand, 10-26 February 1984 English only	1985
34	Bibliography on costal lagoons and salt marshes along the Southern Mediterranean coast (Algeria, Egypt, Libya, Morocco, Tunisia) Available in Arabic, English and French	1985
35	Physical oceanography of the Eastern Mediterranean (POEM): A Research Programme. Reports of the Organizing Committee Meeting, Paris, August 1984, and the Scientific Workshop, Lucerne, October 1984 English only	1985
36	Méthodologie d'étude des lagunes côtières. Résultats d'un atelier régional réuni à Abidjan du 6 au 11 mai 1985 French only	1986
37	Principles of Geological Mapping of Marine Sediments (with special reference to the African continental margin) Available in English and Russian	1986
38	Marine Sciences in CMEA countries Programme and results of co-operation Available in English and Russian	1986
39	Development of marine sciences in Arab Universities Meeting of Experts held at the Marine Science Station Aqaba, Jordan, 1-5 December 1985 Available in Arabic, English, French	1986
40	Human induced damage to coral reefs Results of a regional Unesco (COMAR) workshop with advanced training Diponegoro University, Jepara and National Institute of Oceanology Jakarta, Indonesia May 1985 English only	1986
41	Caribbean coastal marine productivity Results of a Planning Workshop at Discovery Bay Marine Laboratory, University of the West Indies Jamaica, November, 1985 English only	1986

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PREFACE

Unesco Reports in Marine Science are designed to serve specific programme needs and to report on developments in projects conducted by the Unesco Division of Marine Sciences, including those involving collaboration between the Division and the Intergovernmental Oceanographic Commission.

Designed to serve as a complement to the *Unesco Technical Papers in Marine Science*, the *Reports* are distributed automatically to various institutions and governmental authorities. Individuals may, at their request, receive copies of specific titles, but cannot be included on the automatic distribution list. Both the *Reports* and the *Technical Papers* series are free of charge.

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ABSTRACT

In a survey preparing for the workshop on future marine science training and education, prospective participants returned responses to six theme questions. These responses summarized the views of nearly 400 people worldwide. The synthesis of these summary responses, presented in the report, reflects, besides a great variety of views, agreement on the needs for an interdisciplinary approach to teaching, training and research; for a solid, broad foundation in basic sciences; and for regard to the cultural context, especially in countries with limited marine science capabilities.

Working group discussions during the meeting (Paris, 6-10 June 1988) concerned main issues in (i) research; (ii) industrializing coastal states, especially small islands; (iii) economic and social potentials; (iv) sustainable development and management; (v) data management and information acquisition; and (vi) continuing education and retraining. Recommended guidelines concern specialist training as well as general marine science education, and cooperative assistance to countries with limited marine science capabilities.

Three special problem areas were identified: (i) basic knowledge for management of the coastal zone and its resources; (ii) primary and secondary education; and (iii) national, regional and international information networking. Introductory presentations included in the report deal with progress in selected fields, e.g. ocean and climate, marine biotechnology, remote sensing, and with regional perspectives.

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EXECUTIVE SUMMARY

I. GENERAL RESULTS

The purpose of the activity was to consider future education and training required towards addressing marine science and technology questions and problems in various key areas. The workshop's guidelines and recommendations were prepared by 25 invited participants in marine science and ocean engineering from 17 countries and three organizations. The guidelines and recommendations in this report form a basis for orienting institutional and international education and training programmes to respond to future needs.

The Introduction Chapter summarizes the rationale and the preparatory and organizational details of the meeting. Prospective participants were involved at an early stage in preparing for the workshop by seeking from and through them responses on six theme questions. A Synthesis was prepared on the basis of the summary responses received (presented in the subsequent Chapter). A consistent feature of the responses was reference to the necessity of an interdisciplinary approach to teaching, training and research in marine sciences. Of the 28 summary responses analyzed-reflecting the views of nearly 400 people worldwide - a great majority made specific, and usually repeated, reference to this point. In the remaining responses, it usually was implied. Another common feature of responses was that a solid, broad-based education was preferred for basic education in marine science. The need for teaching the teachers was also signalled by a fair number of respondents.

In the Synthesis, several respondents with developing countries' needs in mind make the point that education and training must be adapted to the appropriate cultural context in which marine science is to be conducted. Concern is evident about shortages of funds for marine science, and about the general lack of understanding of marine science by the public in general and by policy-makers in particular. These problems are seen to result largely from a difficulty of the marine science community to communicate well with these groups.

The Chapter on Working Group Results provides the results and recommendations of the six working groups that were set up during the workshop on : I. research; II. developing coastal states with special reference to small islands; III. economic and social potentials; IV. sustainable development and management; V. data management and information acquisition; and on VI. continuing education and retraining. Each working group identified specific problems and needs in its area of concern and made proposals and recommendations for action, accordingly. Those that do directly concern education and training broadly fall into three categories: A. marine science specialist training; B. general marine science education; and C. educational techniques. An important general category of proposals and recommendations concerns: D. the cooperative assistance required by countries with limited marine science capabilities. Details on these four categories are summarized in section II below.

The working group on research concentrated on general approaches applicable to all areas of marine science education and training. It recommended an increasingly multidisciplinary approach; greater access for students to computers; training in modelling, remote sensing, mathematics, statistics and English; the establishment of communication and information networks also using electronic mail; training of qualified technical support staff; offering introductory marine science courses to all first degree students; using marine parks and reserves as teaching laboratories; and attention to climate change aspects, to taxonomic heritage and to the role of ultraplankton and gelatinous organisms in the marine food web.

The second working group recognized that needs of developing continental coastal countries are in general comparable with those of small island nations. Nevertheless, small island communities face particular problems in view of the large economic zone relative to the land mass and population size. This requires a regional sharing of teaching, training and research resources and infrastructure in order to tackle urgent problems such as coastal pollution, erosion, management of living resources and development of non-living resources. Particular attention should be given to enhancing communication and information exchange among islands on one hand, and with other parts of the world on the other. Distance teaching was considered of particular relevance to island communities. The relevance of traditional knowledge and management practices was emphasized.

The working group on economic and social potentials considered these in the framework of uses, assessment of impacts, supporting technologies and marine regional planning. Most potentials were believed to already exist in one form or the other and to be intensified due to increasing use of marine living and non-living resources and amenities. Education in marine science-based topics was seen as required at all levels (primary, secondary, tertiary), and for generalists as well as specialists in view of the great diversity of potential uses of the sea and the complex management requirements.

The remaining three working groups are referred to in section II below.

The Chapter on Special Problem Areas presents three transversal problem areas that appeared in the deliberations of all or most of the working groups, and which the workshop recommended be given special attention: A. basic knowledge for the management of the coastal zone and its resources; B. primary and secondary education; and C. national, regional and international information networking.

Recommendations made by the workshop for the overall follow-up on the results of the meeting are given in the last Chapter.

II. TRAINING AND EDUCATION RESULTS

A. MARINE SCIENCE SPECIALIST TRAINING

Many new subject areas need incorporation into the marine science curricula and others need greater emphasis in order that marine science be more responsive to future marine-related problems. Such subject areas include: modelling theory and techniques; remote sensing; climate change impacts; traditional marine knowledge and management practices; deep-ocean resources; and data management and information acquisition. The latter subject area was considered in detail by one of the working groups, whose recommendations concern, among other: fostering awareness on existing exchange systems and historical datasets; the setting up and searching of databanks; the need for a reference to existing services, networks and databases; the evolving role of librarians; and the potential of taxonomic expert systems in the light of decreasing expertise in species identification.

More general curricula items that require attention concern the multi-disciplinary nature of marine science, and the importance of: mathematics and statistics; fluency in English; qualified technical support staff; dialogue among marine scientists, planners and decision-makers; field, shipboard and relevant work experience; communication skills; outside instructors, e.g. from industry; and continuing education and retraining. The working group that considered the latter item, drew attention to the needs of professionals with marine science training as well as of personnel not trained as marine scientists or engineers but involved in marine-related affairs. The continuing education needs of teachers and trainers themselves require particular attention.

Participants agreed that educational and training activities need to be specifically addressed to improve basic knowledge in order to develop a basis for effective coastal area and resource management. While a steadily increasing number of programmes now addresses such management, significant deficiencies remain with regard to education, teaching and training. The working group on sustainable development and management gave particular attention to the this subject area. The group identified training needs concerning: coastal processes; disruption of coastal equilibrium; land-sea and ocean-atmosphere interactions; water pollution and management. It recommended, among others, the establishment of coastal zone management and planning courses in university curricula.

B. GENERAL MARINE SCIENCE EDUCATION

Teaching and training in marine science throughout the world is mainly offered at the university level. In many, if not most countries, however, there is little or no general recognition of the influence of the oceans on all people, wherever they might live. There is a critical need that the general public understands the necessity for marine research and the conservation and management of living and non-living marine resources. The introduction and strengthening of marine science at the primary and secondary education levels, at the post-secondary level for non-marine science students and through non-formal public education, may be a critical factor for the future health of the marine environment and the sustainable development of its resources. Skilled marine scientists and engineers have an important role to play in this respect.

C. EDUCATIONAL TECHNIQUES

A number of recently developed techniques were cited as important in future marine science training and education, especially in view of the increasingly complex knowledge to be imparted to marine science students, and of the need to educate more people at different levels, as described above. Such techniques include computer-aided learning and expert systems, remote sensing imagery, distance teaching, and multi-media learning packages. Instruction using such techniques was seen as complementary to using more traditional methods. Participants emphasized that practical training at sea, in the laboratory and in the library (training through research) is a particularly important part of any marine science curriculum. Marine parks, aquaria and museums have a useful role to play in training specialists and educating the general public. Networking arrangements would allow the sharing of training and education experiences and facilities.

D. COOPERATIVE ASSISTANCE

Workshop participants reiterated the concern expressed in several of the responses summarized in the Synthesis Chapter about the gap between countries and regions having limited and those having advanced capabilities for the acquisition of marine science data and information - a gap which is widening due to rapid developments in marine science technology in general and in computer and information technology in particular. Ways and means should be considered by international organizations, donor governments and the scientific community to step up the assistance to institutions and countries for the establishment and strengthening of marine science infrastructures in general, and of systems for exchange of marine science information at the national, regional and international level, in particular.

The establishment of national and regional networks among institutions and scientists for cooperation and for information exchange was seen as particularly useful in promoting marine science development.

Other needed forms of support include assistance with institutional build-up, for instance through affiliation between institutions in countries with different levels of advancement in marine science; equipment provision, etc. Areas for which training needs were identified include data management, exclusive economic zone-related matters, mariculture techniques, marine regional planning, and equipment handling and maintenance.

INTRODUCTION

I. BACKGROUND

Training and education are essential to the development and application of knowledge on the marine environment and its resources. It is mainly through the prerequisite of training and education of scientists and technical support staff that marine research can be undertaken and the results added to the body of knowledge necessary for proper understanding and decision-making concerning the marine and coastal environment and resources.

Over the past several decades, there has been rapid development and growth of marine science and its applications with respect to subject matter, sophistication and people. The marine science and technology community is estimated to be ten times larger now than it was some 15 years ago. Studies of the deep sea, coastal processes and climate-related events, to name just a few examples, have accelerated in response to improvements in knowledge and research techniques. Recent technological advances, notably in electronics, remote sensing and computers, are changing the way marine research is carried out. The measure of the resulting scientific contributions to applications is best judged from the high volume of current marine resource exploitation and management activities like mariculture, ocean engineering, marine fisheries, pollution control, etc.

As a consequence, teaching and training programmes in marine science, in related sciences and in ocean engineering need continual adaptation and updating in order, on one hand, to incorporate the new knowledge and technology, and on the other hand, to keep abreast of the changing potentials concerning (i) marine resource exploitation and (ii) the impact of human activities upon the marine environment. This is all the more important in view of the additional responsibilities that coastal nations are assuming under the new ocean regime.

There are two Unesco approaches: direct training of specialists through formal teaching and research, and strengthening of the training tools and infrastructures. In the first approach, Unesco has provided many hundreds of international fellowships and training grants in marine science since its inception forty years ago. Evaluations were made of the marine science fellowship and grant programme for the 1950-1975 and the 1976-1985 periods, which confirmed the essential contribution of the programme to marine science development in many parts of the world.

While instruction abroad is important, up-to-date in-country teaching and training is essential, which requires a relevant local infrastructure. Thus as part of the second approach, a number of workshops have been organized since 1973 on university curricula, such as on postgraduate marine science training (1973), on fisheries sciences (1980), on ocean engineering (1982), and on first degree marine science training (1986). The results of these workshops have been published as recommended guidelines to allow for adaptation to local priorities and needs. Workshops on marine science in universities of particular regions have also been held in order to foster regional cooperation in teaching and training. A number of extra-budgetary projects have been executed over the years to strengthen university marine science teaching at the national institutional level, for example in Burma, Iraq, Mexico, Qatar, Thailand, Turkey and Uruguay.

II. OBJECTIVES AND GOALS

The present workshop, convened at Unesco Headquarters from 6 to 10 June 1988, was planned to: (i) provide guidelines and recommendations to universities, educational authorities and decision-makers on orienting teaching and training programmes to respond to future needs, and (ii) provide a common basis for the long-term marine science training and education programme of Unesco and related programmes of other organizations.

The participants agreed upon the following three goals of marine science training and education - to:

1. Provide a core of trained professionals and technical support staff equipped by knowledge and experience, which would:
   i. perform basic and applied research in the marine environment;
   ii. supply high quality marine training and education to students;
   iii. supervise marine conservation, protection of the marine environment, and management of marine resources;
   iv. initiate and facilitate marine science, technology and other related studies;
   v. plan, design and undertake marine resource exploitation and development projects.

2. Establish continuing education and training for both professional and support staff in order to maintain and enhance the quality of their expertise and to satisfy individual aspirations.

3. Increase the availability of marine knowledge, and to promote its dissemination among all people, so that decision-makers, teachers and others can better understand and appreciate the relevance and value of the marine environment and its resources to national goals and international affairs, and hence the need for their wise use and planned management.

The period initially under consideration - until the year 2000 - was considered a relatively short one. The scientists and decision-makers of the early part of the next century will be those that are trained now and in the coming years. Therefore, the workshop expanded its deliberations to include marine science training and education for the early part of the 21st century.

III. THEME QUESTIONS

The following six theme questions were posed to the participants prior to the workshop. Their purpose was to stimulate thinking on areas of major relevance to the future of marine science education. A synthesis of the ideas and comments brought forward by this process is given in the following Chapter.

1. What new occupational areas that require exclusive or partial expertise in marine science can be foreseen as developing towards the year 2000? What areas will significantly decrease in importance?

2. What key knowledge and skills will be required at that time and how will these differ from today's?

3. Will the university teaching methods used to impart the knowledge and skill change? If so, how? How can developments in technology improve the methods to acquire knowledge and skills for those having finished their formal education? What will be the roles for distance learning and computer-based instruction? How can methods be adapted to deal with the enormous growth in information and specialization?

4. What are and will be the main obstacles to applying such instructional methods, particularly in countries developing their marine science capabilities, and what is needed to overcome them?

5. What will be and should be the main similarities and differences in educational requirements in marine science between regions and countries? What will this mean for national teaching and training programmes? Taking into account certain negative impacts of the international development strategy of the 70s and 80s, what experiences from countries with a long tradition in marine science teaching and training are and will be relevant for countries developing such capabilities and vice versa?

6. How can marine science teaching and training be made more effective in achieving the perceived goals for the state of the environment and the management of marine resources for the year 2000 and beyond?

IV. ORGANIZATION AND STRUCTURE

The above theme questions were sent to the majority of the invited participants eleven months prior to the meeting with a request to return responses within eight months. Consultations on the questions and responses with colleagues and other qualified people at home and abroad were strongly recommended. They turned out very widespread, involving nearly 400 people active in the various marine science and technology disciplines in academia, government and industry, in all parts of the world. Summary responses to the theme questions were received from and distributed to the participants prior to the meeting.

The synthesis of the summary responses (as given in the following Chapter) and a list of key discussion items distilled from them, were made available to the participants at the start of the workshop to facilitate discussions, especially in the various working groups.

Six working groups were set up during the workshop on: I. research; II. developing coastal states with special reference to small islands; III. economic and social potentials; IV. sustainable development and management; V. data management and information acquisition; and on VI. continuing education and retraining. They were asked to respectively address the following areas:

1. What main questions in basic research are facing marine science? What education, training and techniques towards solving these problems are required? By and for whom? What new approaches are needed?

2. What marine science problems are faced by small island communities? What education, training, techniques and information (including on traditional knowledge and management practices) are required? By and for whom? What new approaches are needed? What should be the balance between the training of local communities and the calling upon outside expertise in order to address the problems faced?

3. What economic and social potentials are available or most promising in marine science and ocean engineering, e.g. new or changing uses of the sea, new products from the sea, new genetically modified marine organisms, implications of molecular biology, etc.? What education, training and information are required? By and for whom? What new approaches are needed?

4. What main scientific problems for the sustainable development and management of the coastal zone, the oceans and their resources are facing the marine science and ocean engineering community and the decision-makers? What education, training, techniques and information towards solving these problems are required? By and for whom? What new approaches are needed? To what extent should marine policy, ocean management and similar concerns be considered?

5. What major problems in data management (e.g. quality control, storage, processing, access) are facing the marine science and ocean engineering fields? What education, training and techniques towards solving these problems are required? By and for whom? What new approaches are needed?

6. What lifelong/continuing education and retraining needs are facing the marine science and ocean engineering community? And how best to satisfy these needs? What bodies of knowledge and skills can be usefully translated into interactive training software or other instructional packages? How best to promote and arrange their production and distribution?

The first three working groups met concurrently during two half-day sessions with assigned participation for the first session only. The second three working groups met subsequently in a similar way. Participants considered that marine science problems faced by small islands are similar to those faced by developing coastal states, which is reflected in the title and results of the second working group. In a similar vein, information acquisition was also considered by the working group on data management and is reflected in the title and report, accordingly. The results of the working group discussions are given in the Chapter following the Synthesis.

These working group results together with the synthesis of the summary responses constitute the primary output of the activity. While the summary responses were synthesized, the working group reports were not in order to maintain the workshop specificity. The differences in the working group reports reflect the differences in subject matter and approach of each group. Some overlap inherently occurs as a result of the working groups having dealt with overlapping problems.

Ocean engineering (cf. Unesco, 1983) was included in several of the above-mentioned working group discussion areas. The participants agreed with the following statement in Unesco report in marine science 45 (1987a): "In a general sense, engineering is regarded as a branch of science. However, marine science and ocean engineering tend to be considered as separate but closely related, mutually supportive fields. The separate identification of the two fields should not obscure their interlinked continuity." At the same time, the participants considered that the ocean engineering expertise at the workshop was too limited to adequately cover this field, especially taking into account the forward looking character of the meeting.

The keynote address of the workshop was given by Dr J. Baker, Director of the Australian Institute of Marine Sciences. The address is given in Annex 1.

Five introductory presentations concerned the recent and projected progress in selected fields as follows : ocean and climate (by Prof. R. Stewart); coastal engineering (by Prof. A. Watanabe); Third World fisheries (by Dr D. Pauly); marine biotechnology (by Dr M. Walch); and remote sensing (by Dr I. Robinson). Summaries of these presentations are given in Annex 2.

Three introductory addresses on regional experience and problems in relation to the subject matter were presented by Prof. Wang Pinxian, Prof. S. Diop, and Dr W. Hunte. Their presentations are summarized in Annex 3.

Annex 4 contains the descriptions of the four demonstrations given at the workshop on: computer-assisted training in marine remote sensing (by Dr I. Robinson); computer(with videodisk)-assisted learning (by Dr A. Edwards); marine affairs instruction at the World Maritime University (by Prof. A. Couper); and computer modelling of pollution input into the North Sea (by Prof. J. Backhaus). The above-mentioned and several other computer-aided and video-assisted learning materials are included in the references and selected bibliography (Annex 6).

The present report reflects the fine efforts and long working hours by all participants, who are identified in Annex 7. The Chairman, Dr A. Richards, and Vice-chairman, Prof. J. Castilla, provided expert guidance to the meeting. The Rapporteurs, Drs T. Hopkins and G. Baines, and the secretarial staff of the Unesco Division of Marine Sciences ensured the compilation and preparation of the draft summary report. Clarification of several topics, which could not be adequately discussed during the workshop because of time constraints, and preliminary editing was authorized by the participants to be undertaken at a subsequent two-day session by Drs G. Baines, A. Richards and D. Troost. Prof. Castilla was to have joined this group, but logistic problems precluded his participation. Final editing was done by Dr D. Troost, with contributions from Drs T. Hopkins, D. Krause and A. Richards. Ms C. Williams and Ms M. Kravetz worked diligently to enter on word processor the many corrections to the text.

SYNTHESIS OF SUMMARY RESPONSES TO THEME QUESTIONS

I. GENERAL POINTS

A total of twenty-eight responses was received from the invited participants and a few other scientists in Australia, Barbados, Canada, Chile, China, Egypt, France, F.R. Germany, India, Italy, Japan, Mexico, Netherlands, Philippines, Senegal, Solomon Islands, Sweden, United Kingdom, Union of Soviet Socialist Republics and the United States of America. Many consulted widely with colleagues before preparing their responses. In total, nearly 400 individuals worldwide contributed to the exercise.

One particularly interesting collective response was collated through the recently formed Network of Tropical Fisheries Scientists (NTFS). This involved over 130 individual responses and, since most of the NTFS membership is made up of young scientists from countries with limited marine science capabilities, it is particularly relevant. Even so, it must be noted that the NTFS membership consists exclusively of fisheries scientists and so represents a particular subset of the marine sciences. This collective response, not being included in the present synthesis, is attached as Annex 5.

The responses contained a great deal of valuable information and ideas. The greatly varying styles of presentation, however, did not make it easy to bring them all together. The inevitable overlapping of subject matter between the six theme questions also has meant that many respondents sometimes were not able to adhere closely to the requested format.

II. OCCUPATIONAL AREAS

The first theme question posed was:

What new occupational areas that require exclusive or partial expertise in marine science can be foreseen as developing towards the year 2000? What areas will significantly decrease in importance?

One respondent provided a broad categorization of occupational areas:

- basic research;
- academic instruction;
- data storage and management;
- marine science application;
- marine science management.

This theme question was interpreted by respondents in a variety of ways: as areas of professional occupation and/or as areas of research involvement. Few new "areas" were indicated. The main response was to list existing occupational areas which are expected by respondents to become more important by the year 2000 or which respondents feel should be stressed in relation to their own particular research and/or management preferences. As far as the matter of a decrease in the importance of certain occupational areas is concerned, many respondents were not prepared to "write off" any area of marine science.

Occupational areas seen as developing (listed in random order):

- coastal zone management;
- marine park management;
- fisheries management;
- marine resource management, planning;
- information management;
- mariculture of macro- and microflora and fauna;
- environmental toxicology;
- pollution monitoring and control;
- biological and microbiological control and treatment of marine pollutants;
- tourism -- surface and submarine;
- marine archaeology;
- coastal engineering;
- submarine engineering;
- administration and management of offshore engineering projects;
- seabed geological survey;
- offshore mining -- shallow water and deep seabed;
- development of new products of marine origin;
- marine veterinary science;
- marine pathology;
- diving physiology and technology;
- remote sensing interpretation and application;
- information science and technology;
- marine electronics applications;
- meteorology and climatology;
- materials science;
- marine pharmacology;
- marine biogeochemistry;
- marine species taxonomy;
- marine law;
- maritime geography;
- marine survey;
- waste disposal management;
- environmental assessment and protection;
- coastal and ocean administration.

Those who did venture to suggest areas where a decline in importance might be expected included the following:

- fishermen and seafarers;
- traditional fisheries;
- descriptive marine ecology, biology, oceanography;
- classical methods of reducing oceanographic data;
- whaling.

In one case, concerning the until now largely neglected area of coastal and ocean administration, it was argued that:

> "Few governments have moved far towards catering for this need. There will be considerable costs in resource waste, environmental damage and political dispute by the year 2000 if conscious and determined efforts are not made to develop effective administrative systems and to train and teach those who are to operate them."

> "Administration of the coastal zone is made especially difficult by split and overlapping administrative responsibilities. Yet the physical and environmental problems of the coastal zone are fast increasing as more coastline is engineered, and as population pressure intensifies - be it the developing world's pressure of increasing numbers, or the pressure of developed country affluence as more people seek to spend more time and money at the coast. As sea-level rise begins to exacerbate these problems, public and political awareness of the need for more rational administration of the coastal zone must increase, making this a key new occupational area - coastal and ocean administration, requiring supportive training in marine science."

A few respondents raised a need for individuals with multiple skills. Referring to a management context one wrote:

> "There will probably be more emphasis on multi-skilled personnel, e.g. navigational (sic) combined with engineering..."

This was seen to be connected with the prospect of routine transfers of personnel between sea and shore duties, as from sea surveillance, mapping to shore management and traffic control.

The same respondent went on to state:

> "...in addition to specializations in, say, biology, surveying, engineering, navigation, economics...there is the need for additional subjects which will serve to integrate the marine and human ecology involved in coastal and offshore activities."

III. KEY KNOWLEDGE AND SKILLS

The theme question asked was:

What key knowledge and skills will be required at that time (year 2000) and how will these differ from today's?

There was widespread agreement among respondents that, as with the present, future work in marine science will require a solid basic foundation in the traditional science subjects of zoology, botany chemistry, physics, geology, and mathematics. Some would see molecular biology as becoming, by then, one of these basics. And, it was widely recognized that an interdisciplinary approach to education in these basics would be necessary.

Respondents' choices for knowledge and skills deemed important for the year 2000 included:

- artificial intelligence;
- communication skills;
- numerical modelling skills;
- computer literacy;
- information management and transfer;
- interpretation and application of remotely sensed data;
- taxonomy invoking interdisciplinary skills;
- mariculture;
- marine microbiology;
- genetic engineering/biotechnology;
- ecological processes;
- nature and consequences of environmental change;
- restoration/rehabilitation ecology;
- ocean-atmosphere interactions;
- role of the sea-surface layer;
- predictive/forecasting techniques;
- offshore and deep-sea engineering;
- submarine technology;
- materials for ocean engineering;
- hindcasting of climate, sea levels;
- sublethal effects of pollutants;
- traditional knowledge of coastal communities;
- marine resource and environment economics;
- geographics.

In considering how the knowledge and skills needed for the year 2000 would most differ from those used today, respondents remarked on:

- expected massive increase in data;
- imperative for improved technology and methodology for data storage and access;
- the need for marine scientists to have a greater range of computer skills;
- better modelling;
- better understanding of techniques for manipulation of remotely sensed data and its combination with traditional types of data.

An unusual source of knowledge was identified:

"An area of marine science knowledge which has been largely ignored, because unrecognized, is that of traditional societies. This is knowledge which, though largely empirical, has developed through scientific methods of observation, and of trial-and-error experimentation, and now is contained within a cultural knowledge complex in which science and non-science are closely intertwined. A great range of knowledge is available from this source - on fish behavioural ecology, fish schooling behaviour, species taxonomy, subsurface wave motions, and weather indicators, to name but a few.

However, it is not an easy task to elicit that aspect of traditional knowledge which is of value for marine science."

On the need for improved communication skills one respondent wrote:

"Successful management requires effective communication across disciplinary and specialist boundaries. Marine science curricula need to embrace communication skills. Not only should this be done in a formal context - an atmosphere of communication, of tolerance, understanding and cooperation needs to be provided. Past experience indicates that this will not be easy."

Particular reference was made to communication with traditional informants:

"If useful marine knowledge is to be obtained from traditional societies then special skill in communicating with traditional informants is needed - and the approach must be that of partnership between scientist and informant. The best use of this traditional knowledge is in combination with the knowledge derived from modern marine science - using environment and resource management knowledge developed through centuries of experience, and strengthening that with the refinements and insights of modern science."

IV. TEACHING METHODS

The first part of theme question 3 was presented as:

Will the university teaching methods used to impart the knowledge and skill change?

Though specific reference was made to "university" education, most respondents dealt with teaching in a somewhat wider sense. Some saw great scope for the more widespread use of modelling as a future teaching method as, for instance:

"In this context the scientific and technological development in modelling plays an important role. It allows the study of a combination of processes but also of isolated phenomena. This separation, which can provide a deep insight into marine processes and their interactions, usually cannot be achieved solely from observations. Therefore, models offer a great potential as valuable didactical tools to study and explain complex phenomena..."

Inevitably, all respondents made reference to the increased scope of computer-assisted learning (CAL) in the future and to the increased sophistication of the visualization and other techniques which are to become more widely available.

"It must be recognized that personal computers will progressively become a standard part of the student kit, complementing the pen, pencil and paper of former times."

The same respondent however, also stressed that:

"At all levels of education it is agreed that the temptation to use only electronic media as a teaching method should be avoided and that personal interaction between teacher and student be retained at all levels."

This important point was echoed by many others.

A need for greater flexibility in study programmes was expressed by a number of respondents. Among suggestions for accommodating this need were:

"...extend the practice of several American institutions where certificates are given for courses taken after a specialist degree...one may obtain a higher degree in an area of specialization and extend interdisciplinary knowledge by undertaking specific certificate courses in a continuing training programme and/or in the - generally accepted as essential - retraining periods."

"Simulations...may be particularly important in achieving an understanding of the interactions of marine phenomena and economic activities, and the consequences of planning and management decisions relating to environment and society."

"...the teaching of scientific and technical personnel should be combined to a certain extent. This would mean that basic courses are attended by both groups...a common background is important for cooperation in professional life. With increasing level of sophistication the teaching system should allow for "exits" into professional life on several levels. The decision as to what group one would belong can be made during the education and not at its beginning."

It was also pointed out that:

"With the presence of these computer-aided learning techniques more of the formal teaching will be done outside the classroom and instructor time can be used for "hands-on" demonstrations."

This points to a need to consider the further development of teaching methods in practical aspects such as instrument calibration and maintenance, sensor deployment, etc. Teaching methods are also expected to have to change in order to address the need to:

"clarify concepts and express them in alternative ways so that they can be made clear to people with different approaches and styles of thinking."

V. TECHNOLOGY FOR POSTGRADUATE LEARNING

The question raised in this context was:

How can developments in technology improve the methods to acquire knowledge and skills for those having finished their formal education?

It was generally believed by respondents that technology available for formal education was adequate for "postgraduate" learning. The question did, however, give rise to useful ideas for techniques which are particularly suited to this advanced aspect of learning. For instance, the simulation technique:

> "...is regarded as particularly important in the resource management field where an integrated approach is essential. The students are placed in various situations and have to adopt different roles dealing with issues which require an integrated approach but have no easy answers."

And an interesting example of interactive education being developed in the USSR appears particularly well suited to this category of educational need:

> "... a computer-based instructing and controlling system for marine seismo-acoustic investigations is worked out. Its conditional name is an "electronic professor". The geophysical mapping of continental margins is known to need an accurate selection of working characteristics. At the first stage an operator puts in the computer the main parameters of the mapping - a required penetration of seismic waves and depths of water, characteristics of bottom relief, measuring precision, oceanological situation, etc.
> The computer gives the main technical parameters of the work (required length of a seismic array, a main frequency of the sound source, an impulse period and source power, optimum vessel velocity, etc.). The operator may ask the computer concerning any technical parameter and receive a complete answer with graphical examples. In the case of an operator error or of a parameter change in the course of the work independently of the operator, the computer immediately reacts to indicate an error."

Such a system is said not only to give good results irrespective of the level of training of the technical staff operating it but use of the system involves continuous learning by the operator, so raising his competence and understanding.

VI. DISTANCE LEARNING

The responses here are based on the theme question:

What will be the roles for distance education and computer-based instruction?

While bearing in mind that "enhanced learning will still rest with the individual", as one respondent expressed it, several individuals saw a definite future for distance learning:

"Although some regard distance learning with some suspicion...there is general agreement that provided the recipient of the distance learning has had the benefit of sound basic training and also has the opportunity for periodic refresher courses, then distance learning and computer-based instruction will become important components of education in the future."

"Distance learning will help the general public to acquire a better understanding of marine sciences and a proper recognition of the importance of the oceans."

"A global system of distance learning supported by satellite communication techniques will be needed to meet the principle of equal opportunity for knowledge, information and technology among developed and developing countries."

His extensive experience in distance education led one respondent to comment:

"Distance learning and computer-based systems must concentrate on development of interpretive skills, as data and information are nowadays readily available." and "Distance learning is inefficient and ineffective without good infrastructure, a "pacing" system of assessment, and a good tutorial back-up, whether by person r computer-based systems."

A few respondents remarked unfavourably on the subject of distance learning, as for instance in:

"...the role will be minimal. This is because it takes a very dedicated student to use the methods effectively. Direct teaching methods were strongly preferred."

This response implies that there is a choice. For some situations there is not - as among the widely scattered, low population island nations of the Pacific:

"In the Pacific island region, at least, distance learning using satellite communications technology has proven effective. What began as an experiment in education 17 years ago is now entrenched as the fundamental basis of tertiary education for 54% of the University of the South Pacific's enrolment. The learning links are not only with the ten decentralized USP (University of the South Pacific) extension centres, but also with individuals and institutions of the Pacific Rim. In this way a considerable educational resource is available."

VII. COMPUTER-AIDED LEARNING (CAL)

Among respondents none questioned that computer-aided learning (CAL) would feature strongly in marine science teaching and training for the year 2000. Many useful points were made, not only about the exciting opportunities opening up through this technology but also concerning the caution to be adopted in achieving a proper balance between CAL and other approaches - not forgetting the cardinal principle that personal student-teacher interaction must not be displaced.

One respondent provided a very useful set of basic points regarding CAL as related to the theme questions:

- "CAL is a suitable medium for teaching in *some* subject areas;
- Over the next 20 years the provision of *intelligent* CAL will improve and increase, offering better quality teaching in more areas;
- Interactive video offers some new teaching opportunities, but is by no means a universal medium;
- CAL is one medium which fits well with distance teaching methods, and distance teaching is an attractive way to deliver in-service training;
- Computer-based simulations can be used to teach about processes which are difficult or dangerous to teach directly;
- CAL material *can* be written such that it adapts to individual learners, though in practice this flexibility is often limited;
- CAL is a complement for teaching by people, it cannot be a replacement;
- The production of CAL material is very labour intensive and expensive;
- Over the next few years there will be an increasing shortage of courseware authors (who are essentially specialist programmers);
- Difficulties in communication between educators and courseware authors is a serious obstacle to efficient courseware production;
- Presentation of CAL is expensive since each student must have access to hardware;
- The distribution of CAL material is inexpensive;
- Development and distribution of CAL courseware (and other forms of software) is retarded by lack of standardization of hardware

and software."

Among the various roles for CAL which were mentioned by respondents:
- data accessing;
- data analysis, especially sequence searching and structure searches;
- visualization;
- modelling.

"In particular the intelligible display and visualization of observational as well as modelled data by means of high resolution screens and digital video techniques offers a wide range of didactical possibilities. Complex functional relationships can be visualized by means of a computer-aided display in order to promote understanding while avoiding confusion."

"Models are almost the only tools to condense, analyze and assimilate the enormous amount of observational data which in particular is or will be provided in the near future by satellites. Nowadays the development and the application of advanced models does not depend anymore on the availability of a powerful and expensive mainframe computer. The increased availability of very powerful and inexpensive desktop computers, which already have the same potential as existing mainframes, will certainly allow for a broader and more efficient use of modelling. It will even be possible to take models at sea and to run them for the (online) support and interpretation of field observations on board a research vessel."

VIII. HANDLING INFORMATION

The theme question:

How can methods be adapted to deal with the enormous growth in information and specialization?

"This is not a problem only for marine science", pointed out one respondent, it affects all areas of knowledge. Marine scientists should therefore search widely for ideas on dealing with this problem.

The multiplicity of approaches to data gathering, data storage, analysis and access were identified by many as a key problem. There were few answers, however. The developing CD-ROM technology was viewed with hope. This will vastly increase the capacity for storing data (though in a form which, according to the present "state-of-the-art" can be once "written to" and thereafter many times "read from") but will heighten the need for better access, standardized analysis, etc.

Some saw an easing of the problem through wider and more efficient use of electronic networking, the visualization of data using graph processors, and the establishment of regional databases and referral centres. Another was more specific:

> "The World Data Centres and the designated National Oceanographic Data Centres should become more active and easily accessible to users. Efforts should be made to link up data acquisition with the Data Centres..."

From a Third World perspective a thoughtful point was raised:

> "Impressive information networks exist in the developed world and in theory they could be used by developing country scientists. Nevertheless that does not occur, either due to lack of funds, knowledge, hardware or other. Local and regional networks should be established first. Otherwise the use of larger information networks - from where most of our locally generated information is excluded - will occur to an extremely low speed and profit. Horizontal communications come first. As the situation stands now, a totally vertical (developed -developing countries) system is trying to impose itself. This is a critical point for the year 2000."

Another idea put forward:

> "Libraries will play an essential role to filter out essential relevant information for scientists...In this sense libraries will become a tool, like computers, and will enable scientists to devote their valuable time to the "real" scientific work and not to the increasingly difficult task of searching and selecting relevant information. Professional organizations will provide library personnel with information on:
>
> - marine information systems and products;
> - how to set up and run marine libraries and information centres, on cooperation, on network development and interaction with international systems, on how to build up local capabilities and how to provide general and specific services;
> - technical aspects of database creation and exchange of bibliographic records, input preparation for local, regional and international information systems;
> - methods of information analysis and synthesis, and dissemination of information products."

From the teaching viewpoint another respondent made a proposal regarding the duration of marine science courses;

> "Faced with the challenge of ensuring both a sound basic instruction in the traditional scientific subjects and the necessary specialization in one or more marine-related disciplines, together with the challenges of meeting an enormous increase in information availability, it is recommended that marine science curricula should be one year longer

than basic science curricula."

IX. OBSTACLES TO IMPROVEMENTS

The fourth theme question was worded:

What are and will be the main obstacles to applying such instructional methods, particularly in countries developing their marine science capabilities, and what is needed to overcome them?

In summary, the obstacles identified by respondents are:

- shortage of funds for teaching and research;
- shortage of trained personnel;
- low salaries for staff;
- lack of access to the technology necessary for training;
- weak technical support infrastructure;
- barriers between disciplines;
- inadequate telecommunications links;
- resistance to innovation in long-established educational institutions;
- increasing capability and decreasing prices of computer technology encourages educational administrators to "wait and see";
- the problem of allocation of scarce computer technology among students;
- shortage of textbooks in languages other than english;
- shortage of good teaching software;
- multiplicity of computer languages and systems;
- limited number and availability of research and training vessels;
- the high costs of marine research and its relatively low budgetary priority;
- shortage of "generalists" able to apply the results of specialist research;
- limited regional and international cooperation;
- lack of innovation in curriculum development;
- poor public appreciation of ocean resources and environment;
- serious shortage of trained and experienced instructors for the development of CAL software;
- rapid obsolescence of computer technology;
- relatively small number of teachers and researchers with the necessary ability to promote interdisciplinarity, and foster an integrated management approach.

One respondent's notes on problems faced in countries in the process of developing a marine science capability were:

"In developing countries overpopulation of the educational system will continue to hamper progress...(and) this progress cannot be dissociated from progress in basic scientific culture and technological skills."

"The interaction between the socio-economic setting and the permeation of scientific culture will remain the key to progress in developing countries. (and) Language also remains one of the main obstacles to progress in marine science in these countries."

A most interesting example of the effects of economic development philosophy on the development of a marine science capability was provided by one respondent in these words:

"China, for example, used to offer rigid and narrow specializations in marine and other sciences teaching and training at the first degree level - what was suited to the centralized planned economy in the country. With the development of a commodity economy the jobs will be no more directly assigned by the governmental administration to the graduates but the employers will accept graduates only according to their own needs. Thus the narrow and rigid specialization in marine science training will be replaced by degrees with broader scope and greater flexibility so that the graduates will be adapted to jobs in marine-related as well as non-marine occupational areas. The relevant marine-specialized departments and colleges will accordingly revise their scope and direction."

The same respondent proceeded further on a related theme:

"The adoption of "open policy" in more and more countries will lead to strengthening of international cooperation in marine sciences at a regional or global scale which in turn will provide an ideal opportunity for personnel training...It can be foreseen that towards the year 2000 more and more countries will develop their marine science capabilities and, being not satisfied with the current practice of training marine science experts abroad, will make efforts to establish local training with support by international collaboration, particularly by countries with a long tradition in marine science."

How, through teaching and training, can those countries with a well developed marine science capability best assist others? This question emerged implicitly from the responses as one of the more critical for the year 2000 - and some marked differences of view were revealed.

Comments from respondents from countries with a developed marine science capability included:

"Most developing countries are best served by local marine education programs through the baccalaureate level and that graduate training should be at a regional or foreign center."

"The ways of solving these problems may be the training of specialists abroad, the purchase of equipment and instruction programs abroad, the close scientific contacts with countries leading in this area, the invitation of specialists from abroad for teaching, etc."

"Developed countries should provide the educational base for foreign students. It is unlikely that developing countries will be able to organize the sophisticated educational and instrumental facilities required by the year 2000." and

"The developed countries in general have more trained personnel...and may offer training programs, but the mere existence of a trained person does not guarantee translation of skills and information to another country. Selection of personnel for training of people from developing countries requires very careful consideration of personality, communication skills, empathy and commitment to the long term involvement in marine science education."

"Developing countries may be able to learn from the experiences of more advanced countries because of the basic similarities of problems confronted. They may find it profitable to closely follow the example/procedures of an established institution in a developed country."

On the other hand, those responding on behalf of those who might seek assistance in the establishment of a capability in marine science said, among other things:

"Unless there is a striking change in policy within the majority of developing countries the lack of national commitments to support and encourage the development of adequate infrastructures in marine affairs will remain a major deterrent. For example, it does little good to produce marine scientists in national environments which are non-supportive."

"Overall, a lack of confidence from international agencies about capabilities in marine sciences in the third world countries. Most of them are always concerned with the number of "experts" that should be incorporated in a particular project. In my experience, these experts often increase budgets and usually do not solve the problems under study...it is almost impossible to include local people. A critical approach is needed...seek problem areas, look for the existence of local teams and do not impose foreign experts unless the leaders of the projects do need them."

"A major frustration in attempts to bring economic development benefits to the general population of developing countries is the external orientation of those countries' foreign educated elite. Wherever practicable, marine science education should be provided in a socio-cultural setting approximating that of the developing country students' own."

Another obstacle identified was:

"Underdevelopment of ocean-related business and enterprises. They should be developed, possibly by introducing international joint venture projects, in order to attract investment from abroad, to encourage capable young fellows and to establish a basis for marine science."

A number of respondents offered suggestions for overcoming the obstacles to the effectiveness of improved instructional methods:

"make teaching and training materials available in more languages."

"teacher workshops and resource centers in key regions of the world."

"international teaching and training centres and overseas study programmes...to acquire knowledge and skills but also to gain a better mutual understanding."

"a lack of intellectual stimulation and a sense of mission in those involved in marine science...Unesco may contribute...by setting up regional research centres."

"efforts must be directed at increasing public awareness of the relevance of marine science to the welfare of mankind."

"governmental willingness...can be stimulated by frequent and effective public relations activities of the national marine science community; how to do this could be part of a teaching/training programme."

"the software problem can be approached by emphasizing the possible marine science applications of readily available utility software (i.e. databases and spreadsheets); funding of program development projects; and survey, cataloging and sharing of information on current uses of computer technology by marine science educators."

"Too many people from developing countries have been trained in developed countries only to return to their own countries and be transferred from a marine science teaching environment to an administration position which has no marine component...it is generally agreed that government to government agreements on training may be more effective in the long term..."

With reference to the "scatter" of teaching and training resources it was suggested that:

"There would appear to be merit in considering the establishment in each country of a relatively few centres of excellence which would be guaranteed to maintain staff and facilities of the highest level. With this concentration...there should be no discouragement of...other teaching institutions which would access the centres of excellence as major resource facilities. Each centre of excellence in each country would establish its own specific range of skills and knowledge, adjusted to local needs and also provide the necessary facilities for training and retraining of educators from other institutions."

X. DIFFERENTIAL REQUIREMENTS

Theme question 5 was worded:

What will be and should be the main similarities and differences in educational requirements in marine science between regions and countries? What will this mean for national teaching and training programmes? and

Taking into account certain negative impacts of the international development strategy of the 70s and 80s what experiences from countries with a long tradition in marine science teaching and training are and will be relevant for countries developing such capabilities and vice versa?

The words of one respondent fairly well sum up the views of the majority:

> "There must be a common core of knowledge and understanding. The basic principles of marine science are international and must be properly taught. The basic principles in turn must be applied to regional/local projects and problems."

> "Marine scientific research and development is universal in its application subject to local needs and variations. Educational patterns should be tuned to the needs of the country. As an example, Japan is very highly dependent on fishery wealth of the ocean and therefore they have a very strong fisheries educational programme. India, in view of its interest in mining manganese nodules and krill resources, should gear its educational programmes to train manpower for exploiting the above resources."

Another respondent felt that:

> "The main similarities in educational requirements...should be common access to the major data-bases, a sound basis of core subjects followed by the specialist training necessary to give the emphasis to the marine environment, the provision of continuing education facilities such as short course and refresher courses and the use of research information as the teaching base."

and that:

> "The differences will result from the educational philosophies of the different countries and their national priorities."

He also maintained that:

> "...a vast number of the developing countries lie within the tropical regions and much of the accumulated knowledge of marine science has been developed in temperate waters. There is a need for a stronger information base on tropical marine systems."

From his colleagues, one respondent received three different views on teaching and training for countries in the process of building up their marine science capability:

> "...countries and regions differ substantially in their level of scientific development but this should only mean that, in less developed areas, there is a need for more basic training, using simplistic approaches..."

> "...at the graduate level the most important requirement is to complete a good research project, publishable in an international journal after peer review....no need for national teaching programs, and developing countries should not attempt to create marine science educational programs - it being more useful for students to get an undergraduate degree in the developing country in the basic sciences and then go to a developed country to get a higher degree."

> "...it is necessary to have a fit between the needs of a developing country, its programs of research and the teaching and training programs."

The point made, above, about an emphasis on simple technology for certain stages of the development of marine science capability was taken up by others:

> "teaching should focus on local or regional needs using the knowledge and technologies locally available."

> "for many countries of the developing world it is appropriate to emphasize the less complex technologies for marine science research and monitoring. A great deal of good and scientifically valuable data can be obtained with relatively simple methods backed, where needed, by the more sophisticated. Extensive data coverage can more readily be obtained in this way, the "rough" results being calibrated against more precisely measured parameters."

The importance of being aware of, and of understanding, cultural differences when attempting to transfer teaching and training ideas from the cultural context in which they were shaped, to another, was highlighted by some respondents:

> "...(basic) marine science education should be provided in a socio-cultural setting approximating that of the developing country students' own."

> "One of the most serious problems is that marine geopoliticians, administrators and teachers from the (developed) countries have too little knowledge of local culture, lifestyles and needs in the (developing) countries; consequently they often try to force upon others research and teaching methods that may have incompatibilities."

> "Attention should also be paid in technology transfer and training programs to differences in national characters, customs, traditions,

academic standard, national goals."

"...it is important to recognize the different cultural backgrounds of the people concerned and it is important that the improved scientific training does not destroy the cultural heritage."

One respondent pointed out that:

"...unlike the transfer of technology, organizations, administrations and human resource management skills will transfer less well. Teachers have to be able to adapt models and cases, and to teach relevant environmental and social impact assessment techniques in sympathy with local conditions. Transfers of "western" models, or the creation of scientific institutions divorced from the socio-economic problems, and the techniques and knowledge of the local maritime societies, are likely to be defective in obtaining many worthwhile results in the wider field of EEZ planning and management."

On the ecological differences between cooler and warmer areas of the marine environment the following was stated:

"There is a distortion in the approach to marine science problems, caused by the geographical location of developed countries in temperate and colder regions. Developed countries obtained understanding of marine science from *low diversity* environments; developing countries are mostly located in *high diversity* environments - with the exception of tropical upwelling areas."

Another respondent had touched on one of the "distortions" arising from this important distinction:

"There is a presumption by some developed country institutions that they can educate and train students in tropical marine resource management in temperate area classrooms near temperate coastlines. This is, to say the least, unreasonable. Education and training in marine resource management must be related to the ecological and social circumstances in which it is to be undertaken. Developed country institutions should heed the calls for "north-south" cooperation by seeking supportive partnerships with developing country institutions rather than acting so as to supplant those institutions. Through such partnerships the undoubted talent and tropical experience of some developed country institutions can be applied meaningfully, using the tropical area facilities of a developing country institution."

XI. EFFECTIVE MARINE ENVIRONMENT AND RESOURCE MANAGEMENT

The sixth and final theme question was presented as:

How can marine science teaching and training be made more effective in achieving the perceived goals for the state of the environment and the *management of marine resources for the year 2000 and beyond?*

Overall, most emphasized the need for a greater public awareness of the increasing importance of the marine environment and its resources for society at large. Improved awareness was seen as the key to greater commitment by governments and international organizations.

> "In the longer term sound management of the marine environment depends on an educated community in which all members understand the importance of a mix of conservation, development and wise utilization of natural resources."

A global perspective was implicit in most responses. Some were specific about this:

> "The world-wide concept of the ocean environment and marine resources as common property should be first established."

> "The science community needs to develop and nurture an ocean ethic that views the oceans as a resource in need of our stewardship and not simply a commodity."

This leads to the subject of the extensive ocean resource management obligations of the *Law of the Sea Convention*, to which little reference was made by respondents. One did implicitly raise the matter of section XIII requirements of the Convention for permission for research inside exclusive economic zones, referring to the fact that:

> "Increasingly a demand is voiced in favour of the principle of "open skies" for satellite data and information. In some countries, on the other hand, it is becoming more difficult for one nation's scientists to obtain permission from another national government to do ship-based research in its EEZ. There is a need for ocean policy shared by all countries."

One way of easing the suspicions which some countries harbour about research may be through what one described as:

> "Increased international cooperation, not least by inviting Third World scientists to participate in major projects and cruises, to acquire hands-on experience of new technology and approach and build this into their own programmes."

Further reference was made to the new law of the sea regime in terms of:

> "Traditionally, many foreign nations have exploited waters which now come under control of relatively small and developing countries which cannot themselves exploit the marine resources. It is important for the future security of the countries concerned that management skills are developed to allow sound negotiation on rights with more powerful international partners and that the strategies of management of marine

> resources be developed on the basis of mutually agreed conditions between different countries."

Though the need for greater public awareness was referred to, there was little elaboration, except for this statement, drawing on some of the findings of the World Commission on Environment and Development (1987):

> "The extent to which local community participation in marine environment protection and resource management can be fostered will be a significant factor in determining the quality of the marine environment and the availability of marine resources in the year 2000."

WORKING GROUP RESULTS

I. WORKING GROUP ON RESEARCH

A. INTRODUCTORY STATEMENT

It was not considered wise, or even possible, to attempt to list all research topics which will be of importance in the year 2000 and beyond. Other documents exist which cover this ground; for example, many themes are listed in the IOC/Unesco "Ocean sciences for the year 2000" (1984) and in the referenced publications listed in Annex 6. It was considered more productive and useful to concentrate on those general approaches appropriate for a variety of research fields. Because of this approach, only a few instances have the "by and for whom" statement, given in the terms of reference, been specifically addressed.

The worldwide climate for research is largely determined by shortage of government funds and by a marked interest of the private sector in funding only marketable research (as opposed e.g. to setting up foundations or chairs). This shortage certainly is related to the perception of politicians and administrators that many scientists, claiming to conduct "basic research", produce very little. Overcoming this situation implies making preparation of publications an explicit part of scientific education and training. This also implies recognition that the much-cited evils associated with the "publish or perish syndrome" are localized phenomena connected with particular modes of research funding and university faculty promotion in certain countries and that not publishing enough is the more widespread problem in many regions.

B. MAJOR AREAS OF CONCERN

Problem 1: How to deal with the multidisciplinary nature of marine science?

Education and Training Recommendations: It was agreed that a balance in education is required. Students should become thoroughly competent in their specialized disciplines as well as have access to multidisciplinary marine science courses. Because marine science is multidisciplinary by nature, efforts should be made to provide students with the elements needed to develop a common scientific language in marine science, facilitating a broader understanding and/or the interchange of information, and to permit specialists in one discipline to understand the problems and capabilities of other disciplines.

Research institutes should be structured so as to bring professionals in different disciplines into close working contact, so that they may become acquainted with one another's problems, provide mutual aid in problem solution, and be able to transfer this expertise to students.

Other Recommendation: It is recommended that establishment of multidisciplinary laboratories, departments and institutions be encouraged so that disciplines can be integrated for research activities, for graduate activities or for both.

Problem 2: How to deal with the appropriate use of computers in research and education?

Comments: There was agreement that computers will be used increasingly in the education of marine scientists and technologists. This will be promoted by at least three factors: i) increased use of computers as a basic tool in marine science, ii) a projected shortage of skilled teachers, and iii) increased requirement for in-service continuing education.

The major priority will be to ensure that students have full access to computers, for all forms of use. There will be a trend towards more use of computer-aided learning, which will be to a greater degree independent of human teachers. Whether computer-aided learning which is entirely autonomous is likely or desirable, could not be determined by the working group participants.

It was agreed that in the year 2000 and beyond, marine scientists will be making increased use of expert systems, and educators should be aware of this. However, it is difficult to predict what form this will take. In light of experience of expert system development thus far, which generally has not measured up to expectations, caution was advised.

While the construction of expert systems will certainly be important in the future, it was felt that knowledge engineering itself should be left to the knowledge engineers and not be a part of marine scientist's education.

Recommendations: Students should have full access to computers, and use should be made of computers in education and research. Computer-aided learning and the use of expert systems should be phased in as appropriate. Scientists however should be encouraged to participate wherever possible in developing, setting up and making operational such systems.

Problem 3: How to deal with models and modelling?

Comments: The use of models as both a learning and research tool has expanded tremendously in the last two decades and we see no reason for the expansion to abate. A prognosis of the state of the art by the year 2000 would be clearly beyond the scope of this workshop. However, the utilization of models in marine science has reached such a level of maturity and sophistication that we can confidently say that it will likely permeate all aspects of marine research and training by the year 2000 and thus merits a particular emphasis.

It should be pointed out that a wide range of techniques are implied by our reference to the use of models in marine research and that within this range could be found a modelling technique suitable to nearly any research problem or facility. For example, holistic models (constructed from observed effects) are much less costly and require only hardware simpler than that needed for mechanistic models (constructed from formulation of component processes) which require very large computer resources. These distinctions, in addition to reviews and applications of models in marine ecosystem, can be found in Unesco Division of Marine Sciences publications (Platt et al., 1981; Hopkins et al., 1983) and in scientific journals.

One of the hazards of the increased research potential offered by models is the increased difficulty to evaluate and understand the results. There is the potential that model output will be more credible than the real world simply because it is more accessibly formatted and often appears more comprehensive in coverage. This tendency generates a greater need to educate the general audience to whom the model results are directed and it is up to the researcher who has authored the model to convey the uncertainties and errors of the modelling technique that accompany the model results.

Recommendations: That modelling theory and techniques be incorporated into the basic marine science curriculum, including specialized subjects, as appropriate according to the disciplines offered, e.g.:

- the interfacing between databases and models;
- the use of large global models as input data to local models;
- the use of conceptual modelling for marine science research management;
- training in current software packages as data processing tools;
- adaptation of packaged "ecosystem" or "circulation" models to specific marine zones;
- respective course material in the basic disciplines.

That those professions that interface with researchers producing models, receive some educational exposure to modelling technology in their respective curricula.

That models be recognized and utilized as an important educational tool, for example, to demonstrate cause and effect relationships, non-linear feedback loops, sensitivity analysis, etc.

Problem 4: How to deal with the fact that some disciplines in marine science traditionally have not used much mathematics or statistics?

Recommendation: The teaching of mathematics and statistics at an appropriate level for quality research is recommended for all marine scientists and technologists including marine biologists, chemists and geologists.

<u>Problem 5</u>: How to deal with the lack of communication and transference of information related to research - at the national, subregional and regional levels, in several areas in the world?

<u>Comments</u>: Close interdisciplinary collaboration and cooperation among different institutions, both within countries and within regions or subregions, can be a powerful and efficient networking tool. This will include: information and scientific documentation exchange (particularly of that which is not covered in existing databases); cooperation in joint research programmes; integration of different research methods; and intercalibration exercises.

<u>Recommendation</u>: The establishment and/or reinforcement of regional or subregional networks is recommended which will serve, among other aims, as catalysts to reduce the problem of scientific isolation and, at the same time, to promote scientific publications of local or regional interest and international value.

<u>Problem 6</u>: How to deal with (i) the "information explosion" and (ii) the need for scientists to actively *use* the literature generated by their colleagues and predecessors, rather than be overwhelmed by it?

<u>Comments</u>: Publication of original research is an obligation, and knowledge of past work is a necessary part of research. Most recent literature in science and technology is in one or more literature databases, and some relevant databases presently are available on CD-ROM. Examples of these are: Aquatic Science and Fisheries Abstracts (FAO), which cover both living and non-living resources, as well as some ocean and coastal engineering and policy issues; and the science citation index of the Institute of Scientific Information. Other literature databases may soon be available in this format.

<u>Recommendation</u>: It is recommended that financial and other support be given to institutions which intend to produce or to acquire CD-ROM disks for the purpose of making or facilitating printouts of literature searches at low or no costs to users without access to electronic networks, databases or adequate library facilities.

<u>Problem 7</u>: How to deal with electronic networking?

<u>Comments</u>: Communication among scientists and engineers within a country is not always easy. Between individuals in different nations communication is even more difficult. There is an increasing need for communication among working scientists and with administrators in governmental and non-governmental bodies, such as Unesco, FAO, etc. and SCOR, ECOR, etc., respectively. Modern information technology (computers, telecommunication

and office automation) provides a solution to this problem. Already, existing electronic networks link scientists and engineers not only within a country but also with their colleagues in other countries. This can be done in a number of ways. The first way is through electronic mail, or e-mail, to individual electronic mailboxes and to have electronic bulletin boards to which messages can be addressed on specific marine science and technology subjects. This modern way of exchanging information often is much more convenient than using the post, telex, courier, etc.

The second way is to use facsimile (also called telefax or fax) machines. Now that internal and external fax attachments can be added to a personal computer, coupled to a telephone line by a modem, the means exist to compose messages in a word-processing programme and to transmit them in a digital format to a remote fax machine or to a computer that also has a fax attachment.

Recommendations: Recognizing that there are a number of e-mail systems serving the world, that commercial and society systems exist and that Unesco has a specialized type of e-mail system for communication within Unesco and to Unesco field offices, Unesco is requested to study the situation and to make recommendations to universities, research organizations, national centres and others involved with marine research regarding the advantages and disadvantages of each, as to whether the existing Unesco system can be extended conveniently and economically to other users and to whether the system is likely to satisfy all of the needs normally covered by commercial or society systems.

It is also recommended that Unesco determine the availability of the EARN communication system understood to be available to Unesco and to universities in many parts of the world and to provide information about who should be contacted to obtain information about EARN and the use of the EARN system.

Problem 8: How to deal with information technology?

Comments: All marine scientists, engineers and administrators throughout the world require timely information of all types, together with ease of internal and external communications among individuals and organizations. A knowledge of the relevant aspects of information technology, or the use of computers, telecommunications and - to a certain extent - office automation, is essential for the understanding and efficient management of information.

Recommendation: That Unesco establish pre-eminence in information technology for the purpose of providing information in this subject necessary to educators and administrators in the parts of the world where it is difficult to obtain expert information of this type.

Problem 9: How to deal with remote sensing?

Comments: There are many ways to observe the marine environment remotely. Satellite images are increasingly common and useful to show static conditions, such as major tectonic features, seamount distribution, etc., as well as dynamic conditions, such as temperature distribution, the spread of hydrocarbon spills, etc. Remote sensing from aircraft is also well established using colorimetric, electromagnetic and many other types of sensors. In addition, other types of remote sensing are being used from ships, buoys, etc. Also, many research institutions already routinely use remote sensing displays to assist in making decisions concerning research ship deployment.

Various means of remote sensing presently are available, and other methods are likely to become available in the near future. It is essential that present and future training and education in marine science and technology introduce to all students the methodology, advantages and disadvantages of remote sensing in general, and specific types of remote sensing that can be used for investigations of problems that would be difficult to study by other means.

Recommendations:

To universities and educators - to introduce remote sensing into marine science and technology curricula.

To Unesco - to investigate, in close collaboration e.g. with ICES, IOC and others, the most effective way to convey information on present methods, applications and availability to the marine science community as well as marine science requirements to the satellite operators and remote sensing data holders.

To scientists and engineers - to use remote sensing imagery wherever practicable in teaching undergraduate and postgraduate courses.

Problem 10: How to deal with the fact that such a large proportion of the world's scientific literature is written in English, most international meetings are conducted in English and English fluency may be deficient for the performance of quality research?

Comments: Instruction in written and oral English to the level of fluency - although there is little concern about accent or oral grammar provided that speech is understandable and receiving ability is high - is required by all professional scientists and engineers. Language instructors, using language laboratories if necessary, who know at least some of the specific technical language can be very helpful to increase English knowledge.

Widely used materials, such as elementary textbooks and a few classical papers, should be translated into languages in which there are numerous readers. However, professionals must recognize that English has become the *lingua franca* of science and technology and they must learn to use English if they are not to be left aside.

Recommendation: Linguistic pride should be set aside by marine scientists and technologists for the sake of effectiveness. As a corollary, it is also recommended that native English speakers should recognize that they will be better accepted if they learn *some* other language.

Problem 11: Instrumentation and supporting staff may be deficient in quantity and quality to undertake quality research.

Comment: In recent years, there has been an enormous increase in the use of sophisticated equipment and instruments in marine scientific research and development. These include electronic systems and automated data acquisition and processing equipment. How do we ensure the proper maintenance of these systems and equipment? It is absolutely essential to train technicians for maintenance and repair of the equipment used in marine scientific research.

Recommendation: It is recommended that Unesco assist in training technicians for support of marine scientists and engineers, if appropriate, through networking. Their salaries and opportunities may also need to be made attractive. Such technicians should be exposed to general knowledge of marine science, so that they may better understand and appreciate the work they are doing in the furtherance of marine scientific research.

Problem 12: Marine science education for non-marine scientists.

Comments: It is important that all undergraduates have the opportunity to be exposed to marine science at an introductory level. In universities where there are marine science educators, courses of this nature have proved to be extremely popular and they provide the students taking them with an important background knowledge of oceanography, which enriches their knowledge of the world. This may encourage students to enter marine science as a career. There are, however, many educational establishments where there are no marine scientists prepared to offer such courses. They should be encouraged to develop an introductory ocean science course. The means to do this requires further consideration, but it might include the sharing of teaching resources and the establishment of networks in which marine science departments can support the teaching of courses in universities where there is no marine science department.

Recommendation: Wherever possible, marine science courses at non-specialist level should be made available to students, even in universities which do not specialize in the subject.

Problem 13: How to deal with anthropogenic changes in the marine ecosystem?

Comments: Human beings have been using and modifying marine ecosystems for thousands of years. Nevertheless, due to advances in technology and to food shortages their perturbations, both continuous and sporadic, have increased heavily in recent decades leading to substantial modifications in marine ecosystems. This is particularly true for coastal and island ecosystems and is coupled with pollution and/or overexploitation of marine resources. In this sense human beings are critical components of marine ecosystems.

Recommendations: Anthropogenic influences on marine ecosystems should be carefully monitored in the future. Particular attention should be paid to fragile marine ecosystems such as coastal and/or island systems. Monitoring programmes should be in a proper time and space scale (see Ocean science for the year 2000, IOC/Unesco, 1984)

Establishment of marine parks and reserves that include a wide range of ecosystems should be stimulated around the world. Marine parks and reserves should become natural marine teaching laboratories. Monitoring programmes should be established, and core versus non-core zones within them should be distinguished, hence allowing both observational activities and manipulative experiments. The biosphere reserve concept is a useful model to consider in this respect.

Problem 14: How to adapt to climate change?

Comments: It seems probable that the next century will see the most profound climatic changes which have been experienced in historical times. These changes can be expected to have very important ecological impacts. Ecosystems will have to be regarded as being in transition, rather than in steady state.

It is particularly important that coastal and pelagic marine ecosystems be studied, since in the marine environment the expected changes are large compared with "normal" interannual fluctuations.

Recommendations: Both professionals and students should be encouraged to examine all aspects of their disciplines, to consider the consequences of a changing environment. Very comprehensive monitoring of important ecosystems should be undertaken, of such a nature that fundamental as well as superficial changes will be recognized. The monitoring will have to have century-long persistence.

Problem 15: How to deal with the fact that taxonomy has been out of favour for many years, and many taxonomists are reaching the end of their working lives?

Comments: Taxonomy of organisms is basic to all marine biological and ecosystem studies. Unfortunately, in recent years this important field has been neglected. This has been much to the detriment of marine scientific research, particularly within the fields of marine ecology, conservation, pollution etc. During the International Indian Ocean Expedition (1960-65) several scientific centres were opened in different regions of the world, supported by Unesco, with a view to develop not only expertise in taxonomy, but also to study thousands of plankton samples collected during the expedition. Excellent work was done in these centers for nearly 10 years, or to about 1975, but subsequently they were closed or absorbed into other organizations. The taxonomic expertise was lost.

Recommendation: It is recommended that Unesco assist in serving the remaining scientific centres and, if this is not possible, give support for publication of regional taxonomic monographs, particularly for tropical waters. The use of computer aids should also be investigated and encouraged.

Problem 16: How to better understand marine ecosystems?

Comments: It is anticipated that there will be major advances in the understanding of marine ecosystems over the next decade or two. In the past, most of the research has been aimed at the main food chain culminating in fish or marine mammals. This research overlooked the importance of two components of the marine ecosystems for technical and methodological reasons: (i) the ultraplankton and the cyanobacteria which were too small to be captured and seen by older methods, and (ii) the gelatinous plankton organisms which tended to be broken up by the biological nets and which were difficult to preserve.

It was recently shown that the ultraplankton contributes as much to the ocean's biological production as do all of the previously studied plankton. This part of the ecosystem is now being vigorously studied. The presently planned global ocean flux study will, in part, specifically examine the interaction of ocean chemistry with this part of the ecosystem. It is recognized that the gelatinous organisms are abundant and probably interact in significant ways with the main food chain. Methodology is still inadequate for studying this part of the marine ecosystem. Even a general understanding of the role of these organisms in the marine ecosystem is some years off.

Recommendations: Concerning research, the marine biological community should systematically study the components of the marine ecosystem represented by the micro- and nanoplankton and the gelatinous organisms, so as to understand their composition, distribution and functioning. Marine biologists should work closely with marine chemists on micro- and nanoplankton problems. Models and other studies of the marine ecosystem, including those of the living resources and the environment, should be modified so as to include these components where relevant. Training programmes in marine biology, marine chemistry and modelling should be adjusted to (i) include the new information as it becomes available, and (ii) prepare scientists to carry out research in these cases.

Problem 17: What is the role of research in training?

Comments: Training can take many forms, all of which are valid in appropriate situations. For example, programmed training through formal courses are an effective teaching method, but on a global scale usually ends when the student leaves his/her school or university. Research is also a very effective teaching method. The requirement that the researcher review the current and older literature as part of one's research technique, is simultaneously an excellent method of self-study that provides for learning new techniques and new scientific knowledge, and also combats the inevitable obsolescence of school education and university training.

Recommendation: Educational and political authorities should recognize that scientific research and literature searches are an essential part of the science and technology training effort.

II. WORKING GROUP ON DEVELOPING COASTAL STATES WITH PARTICULAR REFERENCE TO SMALL ISLANDS

A. INTRODUCTORY STATEMENT

There is often not a sharp distinction between coastal countries having advanced marine science capabilities and those with limited capabilities. Nevertheless, for various social, economic and political reasons, it is appropriate that particular attention be paid to the latter. Further, the circumstances of small island nations, for whom the marine sciences have proportionately greater relevance, require special attention.

Small island nations have a large coastal area to land mass ratio. Their coastal environment is therefore particularly important, both socio-economically and culturally, and there is typically a high level of conflict of use of their coastal zones. This conflict is often accentuated by high population densities on the coast and by tourism.

Small island nations usually have large exclusive economic zones for their land mass and population size. This conveys benefits, but it also imposes important responsibilities for the management of these zones.

Many island nations do not have the infrastructure and technical capability, nor the financial resources, to address these issues. Moreover, given the population size of many small island nations, it may be impractical to attempt to develop the technical capability individually for each nation. Regional marine centres are a possible solution, if there is a strategy to provide for long-term continuity of funding, together with an agreement for regional cooperation. Islands are often ideal locations for oceanographic research and, because of their biotic diversity, for scientists interested in marine biotechnology. This may facilitate the development of regional marine centres.

Although many problems are, or will become, common to all islands, the following factors vary considerably between islands: the current urgency of the problems; the capacity to address them; the environmental and resource characteristics of the islands; and their land area, population size and population growth. Consequently, the appropriate approach to assisting with the development and application of marine science on islands will necessarily be site-specific. Particularly given the population growth characteristic of islands, the problems they face are likely to increase in all cases.

It is important that the circumstances of small island nations be presented as a special case for the reasons previously stated. Nevertheless, it is pointed out that their marine science teaching and training needs are often not distinct from those of other developing coastal states. The principal difference is the fact that the very small sizes and populations of island nations make it essential to adapt approaches based on regional sharing of teaching and training resources and of infrastructure.

B. MAJOR AREAS OF CONCERN

1. Islands are faced with increasing problems of coastal pollution of land origin, and of pollution threats of external origin. The land-based pollutants include domestic sewage disposal; run-off of soil, fertilizers and pesticides; and, in some cases, industrial waste. Problems of domestic sewage disposal are aggravated by tourism and problems of land run-off by the clearance of coastal vegetation for housing and hotel development. The external pollutants include hydrocarbon pollution, originating from local and international shipping and offshore activities, and the fast growing threat of disposal of the toxic wastes of industrial nations in the exclusive economic zones of island nations and at land sites from which coastal waters can become contaminated.

2. Islands are faced with an increasing problem of coastal and beach erosion, partly due to the deterioration of coral reefs resulting from coastal pollution. Beach erosion is often aggravated by the use of coral material and beach sand as building material, and by inappropriate forms of coastline engineering. Both coastal and beach erosion problems will escalate dramatically if the predicted rise in global sea level materializes.

3. Coastal resources are accessible and vulnerable to overexploitation. Most island nations have free-access fisheries, and their coastal resources are already overexploited.

4. The non-living oceanic resources of many island nations are under-utilized to some extent because of limited exploitation capacity coupled with inadequate information about the nature and extent of these resources. For some island nations there is no scope for increased exploitation of living oceanic resources; for some others an expansion of fisheries is constrained by the past and present activities of foreign fishing fleets. Even where there is scope for increased sustainable exploitation, the information necessary to quantify and determine appropriate levels of exploitation may be lacking.

5. There are opportunities for increasing fisheries production in small island states through mariculture, yet awareness of these opportunities is limited and training opportunities are few.

6. Both coastal zone and fishery management require monitoring programmes to assess environmental and resource trends and to determine the consequences of management interventions. Few island nations have such monitoring programmes.

7. The equipment and technical expertise necessary to handle the information generated through monitoring and research are not available to many island nations and the ability to interface with regional and global systems of marine data and information exchange is limited.

8. In many island nations there is neither the political or public understanding nor the administrative and legislative infrastructure

necessary for effective coastal zone management. And there are shortcomings in the capacity of small island nations to negotiate with foreign users of the resources of the exclusive economic zone and with those who seek to exploit marine research opportunities in those zones.

9. Some islands have traditional marine area management systems, based on traditional knowledge of the marine environment. In most cases, these systems are not recognized, are deteriorating through neglect and displacement by introduced forms of technology and administration, and have not been incorporated in formal management plans.

10. In many islands nations, particularly those where most of the population has little historical affinity with the sea, there is inadequate emphasis on basic marine science education and the relevance of research. This is reflected in a limited appreciation of the importance of the marine environment to these island nations, and this contributes to the coastal zone and resource utilization problems identified above.

11. For reasons of their small scale it will not be possible for each and every island nation to develop the infrastructure and technical capability necessary to address the issues and problems identified.

12. Through modern telecommunications strong links are developing between the capitals of island nations and the rest of the world. However, communication systems within those island nations remain weak.

C. RECOMMENDATIONS

The following recommendations were written to be applicable to small island states, but they can be considered as also relevant to coastal states with little or no marine science facilities.

The types of organization other than Unesco to which each of the recommendations is directed are indicated by letters as follows:

OIO : Other international organizations
ING : Island national governments
MSET : Marine science educational and training institutions.

1. Identify and support the development of existing national and regional institutions to facilitate their roles in marine teaching, training, monitoring and research on both national and regional levels, and in providing advisory services to island governments. (Unesco, OIO).

2. In situations where island nations have marine science institutes, but limited resources restrict development of full marine science capability, it is recommended that those institutes consider developing complementary programmes, each with a specific focus, in such a way that a regional sharing of expertise and of research effort is possible. (Unesco, ING, MSET).

3. For island nations concerned about their limited capacity to develop a

marine science capability, it is recommended that they be given the necessary guidance and support to establish a basic level of infrastructure and expertise sufficient for monitoring resource and environmental trends, while for more complex and expensive research relying on appropriate arrangements with regional and other institutions. (Unesco, OIO, ING).

4. Support the development of regional and interregional networks which facilitate the exchange of information and experience. An essential corollary of this is support for the necessary effort to improve the telecommunications infrastructure within island nations. (Unesco, OIO, ING).

5. Conduct training programmes in the management of marine science information i.e. the collection, processing, storage and dissemination of data - noting, particularly, the emphasis on basic monitoring in the third recommendation above. (Unesco, OIO, MSET).

6. Facilitate short-term training for island nation scientists in clearly defined specialist skills in countries with a demonstrated competence in marine sciences.In this connection, it is strongly recommended that the field studies of students in research degree programmes be conducted in their own country or region wherever possible. This accustoms the student to performing in the prevailing social and environmental circumstances, adds to the information on local marine organisms and environment, and serves to assist the development of the regional research centres. (Unesco, OIO, MSET, ING.)

7. Encourage dialogue among marine scientists, economic planners and political decision-makers with a view to greater recognition of the role of the marine sciences in island nation development and to improving the administrative infrastructure necessary for coastal zone and fishery management. Support this with appropriate training programmes. (Unesco, OIO, MSET, ING).

8. Encourage the incorporation of marine science teaching into primary and secondary school curricula, and support the development of marine environmental awareness programmes. (Unesco, ING).

9. Support the development of distance teaching for marine sciences as a means of making the best use of scarce teaching and training resources in small and scattered island populations. (Unesco, ING).

10. In those island nations where long-established coastal communities retain a store of traditional knowledge about the marine environment and resources, encourage and support efforts to document, interpret and apply that knowledge in the marine sciences and in marine resource management. (Unesco, ING, MSET).

11. Through teaching and training, seek to impart a capacity to recognize and understand the nature and relevance of traditional community-based island marine resource management systems, and to draw from them ideas and information for teaching and training. (Unesco, OIO, ING).

12. Support training aimed at improving the capability of island nations in surveillance of their exclusive economic zones and in foreign-access negotiations on research and on exploitation of their living and non-living resources. (Unesco, OIO such as FAO).

13. Support the development of the marine sciences necessary for mariculture, and support training in mariculture techniques appropriate to island nations. (Unesco, OIO such as FAO).

III. WORKING GROUP ON ECONOMIC AND SOCIAL POTENTIALS

A. INTRODUCTORY STATEMENT

The working group decided to address the topics in a sequence that would allow an analysis of marine educational and training requirements based on the potential and actual uses of the marine environment. These uses are presented along with accompanying details related to the assessment of impacts, the supporting technologies, and the development of marine regional planning. In the final subsection, a list of statements is included on education and training needs and recommendations concerning education at various levels.

The scope of the considerations is immense. It is essential that their relevance to the long-term wise use and protection of the marine environment be communicated clearly. Priorities should be determined by each country taking into account its specific and changing needs.

It is obvious from the general thrust of resolutions arising from previous Unesco exercises (Unesco, 1974, 1981, 1983, 1986, 1987a) that the primary priority is to find ways to influence all countries to introduce marine and related science education into their respective curricula at all levels. The working group felt it appropriate to re-emphasize the following needs: (i) to strengthen links between the socio-economic system, the scientific community, management and political sectors; (ii) to introduce marine examples in all stages of formal education from primary to the most advanced; as well as (iii) to provide opportunities for training courses to update and upgrade knowledge of the marine sciences.

B. GENERAL FRAMEWORK

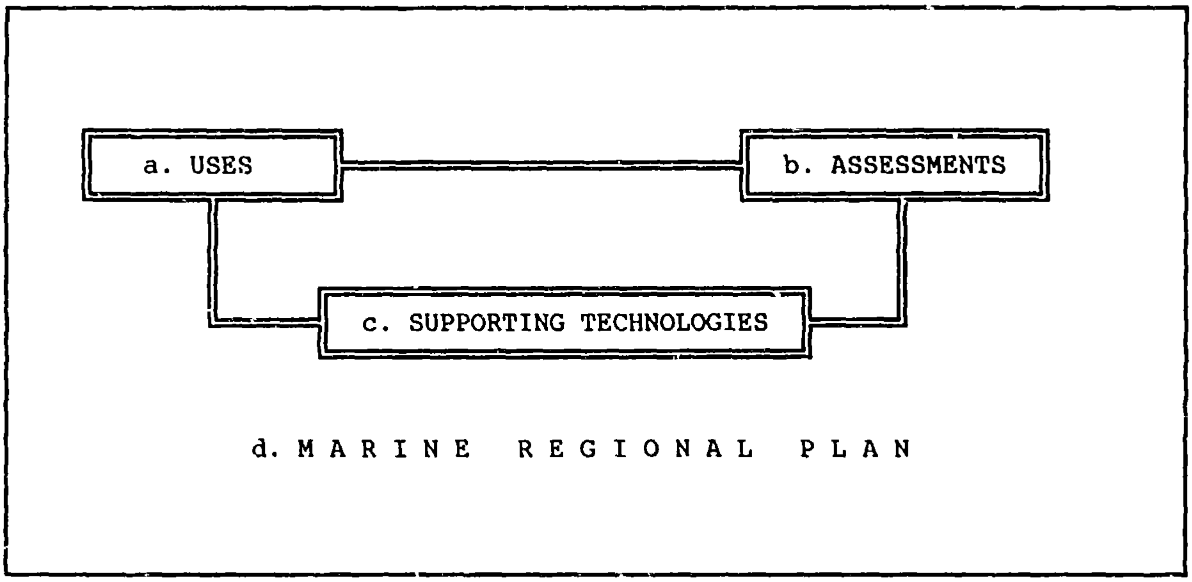
In addressing the subject, the following sequence was used:

Category (a) - Analysis of economic and social potential "uses" of the sea towards the 21st century.

Category (b) - The need for assessment of the impact of each type of use: e.g. environmental, socio-economic, cultural, legal, national and international consequences. In some countries some of these assessments are already in place. But it will be an area of increasing attention which requires scientific input. For each "use" there will be different types of impact assessments. As new uses emerge (and existing uses are made more efficient) new supporting technologies will be required. Such technologies will be required for both "uses" and "impact assessments." Therefore the following must be analyzed:

Category (c) - The developments of supporting technologies.

Category (d) - Because of the requirement to ensure that conflict on all proposed uses of the sea is minimized, consideration is needed for the introduction of the marine equivalent of a "town" or "regional" plan, with areas defined for different types of human activity e.g. areas for recreation, industry, parks, living, etc. This will require new regulations and administrative structures. It will embrace all the activities within categories (a), (b), (c).



We now have a framework within which to logically consider the fundamental education and training required to support each of the requirements in categories (a), (b), (c), for the development of a regional plan (d), and to satisfy all community needs from generalist to specialist.

In the system developed, we now have the ability to consider specific education and training needs in marine science for each country as it progressively develops its requirements for use and protection of the sea within a plan which is directly comparable to any land-use plan.

One can analyze each of the categories (a) to (d) as follows:

a. Potential Uses

The majority of the "potentials" are already existing in some form and one can anticipate increases in most fields because of increasing population pressures, improvements in technologies, equipment and vehicles to access the sea, and the continuing demand for resources of all kinds as well as the expanding recreation and tourism industries. One of the major changes will be the intensity of use and the consequent potential of increased economic return from the sea.

There appears to be an increasing human pressure on all warm-water areas and the marine areas within the tropics are those with the shortest history of systematic study and use.

Particular recognition must be given to the fact that the United

Nations Conference on the Law of the Sea (UNCLOS) agreement has not yet been analysed in sufficient detail to allow definition of the ways in which different countries could apply scientific knowledge to satisfy international obligations.

With respect to living resources the potentials provided by the marine species of tropical and subtropical areas are particularly impressive. Further, in these areas there are many long-established coastal communities with considerable knowledge of the ecology of these plants and animals and their medical and other applications. This knowledge can be a valuable source of ideas for capture fisheries, mariculture and biotechnology. However, it is most important that marine science investigators recognize that this traditional knowledge is of great socio-cultural and even economic significance for the communities concerned. This knowledge should not be regarded as a "free good", as many scientific investigators are prone to see it, but as proprietary knowledge, the acquisition of which needs to be compensated for in terms of appropriate benefits for the communities which provide the knowledge and the nations of which they are part.

A proposed international convention on biological diversity, a draft of which has been prepared by the International Union for Conservation of Nature and Natural Resources (IUCN) makes some provision for these points. Among other things it provides for a share of financial benefits, resulting from the successful marketing of a new product or idea from species native to a particular country, to be provided to the government of that country.

Among the economic and social potentials identified by workshop participants were :

1. Mineral materials, and energy exploration and exploitation:
   - deep-water mining -- manganese nodules, metalliferous muds, hydrothermal sulfides, and gas hydrates;
   - hydrocarbons -- oil and gas;
   - nearshore minerals, e.g. placers, phosphorites;
   - chemical elements (e.g. gold) and minerals -- from the seabed and from sea water;
   - building materials, e.g. carbonate sands for cement manufacture;
   - energy -- waves, tides, ocean thermal energy conversion (OTEC);
   - water (desalination, salts as by-products);
   - new materials, e.g. marine polymers.

2. Sustainable capture of biological resources from the sea

Biological resources include all fauna and flora. "Fisheries" include all animals and plants traditionally harvested from the sea, e.g. fish, crustaceans, molluscs, algae. The effort to increase the catch in many countries is not producing an increasing yield. Scientific studies are necessary to make reliable forecasts on the yields, and to protect the stock from overexploitation.

Fisheries:

- capture -- development of improved methods for different stocks;
- processing -- methods to minimize waste are particularly needed;
- marketing -- including presentation of new marine products.

3. Aquaculture/mariculture

This will be an area of immense growth in most areas of the world and it has an impact on many coastal zone areas:

- Fisheries products (processing and marketing);
- microalgae products (processing, marketing);
- pond design, construction and facilities;
- cage design and construction;
- water quality management;
- disease control and marine veterinary science.

4. Marine Biotechnology

This field of potential use has great scope for new products, particularly because it allows a more extensive use of marine microorganisms than has ever been practicable before:

- aquaculture (strain improvement, control of development and growth, tissue culture);
- vaccines for aquacultural species;
- genetic engineering of seaweeds (strain improvement, chemicals, salt-tolerant plants);
- marine pharmaceuticals;
- new agrichemicals;
- industrial and fine chemicals;
- marine biodegradation;
- new methods of ecological monitoring and research.

5. Engineering works

Greater diversity of marine structures will likely occur in the next century originating out of the present range of engineering works, such as:

- offshore structures, fixed and floating structures, including floating hotels;
- harbours;
- breakwaters, groins, etc.;
- transport systems -- sea-surface, subsurface and seabed;
- artificial reefs.

6. Increased human access to and use of marine ecosystems

With increasing leisure time and increasing wealth these activities will show very significant growth:

- surface and subsurface tourism and recreation;
- marine archaeology;
- placing structures in or on the sea;
- use of special areas of anticipated high attraction, e.g. coral reefs, small islands, estuaries, fjords, continental shelf areas, mangrove areas, sea grass beds;

- defence systems;
- waste disposal.

b. Assessment Requirements

Not all the consequences of exploiting the economic and social potentials available in marine science and ocean engineering, such as those given under the preceding category (a), can be foreseen. There is a particularly important need for effective social and environmental assessment techniques and procedures which are internationally comparable and, so far as possible, standardized. The following types of assessment are pertinent :

- living and non-living resources;
- environmental;
- biotechnological impacts (e.g. release of genetically engineered organisms);
- socio-economic;
- cultural;
- legal;
- national and international obligations.

Special attention must be paid to the circumstances of traditional coastal communities with a long-established association with their marine environment and resources. Where they maintain traditional use and access rights within the framework of customary law these should be carefully examined and appropriate provision made.

c. Supporting Technologies

There will have to be great attention to improving the standard and scope of supporting technologies for the uses and assessments as given under the above categories (a) and (b), respectively. Many methods are today in their earlier stages of development. This is an area which must not be neglected by countries wishing to safely access marine resources.

1. Weather and ocean conditions forecasting:
   - meteorology;
   - ocean currents, tides, and eddies (relevant to understanding of upwelling, pollutant dispersal, interconnection of reef and island communities etc.);
   - air-sea interactions, particularly in more defined and smaller areas of use;
   - catastrophic events;
   - impact of changing composition of gases in the atmosphere and air-sea interactions.

2. Survey data availability and analysis:
   - cartography/mapping (including mapping of the seabed);
   - remote sensing (from satellites, aircraft, spacecraft, seacraft etc.);
   - data acquisition and management;
   - acoustic and radio-frequency transmissions.

3. Instrumentation and platforms for marine applications and assessment:
   - research vessels, ships-of-opportunity, aircraft, submersibles, satellites, and remotely operated vehicles (ROV);
   - monitoring equipment of different types, e.g. for siltation, erosion, pollutants, tides, currents, etc.;
   - communication, navigation, position-fixing instrumentation;
   - seabed sampling instrumentation for very deep waters.

4. Human health matters:
   - marine infections and allergies -- little understood matters of increasing social significance;
   - toxicology -- at present the toxic species are not clearly defined;
   - nutritional value of alternative ocean foods;
   - diving technology/diving medicine;
   - detection and removal of toxic chemicals.

5. Materials science:
   - new materials;
   - fouling, biodeterioration, corrosion control.

d. <u>Marine Regional Planning</u>

This fourth category embraces activities related to the preceding categories on potentials (a), assessments (b) and supporting technologies (c). It again produces new challenges, the majority of which require scientific input. The following example areas should benefit from a marine regional planning approach :

- recreation;
- habitation;
- reclamation of land or sea;
- port and harbour development/location;
- pollution monitoring/control;
- designation of areas for specific purposes;
- management systems;
- living and non-living resource analysis;
- living and non-living resource use planning;
- legal matters including Law of the Sea.

C. EDUCATION AND TRAINING REQUIRED

The potential uses of the sea are so diversified, and the management considerations for control of the marine environment resources so much more complex than for the land, that training and education for the understanding, protection and wise use of the sea and its resources cannot depend on science alone. There is a need to consider ways to develop science-based education programmes which will meet all the needs of society from the generalist to the specialist.

a. <u>Education Needed</u>

Education in marine science-based topics is required by:

- the general public;
- decision-makers in industry and commerce;
- politicians;
- teachers;
- scientists and engineers.

Persons from countries without ocean and sea boundaries were active in the debate on the Law of the Sea, and no country should be excluded from the opportunity of increasing educational (and training) emphasis in the marine sciences.

The overall education system should provide for both general and specific and formal and informal education opportunities throughout life.

b. Training Needed

Whereas education may be considered as an ongoing and essential process for all, training may be considered as specialized events with a well defined emphasis.

Special training courses may be needed for existing research and teaching staff on :

- the scope and limitations of mathematical models;
- the scope, capabilities and limitations of existing international networks or marine services, such as marine data and information;
- the scope and limitations of remote sensing of all types;
- information technology (computers, telecommunications and office automation);
- interaction among the science, economic and scientific aspects of marine studies;
- management strategies;
- marine resource planning.

Additionally, training courses should be developed specifically to encourage understanding and awareness in managers and politicians who have marine responsibilities. These courses must be presented predominantly in the language of the participants, rather than in the language of science and technology.

D. RECOMMENDATIONS

a. Post-secondary Education

1.1. All marine science curricula at the post-secondary school level should include field, shipboard and relevant work experience, and make use of the most modern computers and communication technologies wherever feasible. Students should be made aware of the current and potential resources of the sea and of the economic aspects of their exploitation. Students should also be made aware of the potential impact of different activities on the marine environment.

1.2. All post-secondary school courses should provide a sound basic training in the essential sciences, e.g. biology, chemistry, geology, and physics, and in mathematics in the early years of the programme, with specialization developing in the later years of the courses or in postgraduate studies.

1.3. The courses should also include introductory lectures in such topics as law, economics, management, ethics. (This recommendation suggests that there may be a need for professional marine science degrees having a length greater than a formal science degree).

1.4. It is recommended that special attention be given to oral and written communication skills with emphasis on the requirement to be able to adapt the communication style and content to different situations. Role playing may also add to such instruction.

2. Different courses need to be designed to satisfy the requirements of different types of graduates. The basic core of subjects previously recommended will ensure that there is a common language for research workers to allow interdisciplinary research interaction. Major research advances will often require interdisciplinary interaction of specialists in different areas of expertise. Teachers, administrators, and managers require a stronger interdisciplinary component in their first degree training.

3. Education in marine science should not involve only teachers or researchers. It should also include the practitioners in the field and the users of marine science knowledge in industry. Such a system would extend the awareness of the students and stimulate interaction at the teaching-industry-government interface.

b. <u>General Education</u>

4. Every effort should be made, in all countries, to introduce marine examples in science education from the primary to secondary and to tertiary level, emphasizing interactions in the marine environment, the relationship of air-sea interaction to weather on land, and the consequences of poor management of marine resources and habitat.

5. Countries with teaching and research material and methods available as a result of their long traditions in marine science should make resources available to countries with less history and experience in marine science.

6. Distance education should be encouraged in remote areas, but should be in association with personal teacher-student contact wherever practicable. Distance learning is seen as having high value for "refresher" or "updating" courses as well as for initial learning/education.

7. Skilled marine scientists and engineers who are good communicators should be encouraged to write/produce educational packages (books, teaching manuals, videos, etc.) and general information material on marine topics, particularly those relevant to specific regions, to satisfy the needs of both the specialists and the generalists.

8.1. Governments of countries should be encouraged to establish marine aquaria and museums, which are valuable general and specialist educational resources.

8.2. Governments of countries should recognize the specific problems of data assimilation and transmission. Whenever appropriate a national oceanographic data centre may be set up or expanded to perform the following tasks:

- act as service desk on internal and external queries regarding marine science and marine data;
- provide advice on and assist in handling marine information and data, preferably according to internationally agreed procedures and guidelines;
- maintain international contacts with similar centres in the region and with relevant regional and international organizations.

c. <u>Special Items for Consideration</u> - relevant to efficient education and training in marine sciences

9. In remote sensing applications, close collaboration should be established between the experts in remote sensing and marine scientists to ensure that the resultant programmes and equipment are adequate for the needs of marine scientists. Remote sensing visual displays may be seen as having a useful role in the education and training of managers and politicians.

10. Countries with a requirement to develop in-country expertise in marine science and technology should consider formal affiliation with established institutions or laboratories in countries with advanced marine knowledge, to allow staff exchange, curriculum exchange, technology exchange, etc. The facility for staff exchange should be accessible to :

- research workers in science and engineering;
- teachers;
- technicians;

all of whom would maintain close contact with their local country requirements. This would reduce the tendency for movement away from one's own country. This type of arrangement is seen as applicable as much to neighbouring countries as it is to distant countries.

11. International assistance, particularly the provision of equipment, including research vessels, should only be effected after close consultation with scientists in the recipient country to ensure that the necessary trained staff, maintenance and infrastructure (including funding) are available for the reliable continued operation of such equipment.

12. The system of regional networks of skilled people from different countries should be encouraged, to address specific issues in education and training relevant to marine resources. The development of such a system may be undertaken by an organized group of interested parties to address problems.

13. Mathematical modelling techniques should be recognized as important to the eventual understanding of the marine ecosystem and its interactions. Specific training is needed to inform all students on the scope, limitations and confidence levels of different types of mathematical models and on the need for actual or proposed verification.

d. Topics of Specific Emphasis

14. Investigations of the marine knowledge of traditional coastal communities, much of which is embodied in folklore, are recommended as a means of eliciting information of potential value:

i. for insights and ideas which serve to promote marine science in general; and

ii. for capture fisheries, mariculture and biotechnology - on the understanding that such investigations are carried out with due respect for the traditional informants and with adequate rewards for them.

15. Special attention should be given to general education relevant to the marine coastal zone and information supplied to authorities about the consequences of different types of land practices, e.g. deforestation, which will affect the water quality and resources of the coastal marine environment.

16. The concept of "marine regional planning" should be encouraged in all countries, and appropriate emphasis given in training courses, as a basis for the necessary organization and management of multiple uses of the marine environment.

17. Encouragement to be given to the initiative to establish a convention for the protection and controlled exploitation of biological diversity and to ensure that this makes adequate provision, where appropriate, for the rights of traditional communities to benefit from exploitation of their knowledge of environment and resources.

IV. WORKING GROUP ON SUSTAINABLE DEVELOPMENT AND MANAGEMENT

A. INTRODUCTORY STATEMENT

It is of the greatest importance for the sustainable development of living and non-living marine resources that ocean and coastal zone uses develop under a system of integrated planning and management. Attention should be given to future needs, particularly those relating to training and education in the use, protection, and conservation of marine and coastal ecosystems.

The dynamic interactions between the oceans, rivers, land and atmosphere should be taken into account in order to make maximum use of the marine and coastal environments and their resources. Thus, the design of future comprehensive programmes on coastal zone management and planning will require specific and detailed information on the coastal environments as well as socio-economic and demographic data, and traditional knowledge of coastal and marine activities, including human settlements and industry. Because the environmental data requirements are extremely broad, it is necessary at present, and for the future, to adapt a multidisciplinary approach to coastal zone management and development programmes.

The establishment and or strengthening of regional and subregional networks of marine laboratories will be essential for optimal development of general coastal zone management and planning policies as well as for the specific direction of the research, assessment and monitoring of the immediate local problems such as those of pollution, fisheries and coastal erosion. The pollution of the coastal zone has already been demonstrated in many countries, and the costs of correcting for pollution effects are high.

B. MAJOR AREAS OF CONCERN

Problem 1: Sea-level Rise.

The possible effects of a sea-level rise would be catastrophic for many coastal areas. Information for better understanding of this phenomenon is urgently needed, including a public awareness programme on the problem for coastal communities. Careful monitoring of sealevel and the developing of assessment programmes for its possible effects are necessary and need to be on a global, regional, subregional and local basis. It is also necessary to strengthen networks among scientific institutions for the supply of information on coastal oceanography, meteorology, hydrology and marine ecology in order to properly assess this and related phenomena.

Education and Training: Education is needed primarily for public awareness for university-level personnel, planners, managers and policy-makers. International agencies that need to be concerned include UNEP (Regional Seas Programme), Unesco (its Division of Marine Sciences-OCE, and the Intergovernmental Oceanographic Commission-IOC), and WMO. No specific training is required for particular fields because this is a conceptual environmental issue at the moment. However, the use of specialists in the areas of physical and chemical oceanography, ecology, socio-economic aspects, tourism and policy-making is needed to evaluate the expected effects of sea-level rise.

Problem 2: Coastal Processes.

Information on coastal processes is of great importance in any development plan, because of their strong influence upon marine biota, sea-water circulation, sedimentation and erosion in coastal regions. Local features of the submarine topography can also be significant, especially for the longshore transport of bottom sediments. Knowledge of the nature of the sedimentary regime can help in understanding the origin, pathways and fates of suspended materials. A good knowledge of the sedimentary processes, including transportation and deposition, is required for coastal development planning.

Special attention should be paid to teaching and training with regard to the following topics:

- i. the relationship of terrestrial coastal processes to marine coastal ecosystems;
- ii. mechanisms of coastal processes, such as sediment transport, due to waves, currents, rivers and wind, and the effect of man-made structures, such as harbours and dams;
- iii. monitoring techniques for not only the resultant constant process but also for external forces, such as waves and currents;
- iv. possible counter measures and their functions - experiences acquired in some countries and regions are absolutely useful and valuable to be transferred to less known regions.

Education and Training: Education is needed primarily for marine geologists, ocean and coastal engineers, planners and decision-makers, which is of concern to universities, specialized centres, and international organizations such as Unesco (OCE and IOC) and UNEP. Training subjects to be included are monitoring, especially by satellite observations and aerial-photography interpretation, modelling and simulation of coastal processes, field measurements, offshore observations, land-sea interactions and currents.

Problem 3: Disruption of Coastal Equilibrium.

Coastal area development may affect quality of coastal waters in a number of ways: (i) directly, through the construction of docks, harbours, retaining walls and similar marine works which cause modification of water-flow patterns, and (ii) indirectly, through increased discharges of surface water and domestic and industrial waste waters. The coastal equilibrium can also be disturbed by different phenomena such as eutrophication, desertification, and climatic changes.

There is an urgent need to promote thorough training and eduction in the understanding of the nature and functioning of the coast, and to establish appropriate environmental measures to deal with disturbances of the coastal equilibrium.

Communications with decision-makers, planners and managers, as well as regional cooperation in this context, is suggested. The people dependent upon coastal systems must be involved in establishing management and planning priorities. There is a need for an interdisciplinary approach to the problem and for the establishment of short and long-term monitoring programmes.

Education and Training: Education is needed at the research level, and for managers and planners, which is of concern to universities, environmental centres and international organizations. Training is particularly required in monitoring, satellite remote sensing, aerial-photography and photo interpretation.

Problem 4: Land-Sea and Ocean-Atmosphere Interactions in the Coastal Zone.

The knowledge and understanding of the land-sea and ocean-atmosphere interactions are vital for planning and management. In the coastal zone, physical and chemical oceanographic parameters are to a large extent influenced by the form of the coastline and its topography as well as by meteorological and climatic conditions. There is also feedback from the sea to the atmosphere and to the coast. Intersectorial planning and management for the coastal zone is needed, including broad communication between planners, managers and scientists.

Education and Training: Education is needed for university graduates, governmental planners and managers, which is of concern to specialized institutions working on these aspects, international organizations, such as Unesco (OCE and IOC), UNEP , WMO and others. Training should focus on field measurements concerning the exchange between the sea and the atmosphere, as well as on modelling and simulations.

Problem 5: Water Pollution of Coastal Zones.

One of the more conspicuous problems arising from the use of the coastal zone is the pollution of its waters either by land-based sources, by atmospheric inputs or by the use of coastal areas for human and industrial activities. The problems in some cases are aggravated by the lack of proper management and by the lack of knowledge. At present, and for the future, there is need of information, education and training of people for a proper evaluation and assessment of water pollution in marine coastal areas. The basic information required for a proper evaluation of the water pollution implications of coastal areas is related to:

i. physical oceanography and meteorology;
ii. marine ecosystems and their function;
iii. seabed conditions (bathymetry, sediment transport and bottom deposits);
iv. living resources (particularly those already exploited);
v. riverine inputs, and discharges of sewage and industrial effluents;
vi. physical characteristics of the coast, including fresh-water discharges.

Education and Training: Education is needed for all levels - primary, secondary, university and postgraduate - and also for planners, managers and users. Training is necessary in analytical techniques for the assessment of marine pollution, contingency plans, modelling, dispersion-dilution of pollutants of different types in coastal waters, and the use of devices for the control of marine pollution.

Problem 6: Management.

Scientific problems relevant to the sustainable development and management of the coastal zone, the oceans and their resources cannot be separated from the socio-economic and cultural practices which have been derived from long-term traditional uses. Additionally, in most countries, terrestrial practices have been regulated, marine practices have not been regulated, and the human population will not quickly accept new laws of the sea unless they are carefully developed and the reason for their existence has been clearly communicated.

Regulations should be established for the marine environment which would provide for different types of allowable uses in designated marine areas. These regulations should include provisions for the designation of different types of zones for such uses and may include zones of complete protection from extractive human activity. The zoning scheme would separate competitive operations and may provide for periodic closure of zones, e. g. at known fish-breeding times.

Education and Training: Education is needed at the university (including graduate) and government level, and also for policy-makers, planners, managers and investors. Training will be needed in monitoring, research, planning and multiple-use management as well as in applying methods for sustainable development and environmental impact assessment.

Problem 7: Deep Ocean.

One of the great challenges of the next two decades will be the evaluation and utilization of deep-water living and non-living resources. Cost-effective technologies will have to be developed for deep-ocean engineering works and for estimating the commercial potential of the deep-sea fauna. There is an urgent need to teach and train people for future ocean uses and especially in areas related with evaluating of fish stocks in deeper waters.

Education and Training: Education is needed for researchers, university graduates, governments and private industry and policy-makers. Training will be needed to undertake studies by acoustic methods and concerning legal and management aspects especially with respect to overexploitation.

C. RECOMMENDATIONS

1. Taking note of initiatives made by GESAMP, environmental monitoring laboratories should cooperate with a view to achieving agreement on methodology for estimating levels of major pollutants including methods of tracing the source of pollutants. Procedures should be established to gain national and international agreement on: (i) methods of detection, (ii) standardization procedures, (iii) intercalibration of techniques, and (iv) treatment of different types of pollution.

2. National and international agreement should be reached on the principle that "the polluter pays" for the clean-up of pollutants and for an agreed restoration of the areas affected. (National and international agreement is necessary because waters may carry pollutants across state and national boundaries.)

3. The establishment of long-term monitoring and baseline programmes at the regional and subregional levels is necessary to generate data for:
   i. management and planning of the coastal zone;
   ii. knowledge of coastal ecosystems and their interactions;
   iii. water pollution aspects and its effects on living ecosystems;
   iv. coastal processes;
   v. sea-level rise.

4. Coastal zone management and planning courses should be incorporated in the university curricula.

5. Development of a public awareness and information programme is needed on the following subjects: (i) multiple use of the coastal zone, (ii) sea-level rise, and (iii) marine pollution assessment and control.

6. A continuous programme of seminars and courses on environmental impact assessments for different uses of the coastal zone should be developed for training and education of scientists, politicians, decision-makers, planners and users.

V. DATA MANAGEMENT AND INFORMATION ACQUISITION

A. INTRODUCTORY STATEMENT

The working group noted that in most responses to the theme questions, matters related to marine data and information management, modern computer technology and related subjects have been mentioned regarding a series of problems, already important today and likely to become of even greater significance in the years ahead. Discussions focussed on the increasing amount of data and information available for science and management. A major concern was the need to arrive at an effective mechanism to cope with the present and future problems in managing marine data and information. Education, training and new approaches are suggested towards solving these problems, and recommendations formulated accordingly.

The working group was informed about the existence and scope of the International Oceanographic Data Exchange (IODE) System, coordinated by the Intergovernmental Oceanographic Commission (IOC), Unesco. The system provides information about seagoing programmes around the world and provides tools for (pre)processing, exchange and archival of measurement data. The group also noted the regional microcomputer-related activities of the Unesco Division of Marine Sciences and Regional Office for Science and Technology for Southeast Asia in Jakarta, as well as the set-up of regional and national systems for marine data and information elsewhere in the world, such as NEDRES (National Environmental Data Retrieval and Exchange System, U.S.A.), MUDB (Meeres Umwelt Daten Bank, F.R. Germany), MARIS (Marine Information Service, Netherlands).

B. MAJOR AREAS OF CONCERN

a. Data and Data Management

Problem 1: The lack of awareness within the marine science community on the existing systems like the IODE, their services and procedures.

Education and Training: Marine scientists, as well as the managers in the marine scientific community should at an early stage be made aware of these systems and their characteristics. The IOC Working Committees on IODE and TEMA (Training, Education and Mutual Assistance in the Marine Sciences), are already doing some work but much more is needed. The recently developed IODE brochure and slideshow with cassette can be of great help. This public relations effort should be an ongoing activity and should especially be done through the specialized marine science literature. In this context, specialized modular training packages should be developed to enable teachers and experts at training courses to use standardized training material. Such modules on marine data and information could become part of a larger package for marine science education and training.

Recommendation: Awareness should be promoted on existing data exchange systems such as the IODE system, using facilities like brochures, slide presentations, standardized modular training packages, and publications in specialized marine science literature.

Problem 2: Limited availability of marine data in microcomputer compatible format.

Comments: The Unesco-initiated activities in the Southeast Asian region towards promoting the use of microcomputers in marine science database development have proven to be successful and deserve follow-up in other areas.

Education and Training: Marine-data managers should be made aware of the need for data exchange using microcomputers. They should arrange for distribution in line with the procedures, standards and guidelines, e.g. provided by the IODE (see IODE handbook, 1988). Scientists should be made familiar with the capabilities of microcomputers for marine research, applications, and data exchange.

Recommendations: In training programmes, the present experience with marine data on microcomputers should be given wider follow-up as a regular tool, and soft and hardware should be provided to acquire the necessary experience with this tool. Data managers should anticipate the need for distribution of marine data on diskettes in standard MS-DOS format (or compatible) and, preferably, in an agreed and accepted data format.

Problem 3: Long-term archival and availability of marine datasets is endangered by the increasing amounts of data on the one hand and the limited willingness and resources for proper data management on the other.

Comments: Only a limited amount of data from the scientific community, as well as data from navies, fishermen and from the exclusive economic zone is accessible through national, regional and international systems. Besides problems related to the "right" of scientists to use their data before anyone else, there is reluctance to reveal information on certain matters of strategic or economic importance. Also if data arrive, they often come a very long time after acquisition. This fact may hamper research programmes of national and regional relevance and even lead to duplication of efforts.

The costs of proper data management proves to be only a fraction (5-10%) of the funds generally devoted to the acquisition of such data. The advent of new storage media like optical disks could help to reduce the cost of maintenance of a data archival and distribution centre. The publication of datasets in the form of a data-volume series through the local library circuit, may be an acceptable solution for not too large datasets.

Education and Training: Marine science managers and scientists should be made aware of the value of marine data and of proper data management. They should be made familiar with possible ways to arrive at properly documented archives of marine data.

Special Case: The feasibility of storage of acoustic data of fish and plankton in a digital form, together with details on instruments, catches and calibrations, should be investigated and the resulting system design implemented. Appropriate regional host organizations should be identified to collect, archive and distribute these data. Also the need to investigate existing archives of these data should be evaluated.

Recommendations: The training of managers and scientists should include the importance of proper data management using new media such as optical disks. Ways should be sought to speed up submission of data, especially those used for monitoring, to national, regional and/or international exchange systems. National research funding agencies should consider including in their conditions for financial support, an obligation to submit data in an agreed form through the appropriate channels within a limited period. Appropriate agreement should be reached to settle and protect the interest of the scientist who generated the data. The specific problems concerning acoustic data of relevance especially to marine biology, should be addressed.

Problem 4: Datalists and model descriptions in publications.

Comments: Publishers, in spite of repeated requests, do not regularly wish to include datalists with publications. The same is valid for extensive descriptions of model results. This prevents scientific evaluation, verification and possible re-analysis, which the group considered a serious problem.

Education and Training: Inclusion of awareness on available datasets and on the need to include the datalist or model description with a publication as a means of evaluation, verification and also to prevent data from being lost.

Recommendations: Marine science managers and scientists should reserve the necessary time in project time-scales for working up data for a datalist or a model algorithm to be published. This can take one of three forms : (i) a printed list, (ii) a diskette, (iii) an online accessible dataset. Publishers should be convinced of the desirability to include data with a publication.

Problem 5: Lack of standards for acquisition, processing and formatting of data.

Comments: The lack of standards leads to results which become hard or impossible to compare. In this context, the need was raised for standardization of hardware and software and for exchangeable software packages for processing and formatting of oceanographic data. Experience shows that the exchange of complete programmes is not always easy, partly because of the lack of adequate documentation. It is important that scientists and data managers agree on procedures and algorithms for specific types of data. In this context the problem of maintenance of sophisticated hardware and software was raised.

Education and Training: Scientists should be made more sensitive to the importance of common methods to process data that may be combined into a regional, subregional or global dataset at some stages. They should actively participate in efforts to develop the necessary procedures, standards and guidelines.

Recommendations: Education and training of marine scientists and managers should include instruction on the need to adhere to standard procedures for marine data acquisition, processing and formatting. As a direct consequence of its work on quality assessment, the IODE Working Committee should include the subject of standards for processing of specific types of data into its range of activities. Marine science institutions should consider their capability for maintenance of specific hardware and software before acquiring such equipment.

Problem 6: Lack of awareness on the existence of historical datasets.

Comments: This lack was identified as an important shortcoming in present training programmes in view of the repeatedly recurring need for historical data in marine science projects.

Education and Training: Inclusion of working with quality-controlled historical datasets gives marine scientists not only an increased awareness on how to work with "difficult" datasets, but also they will better appreciate the value and potential importance of historical data.

Recommendation: The training of marine scientists should include, where possible, a section on working with quality-controlled historical datasets, which will lead to an increased experience in data processing as well as to an increased awareness on the potential value of such datasets, e.g. for modelling.

Problem 7: Establishing databanks.

Comments: It can be noted that several existing databanks and networks are not used as fully as they could be, and their effectiveness is sometimes debatable. Databanks may have been set up without a clear view on the specific requirements.

Education and Training: In training programmes a careful approach of the possibilities of databanks should be given in order to promote well founded decisions on the set-up of databanks.

Recommendation: No databanks should be set up and no data be archived permanently unless specific needs or requirements have been brought forward and were agreed upon.

Problem 8: Ambiguous acronyms

Comments: Ambiguous acronyms are causing trouble in computerized searches for literature.

Recommendation: Names for equipment, research and software programmes which also have a "normal meaning" should be avoided, e.g. S.Q.U.I.D. and FISH.

b. Information and Information Acquisition

Problem 9: References to existing materials.

Comments: In view of the rapid expansion of marine data information services, networks and governmental databases, a need was identified for a reference to these - regularly updated and easy to use.

Training and Education: The availability of such a reference would stimulate students early on to make effective use of the tools and services available.

Recommendation: Relevant organizations such as Unesco, IOC, FAO and UN, are to consider developing a reference to existing services, networks and governmental databases relevant to marine sciences. This reference could be in book form, but digital form (diskette, CD-ROM, online system) may also be considered.

Problem 10: Online database searching.

Comments: Online database searching from a microcomputer is probably the easiest way to handle the problem of proliferation of scientific, technical and other forms of literature. There presently are about 4000 databases with new ones being added with increasing frequency. Many of the popular commercial databases can be accessed online through hosts (such as the Dialog Information Services and the ESA Information Retrieval Service) using the search language appropriate to each host. Online searching can be done at relatively low cost if the searcher has a degree of knowledge of searching techniques and strategy.

Education and Training: Established marine scientists and students at secondary and higher levels need to be educated in the vast amount of diverse information available online and to be trained in how to search online or to have others search for them, which requires a knowledge of key words and searching techniques.

Recommendations: Unesco is requested to identify the ways and means of making available information on online databases and how to utilize these databases efficiently at minimum cost. Unesco is further requested to take appropriate action to make available those ways and means to interested parties.

Problem 11: Evolving role of librarians.

Comments: It was identified that the role and position of many librarians in the libraries of marine scientific institutions and similar organizations could help scientists by actively providing relevant information. The following possibilities can be envisaged. Librarians can play an essential role to select, organize and distribute relevant information for scientists. Science librarians are specifically trained to assist scientists in their research. In this sense, the functions of libraries would become a tool, like computers, and enable scientists to devote their time to scientific work and less to the increasingly difficult task of searching and selecting relevant information. Professional organizations can provide library personnel with information on:

- marine information systems and products;
- setting up and running marine libraries and information centres;
- network development and interaction with international systems;
- building up local capabilities to provide general and specific services;
- technical aspects of database creation and exchange of bibliographic records;
- input preparation for local, regional and international information systems;
- methods of information analysis and synthesis, and dissemination of information products;
- many other functions.

Education and Training: Students made aware at an early stage of the active role that a library can play, will use the libraries in their careers more effectively and will be able to better cope with the growing amount of available literature.

Recommendations: In training and education programmes an active role of libraries as a tool for scientists should be included. Managers and librarians of scientific institutions should be made aware of the necessary shift in the role of libraries from their "traditional" role, possibly still present in many places. A library actively supporting scientists in coping with the "explosion in marine information", will become an essential tool for the coming decades.

<u>Problem 12</u>: Loss of expertise in taxonomy.

<u>Comments</u>: The present expertise in taxonomy is likely to substantially reduce in the coming decades if no proper action is taken to store this expertise and to make it more widely accessible, especially through modern means. Furthermore, increasing use of genetic, biochemical and numerical taxonomy methods, particularly for microorganisms, demands expansion of and accessibility to taxonomic databanks.

<u>Education and Training</u>: Expert systems for the identification of and information on marine species would form a valuable tool, not only for applications but also in training programmes for taxonomy.

<u>Recommendation</u>: The development of expert systems in taxonomy should be encouraged and actively supported where already initiated. Scientists should be prepared to contribute their specific expertise to such systems.

<u>Problem 13</u>: How to deal with information technology.

<u>Comments</u>: The important role of information technology (i.e. computers, telecommunications and office automation) in future marine science was generally recognized. The range of present and expected future development in information technology (IT) is vast and, because of this situation, difficult to understand and to use appropriately for education and training in the marine sciences.

<u>Recommendation</u>: A further workshop should be considered by Unesco; topics to be addressed might include :

- information technology in education, in continuing education, and in administration;
- development of computer-assisted learning material;
- the use of computers in distance teaching; in modelling, including simulation; and the standardization of hardware and software;
- office automation for scientists;
- electronic communications;
- local and wide-area networking.

VI. CONTINUING EDUCATION AND RETRAINING

A. INTRODUCTORY STATEMENT

The second and third marine science training and education goals (see Introduction) are addressed by this working group. The second goal concerns the matter of upgrading the skills, understanding and general competence of professionals and technical support staff. The third goal is concerned with a different form of education - of extending marine knowledge to a wider public so as to generate community awareness of the marine environment and support for the marine sciences.

In the expanding world of knowledge, scientists have to be continually exposed to the latest innovations and contributions to keep pace with science and technology development. With the shortening cycles of knowledge renewal towards the next century, continuing education assumes greater prominence.

These general statements apply particularly to marine science, as the scientific problems of the ocean are usually multidisciplinary in nature and oceanic processes are dealt with mostly at regional or global scales. University education cannot be expected to provide students with all of the broad spectrum of knowledge and skills required in the practice of marine science. Much of this must be provided through additional education and training as an individual's career progresses. Also, in this way it is possible for marine scientists to be brought up-to-date with advances in marine science and technology.

There is a great and growing need for general marine sciences education for the increasing number of people whose work relates to the care and use of, or effects on, the marine environment but who lack adequate knowledge of marine sciences. A large proportion of these individuals is unaware of this need. A conscious effort to "reach out" and offer this continuing education is needed.

B. MAJOR AREAS OF CONCERN

1. There are two categories of continuing education: one for professionals with marine science training, including researchers, teachers, engineers, managers and so on; another for personnel not trained as marine scientists or engineers but involved in marine-related affairs, including basic scientists (physicists, chemists, etc.) and engineers without marine science training as well as lawyers, economists, marine area and marine resource managers.

While periodic refresher courses for updating in marine science knowledge of related disciplines are major needs for the first category, basic courses in marine sciences are the greater need for the second. Particular importance should be attached to retraining of marine science teachers, emphasizing the interrelationships between natural, social and engineering sciences. It is also important to ensure that provision is made for informing decision-makers and leaders in society of developments in marine science and technology as these affect their areas of responsibility.

2. There is a great diversity of approaches to continuing education and retraining, ranging from short, intensive courses for small groups to extensive courses using television. However, looking forward to the next century, it can be seen that computer-assisted learning (CAL) and distance learning will be of growing importance. These two methods especially suit the needs of in-service learning and self-education.

Instructional packages made up of interactive training software complemented by video, are likely to be a popular and routine tool for continuing education in marine science by the turn of the century, and their use should be encouraged and supported. These offer promise for introducing new techniques or concepts such as remote sensing, acoustic tomography and mathematical modelling, providing new educational opportunities in areas such as image analysis and problem-solving through simulation. Computer-assisted learning and video may also be used to facilitate teaching and learning descriptive disciplines in the marine sciences, such as taxonomy.

Distance learning can help the general public, including decision-makers, to acquire a better understanding of marine sciences and a proper recognition of the importance of the ocean. Towards the turn of the century optical telecommunications links are expected to improve and become more widespread so extending the scope of distance learning.

3. The difficulty of developing countries in offering marine science continuing education lies in the lack of or shortage of competent teaching staff, necessary facilities and funds. The creation of regional and international networking for marine science continuing education and retraining, the production and distribution of relevant instruction packages, and setting up of a global system of distance learning supported by satellite communication techniques are some suggestions for providing equal opportunity for knowledge, information and technology transfer among countries at various stages of marine science development.

C. RECOMMENDATIONS

Recognizing the imperative need for continuing education and retraining for all levels of scientists, technicians and engineers in the areas of marine science and technology, the following recommendations are made:

1. As a matter of priority must be addressed the need of teachers and trainers themselves for opportunities to refresh their knowledge, upgrade their skills, and keep up with developments in promising techniques such as computer-assisted learning. This is necessary if continuing education and retraining ambitions in the marine sciences are to be achieved and educational personnel to be encouraged not to leave the marine sciences.

2. The contribution of academic meetings and various short courses to

improved knowledge and understanding of the marine sciences would be enhanced if these were arranged so that education and training innovations arising at and from these activities could be organized into learning packages for wider distribution.

3. Networking on regional and global bases is to be encouraged with a view to providing opportunities for exchange of data, scientists, technicians and, at the same time, for continuing education and retraining in the use of specialized equipment, especially at advanced laboratories and on research ships.

4. Institutions concerned with promoting marine science continuing education and training should liaise so as to cooperate and share resources in the development of appropriate approaches and materials, taking particular account of the potential of computer-assisted and distance education.

5. Special attention should be paid to addressing the need of decision-makers, planners and resource managers to keep abreast of developments in marine science and technology so far as these affect their responsibilities.

6. Greater effort should be made to involve local communities in coastal area management through helping them to develop the necessary awareness and understanding of the coastal environment. Appropriate programmes of community continuing education are recommended to that end.

7. The publication of a series of "state-of-the-art" papers - readily available, written in an attractive and easily understandable form and incorporating new developments - would be very helpful for continuing education in marine sciences. This kind of publications must be encouraged and supported.

8. A systematic listing of marine sciences educational and training material should be prepared by or with the support of Unesco, for use as a guide to what is available and what still needs to be developed.

9. All information on training courses should be distributed regularly through publications such as the International Marine Science (IMS) Newsletter of Unesco, under a specific category, indicating any preconditions of attendance, anticipated extension into other areas, and availability of course material. This information should be provided as a matter of course for all FAO, Unesco and IOC activities, while other organizations, such as ICOD, ICLARM, NORAD, EC, should be encouraged to also contribute. E-mail and other modern methods of distribution are also encouraged.

10. Practical training of students and technical staff in handling and maintenance of newly developed or acquired equipment, should be given more attention in order to familiarize them with and hence maximize the use and usefulness of such equipment.

11. Scientists from countries with limited marine science capabilities should be provided more opportunities to participate in relevant international meetings and research programmes in "frontier areas."

SPECIAL PROBLEM AREAS AND RECOMMENDATIONS

I. TRANSVERSAL CONSIDERATIONS

The six working groups produced the principal results of the workshop. Each working group considered the terms of reference and identified a number of significant problems of concern for the year 2000 and beyond. A number of recommendations were made by each of the working groups and, in many instances, directed to international organizations, governments, universities and others for implementation. These recommendations are given in the preceding Chapter. Towards the end of the workshop it was recognized that certain common problem areas were being considered by most of the working groups, that there was a need to identify a minimum number of the most important ones, and that recommendations arising from problem areas should be included in the workshop report. An extended discussion on what to include was made in plenary session. It was concluded that three problem areas were of particular importance, and these are presented in this chapter together with their recommendations and suggestions for implementation.

II. SPECIAL WORKSHOP PROBLEM AREAS

Three problem areas were identified: A. education, teaching and training for coastal zone management, B. teaching and training in marine science at the primary and secondary school levels, and C. education and training for, and utilization of, national and international electronic networking for more effective communications among marine scientists, ocean engineers and others.

A. BASIC KNOWLEDGE FOR COASTAL ZONE MANAGEMENT

Concern for proper management of the coastal zone and its resources has been a focus of discussion over a number of years. A steadily increasing number of programmes now addresses this need. Workshop participants believed that significant deficiencies remain with regard to education, teaching and training particularly with respect to: (i) the complex interdisciplinary and multidisciplinary scientific management problems which must be addressed, (ii) coastal engineering options for solving these problems, and (iii) the need to encourage a greater awareness of the social, cultural, political, economic and other aspects of coastal area management, including those related to a possible sea-level rise. The breadth and complexity of the subject of coastal area management substantially increases the difficulty of educating teachers and public alike.

Educational and training activities need to be specifically addressed to improve *basic knowledge* in order to develop a basis for effective management planning. Particular attention should be paid to those resources unique to any region that has been overexploited, and which, at the same time, appear to be critical for the future of local communities.

B. PRIMARY AND SECONDARY EDUCATION

Teaching and training in the marine sciences already exists in some primary and secondary schools of a few countries. But in many, if not most, countries there is little or no recognition of the influence of the oceans on all people, wherever they might live. There is a critical need to understand the necessity for conservation and management of living and non-living marine resources. The importance of the coastal zone, particularly to people living within this area, is very little understood by young people, who eventually will become concerned citizens, educators, decision-makers and so forth. The introduction of marine science at the primary and secondary levels may be a critical factor for the future of the marine environment and related sciences.

C. NATIONAL, REGIONAL AND INTERNATIONAL INFORMATION NETWORKING

Information technology is providing the means of acquiring online information in science, technology and many other areas, and also the means of communicating electronically within an office or laboratory, within an organization and to the outside world. The rapid developments in modern computer technology, electronic telecommunications and information management are likely to widen the gap between countries and regions having limited expertise and countries and regions having advanced expertise. This gap is likely to be more difficult to bridge in the future, also in view of the dependency it entails, unless something is done very soon to improve the situation. The needs in marine science and technology are particularly acute because of the interdisciplinary and multidisciplinary nature of oceanography, ocean engineering and related areas.

It was suggested that educational and training activities in marine science be oriented to develop local and regional capabilities in order to establish within a period of five years national and regional information networks and interlinking in marine science. This will enhance the national, regional and international transfer of scientific information. It may also lead towards the incorporation of all countries into the international networks and provide input and access to databases from the different parts of the world.

III. RECOMMENDATIONS ON THE PROBLEM AREAS

1. It is recommended that Unesco, other international organizations, governments, and educational and training institutions make special efforts to initiate, support and participate in programmes of formal, and continuing education and training for effective coastal area management. In this regard, emphasis should be given to the necessary interdisciplinary and cross-sectoral approach, improved understanding of coastal physical

processes, and the establishment of environmental benchmarks and monitoring networks based on standardized methodology. The active participation of coastal communities, and the utilization of the traditional coastal resource management knowledge and systems of these communities should receive proper attention.

2. It is recommended to educational authorities, especially in countries where there is limited awareness about the ocean and coastal environment, to include marine science education into primary and secondary school curricula with particular attention to practicals and field trips. University marine science departments and institutions, including teacher training institutions, should be prepared to offer assistance with such educational initiatives, for instance with the preparation of adequate resource materials, the training of teachers and receiving school visits. Unesco and other organizations should provide assistance, especially at the initial stage, through assisting in the development of relevant materials, the training of teachers and the exchange of expertise in these fields among countries and regions.

3. It is recommended to Unesco and other international organizations, to the governments concerned and to the scientific community in general to take measures to assist organizations and countries seeking help in the establishment or strengthening of their marine science infrastructure in general and in the cooperation of systems for exchange of marine science information in particular, and to provide opportunities for training the required staff. Advanced marine science training and transferring knowledge of how offices, computer centers and organizations can be linked together nationally, regionally and to the main world information centres, will be some of the major steps needed to reduce the gap between countries with advanced and limited expertise in marine science and technology.

IV. FUTURE ACTIONS REQUIRED

Workshops, training courses or both are requested methods for providing assistance in each of the three identified problem areas. For primary and secondary education in marine sciences in particular, the adaption of appropriate books and other educational materials to the local or regional situation will be necessary. This may include translation into the national language. In addition, new materials will need to be designed and developed for many regions or countries. For all three areas, preparatory training and education projects are highly desirable.

RECOMMENDATIONS FOR WORKSHOP FOLLOW-UP

I. RELEVANCE OF RECOMMENDATIONS

The recommendations of the workshop are based on: (i) a projection into the 21st Century of the advancement of marine science and on utilization and management of the marine environment and its resources; (ii) a consideration of the need to develop awareness, understanding and concern - in all sectors of the world community - of the necessity to plan carefully for the wise use and protection of the extensive marine environment and its resources, and (iii) an evaluation of the associated education and training needs.

The advantage of this study to relevant agencies and to specific sectors of government and society is that the study is forward looking, universal in its content, and able to be selectively used to meet the needs of all different countries. The report and recommendations *should be promulgated* to many agencies as an important component of the planning of marine education programmes for the future, allowing progressive implementation of its recommendations over the next three to ten years by naticnal, university and other authorities.

II. RESPONSIBILITIES OF UNESCO

1. It is *recommended* that the Division of Marine Sciences should immediately begin their analysis of what parts of the report and recommendations should go to what agencies and people.

2. It is further *recommended* that the Unesco Third Medium Term Plan for 1990-1995 should reflect the recommendations of this report to the extent practicable, and that the biennial programmes and budgets of Unesco should provide for the implementation of the recommendations in a phased manner.

3. The Division of Marine Sciences *should* carefully analyze the report and recommendations, selectively advising the agencies of the UN system and other intergovernmental bodies, as well as the affiliated governmental and non-governmental organizations on those aspects of the report and recommendacions specifically relevant to their areas of responsibility.

It is recognized that this form of operation is consistent with the overall objectives of Unesco, where its staff should carry out the roles of initiation, stimulation, follow-up and assessment of actions resulting from approved programmes.

A valuable component of early communication would be the identification of relevant programmes or projects in the forthcoming Medium Term Plan, in which those concerned could be encouraged to develop proposals for support of specific activities at the local, national, regional and international levels.

III. RESPONSIBILITIES OF WORKSHOP PARTICIPANTS

Workshop participants, who served in their personal capacity, were of diverse backgrounds and from different regions. They are people who have a wide range of contacts within their country and, in many cases, their region.

It is *recommended* that the workshop participants become involved in follow-up activities, both within and outside of their country.

ANNEX 1

KEYNOTE ADDRESS

(Dr J. T. Baker, Director, Australian Institute of Marine Sciences)

I am very grateful for the invitation to be among you for this week. In this keynote address I have not attempted to reproduce the material which came from the report that I prepared on the basis of interaction with many colleagues when Dr Troost sent us his very interesting questionnaire. I hope that those of you who have wanted to read that document have done so - I have brought a copy with me which can be duplicated here if more people wish to see it.

In the keynote address I want to stress more than just marine science. The reason for this is that I am from Australia and the Australian Government has recently analyzed very carefully whether it should stay in Unesco. It has seen the example of some countries withdrawing from Unesco. I was one of the people in Australia that put in an enormous amount of effort in communicating with people that I had never communicated with before. I had to learn to talk science to politicians. I had to learn to talk marine science to people who had no interest in the sea.

In this address I do want to leave with you the enormous challenge that we face if we are to be successful educators. We have the privilege of being together for what I believe will be a wonderful week in which we are challenged to share our different cultural, educational and scientific backgrounds, in a united effort to organize a comprehensive report and set of recommendations which will enhance our common objectives that our respective nations will understand, protect and wisely use the rich marine resources available to them.

In this introduction I have used the words derived from "education", "science", "culture", "nations" and "organizations" and it is not difficult to understand how, some forty years ago, people of like minds and interests to our own, but perhaps with a broader perspective, foresaw the enormous potential of a United Nations Educational, Scientific and Cultural Organization - that is Unesco. Dependent on our performance, Unesco will emerge stronger or weaker.

I have deliberately used this introduction because our challenge this week is not only to debate the important issues of teaching and training in marine science for the year 2000 and beyond, but also to demonstrate through the depth and breadth of our consideration and the clarity and objectivity of our recommendations, that Unesco, and particularly its Division of Marine Sciences, is indeed a body which can show the way forward to a world in which there must be harmony in our interaction with nature and with each other.

We come as equals, yet we are all different. You are all expert in a particular area of research and/or teaching. We must all contribute on the basis of our social, scientific and cultural backgrounds. You must all bring forward your ideas, your experiences and your beliefs. Together in this short time we must forge a trust, an understanding and a willingness to listen, to debate and to compromise so that our deliberations as reflected in the report and recommendations of our meeting are applicable in each of our countries. Again this application of our recommendations cannot be expected to be uniform because we have national differences, but I do believe that the application should have a common objective of developing teaching and learning in marine sciences which will ensure that in 2000 and beyond all societies will practice their responsibilities to understand, to protect and to wisely use their marine resources. I will use those simple words two or three times in this address because if, in education, we can achieve an understanding of what we must deal with in a sufficient manner to protect that environment in an atmosphere of increasing use, then the education will be successful.

A consequence of the trust that we must develop is the recognition that at the end of this week your job is not completed, your job has hardly begun because your job is in the future. If you do not accept the responsibility in your own country to actively promulgate to the educational, industrial and political sectors the recommendations of this meeting, then you, and I, will have failed. You cannot go away saying "Unesco Division of Marine Sciences will follow this up - they will do the work". They cannot. You are the ambassadors of marine science and of the teaching and training of marine science in your own countries. Who could do it better? You are the experts; you are the people who have or must develop the important political, economic and industrial contacts in your own country.

For this and several other reasons, "sciences" in our workshop title must be taken in its broadest context. "Marine sciences" are obligatory, but it is all of the facets of marine scientific studies which are relevant to the education, development and culture of our countries. The decisions in the marine environment must be based on scientific understandings of the total marine environment and on its interaction with the land and the atmosphere. I have already had discussions with some on the differences between marine and maritime. Again, we must address all aspects relevant to the knowledge of the oceans and their resources. Maritime must be equally our concern. Sciences and the technologies are all components of the utilization of this marine resource, for which our future generations must be educated. Do not be too narrow in your interpretation.

Certainly we must agree that the study of science is fundamental to our understanding of the basis of life, its processes and its interaction. Unless we express a concern for the impact of science on culture, on the economy and on all aspects of society, we will not be effective communicators to our respective governments and decision-makers and we as scientists, at least in my own country, have been abject failures in putting before government the importance of science in times of economic constraint.

Marine science in particular has suffered because, despite the enormous area of the sea, in general there is hardly a person that lives on it and there is not a single political vote. We have the challenge to impress people who must live by attracting votes, to commit resources to an environment in which there are no votes. We have to concentrate on the statesmen among our politicians!

I would like to think that during this week you will clearly come to understand the role of Unesco in the exercise in which we practice. In many ways this can be best exemplified in looking at the responsibilities of the Unesco Division of Marine Sciences. There have been many misconceptions of what Unesco does and what it should be doing. Unesco was not set up to be the "do-er" of all things. There are many special agencies with specific responsibility to do these certain tasks. For example Unesco should not attempt to take over the functions of UNDP, UNEP, FAO, WHO or the hundreds of other governmental and non-governmental organizations which do have the ability to undertake what we must initiate. Unesco must show the leadership necessary to ensure that a worldwide concern is demonstrated, and we must interact closely with all these organizations. The communication has to be efficient. Perhaps Unesco has tried to do too much, rather than to promote, to stimulate, to initiate, and certainly to monitor the progress in specific activities.

It is therefore thoroughly consistent that Unesco's Division of Marine Sciences should promote joint regional and interregional cooperative research activities and projects, bringing together scientists from countries of varying levels of advancement in relevant fields. They should also identify and initiate training and education programmes in the marine sciences, especially for scientists in countries with limited capabilities in these disciplines. Certainly Australia is one such country. The Division must cooperate with individual Member States in building up the human resources and infrastructure in this new and challenging field. The Division must advance marine science knowledge through cooperation with international, non-governmental and governmental scientific organizations. The Division should disseminate information including research results and marine science training and other material.

From this workshop we must be the communicators, the translators and the champions of our recommendations. If we do not show that commitment, nobody else will. We have the contacts in our countries and we must stimulate others by our example and by our commitments. The concept of "pyramid selling" has been successful in many commercial ventures. In the marine field it is interesting to note that if we can ourselves influence two other people and those two people themselves influence two others, the pyramid effect grows enormously quickly. In the tropical marine environment, if we are as successful as our bacteria which double their population every nine minutes, within 24 hours you will be enormously successful.

But I do believe that we must refresh our thinking on the way Unesco operates and the way that we as the ambassadors of marine science for Unesco must take our responsibilities to our own countries. The specific challenges that we have to address in this workshop relate to the year 2000 and beyond. I think that you will agree that it is doubtful if any single workshop of any Unesco agency has seen the level of attention before the workshop to attract information from the people who would be present. We have an excellent example from the Secretariat. The questions were well defined and circularized early. The Secretariat has commissioned a person to do a synthesis of all of the summary responses to the questionnaire received by the Division. The synthesis is very good, but no synthesis can capture every deeply felt point that each of you may wish to make. I would urge each of you to read the individual summary responses so that our discussions through this week takes into account fully the enormous amount of work that has been done by so many people.

We do have a strong basis of agreement on many issues, but there are some differences. Our responsibility is to ensure that we do recognize the special needs of each individual country in the preparation that we must make for wise decisions during this week. I have had the good fortune to be involved in the Bangkok meeting and the Qingdao meeting which led up to this workshop. My understanding has been enriched by the strong and friendly debate. The report that I prepared took into account the opinion of more than eighty people and others among you have done similar exercises.

We are well qualified to debate these issues this week but we must be open. We must ensure that the transmission of knowledge is efficient and that what emerges at the end of the week is something we can adapt to our own countries' requirements.

I would like to share with you just a few of the general observations that came from the analyses that I conducted. Some of these will be obvious but they are worth repeating. Firstly, the marine sciences as a subject is a conglomerate of disciplines as broad as any that can be envisaged for the land. It embraces geology, agriculture, veterinary science, mining and many other activities. In fact all the professional terrestrial fields of endeavour can be practiced in the sea and many more can be practiced which are simply not possible on the land. Marine science education and training will inevitably lead to specialized professional courses at advanced levels. But it must also cope with the demand for interdisciplinary knowledge and interaction.

Ultimately, the education system can only develop on the basis of excellent research and on the communication of that research not only through the standard and accepted scientific journals but also in concise and attractive form through the general literature. I submit to you that we have failed internationally in that latter regard.

There is a great need for standardization of methodology in the measurement of marine parameters. We must be able to compare results from country to country. There must be some comparability in the way we teach our students. Already we have seen that in the very quickly developing field of mariculture the people involved are trying to set standard methodology. You will be aware of others; we must share this information. This week we must become aware of everything that is happening in marine sciences, worldwide, in education and training so that we have the desired broad information base.

We have the challenge in keeping the politics out of science, but in finding a way to keep marine science constantly in the mind of politicians so that they will support our marine science endeavours and particularly so that they will support marine science education and training. We can speak from the examples of our own countries; in Australia we do not currently have an emphasis in the government on marine science. We do not have a single department of marine science. We do not have a minister responsible for marine science. Yet, we have an enormous area of marine responsibility. I therefore come seeking your help and your experience to strengthen my performance in our country to influence the politicians in a geographical area which is greater than the total area of our land. Many of you will have areas of sea greater than the area of your land. With the development of population, the coastal zone will continue to be the area under maximum population pressure, and I believe that coastal zone management should be an integral part of our considerations in marine science training programmes.

Education in marine science must have as one of its objectives the wise planning of resource utilization and environment conservation consistent with planned development. Given the general importance attributed to the "greenhouse effect" and the probability of sea-level rises over the next hundred years, education programmes should give emphasis to those regions currently subject to tidal flux and to those areas which would become submerged in the event of sea-level rises. Factors other than the "greenhouse effect" will emerge. Beyond 2000 we will see the construction of cities in the sea, and we will be faced with increasing problems associated with the cities on land, e.g. pollution of the air and sea, waste disposal etc. Education must foresee these difficulties and plan methods of counteracting adverse effects of increased human presence and activity.

One key difference "beyond 2000" could well be that most of our present day teachers have not been trained in the marine sciences. They adapted from general courses. If those representing the new breed of teachers are to be more specifically trained in marine sciences, they will bring skills which were not previously available to teachers, and they should ensure for future generations a better basic knowledge and subsequently a better multidisciplinary appreciation and understanding of the marine environment. It is appropriate to stress that we need trained people at all levels whether they be technicians, technologists, research scientists, developers, planners, administrators or managers. For all of these there must be a basis of marine science in the education.

The world has and will continue to have an increasing need for places to live, for food, medicine, new industrial processes, places to dump waste and places to relax in a relatively undisturbed environment. The sea will be called upon to provide all of these facilities or processes, and the practices must be developed within a policy of wise conservation and management. Local affiliation with the sea changes from country to country and from region to region. Worldwide affiliation with the sea and access to its resources is a comparatively new position for most of us. It is appropriate to strengthen marine science education in all countries, and it is an appropriate time to understand traditional practices which have demonstrated, and are demonstrating, an ability for harmonious utilization of marine resources, i.e. we must recognize and understand traditional practices in all countries and how they can be translated into modern science teaching.

The surveys we conducted of employment requirements in a wide range of marine professions in industry, government and research, revealed the need for consideration of post-secondary training based on traditional basic science subjects, but allowing diversification in later years or in higher degrees. Interdisciplinary interaction is needed and professional degree status in some fields is certainly indicated.

In the very first paragraph of my introduction I highlighted the need to have our nations understand, protect and wisely use the rich marine resources. There can be no more successful education and training programme than that which allows an understanding of the system and the ability to protect it. The demands on our marine environment are ever increasing and as our technology enhances the level of that use, the urgency of extensive soundly based education and training is immediate.

Yours is a particular challenge this week: to show the way forward and to show that we can have a planned system of education applicable to the countries in which we live. You must now in this week concentrate your experience, your expertise and your wisdom to debate the goals of marine science teaching and training as well as the responses to the six theme questions of the workshop. This should be a week of minimum sleep and minimum relaxation. You can start to sleep again next week. But for all of us, this is a week of challenge, of work and of great satisfaction in getting to know people with whom we will have a long-term professional involvement.

Seldom does one have the opportunity to participate in a workshop of such far reaching potential benefit for ongoing human development in the wise use and protection of our most extensive resource and least used facility, i.e. the marine environment. I therefore wish you good debate, good understanding, careful planning and wise conclusions, and that we will have a long-term involvement as the ambassadors for Unesco in the promulgation of training and education in the marine science.

ANNEX 2

INTRODUCTORY PRESENTATIONS ON PROGRESS IN SELECTED FIELDS

a. Ocean and Climate (by Prof. R. Stewart)

It is fitting that this discussion should start with the physical aspects, for these aspects provide the basic setting in which other aspects - biological and chemical - are found. Waves and currents also provide much of the input required for the solution of coastal engineering problems. Much of contemporary physical oceanography is associated with climate studies. Although a great deal has been said and written concerning climate in recent years, it is nevertheless worthwhile to provide a background summary to put the present situation in context. It is useful to divide contemporary concerns about the climate into two categories: (i) secular climate change produced by changes in the greenhouse effect, and (ii) inter-annual climate fluctuations, typified by the occasional occurrence of "El Niño".

With respect to the secular change, one thing is certain; the concentrations of radiatively active gases (the so-called greenhouse gases: carbon dioxide, methane, fluorocarbons) are increasing measurably. Much less clear are the effects to be expected should this increase continue at something like the present rate. Nevertheless serious attempts at estimation can and have been made using the best models we have available. These models indicate that sometime near the middle of the next century, that is within the lifetime of our grandchildren, if not of our children, the mean global temperature will rise by about 3.5 degrees Celsius plus or minus 50%. Three and a half degrees does not sound like a great deal. However, if it is pointed out that we are already in a very warm epoch - 95% of the previous million years has been cooler than the present - and the difference between present conditions and a full glaciation is only about 8 degrees, then 3.5 degrees is rather impressive. If it does occur, we will move into a climatic regime which has not been experienced on earth for several million years.

It is worth noting that the effect of such a climate shift is likely to be more marked upon marine organisms than on terrestrial ones. Because of day/night differences and the effects of variable winds which carry in air from different and distant climates, terrestrial organisms are generally adapted to survival over a considerable range of temperature. However, 3.5 degrees difference from the mean annual cycle is a very large anomaly in the ocean. When they occur, as they occasionally do, anomalies this large usually have substantial ecological effects. Temperature changes of this magnitude can be expected to produce substantial shifts in the distribution of marine organisms.

When climate change is discussed, it is common to draw attention to the possibility of substantial sea-level changes. It should be pointed out that while such sea-level changes are indeed possible, they are by no means certain and there is even some doubt about the sign. Careful examination of the data indicates that sea-level changes during the last century cannot be unambiguously determined because of uncertainty in the data. An increase in global temperature would certainly be accompanied by some expansion of the upper ocean, but the effect of this on mean sea level is not clear or certain. Where the water temperature is already very high, it is unlikely to increase greatly because of the enormous increase in evaporation which would accompany temperature increase. Where the water temperature is very low, increases in temperature do not change water density very much. Thus it is likely only at the intermediate temperature, particularly those in the range from 15 to 25 degrees, where the expansion produced by a temperature change would be expected to raise sea level significantly. This expansion is of course only one of the possible reasons for a rise in sea level. There might be a decrease in the quantity of ice and water on land. This again is uncertain. One of the characteristics of a warmer ocean will be increased evaporation, and therefore increased precipitation. If an important proportion of this increased precipitation stayed on land, either as snow and ice at high latitude, or as ground water at lower latitude, sea level might even decrease.

The implication of this uncertainty for coastal engineering and coastal communities is unpleasant. One thing that is almost certain is that the next 100 years will not be like the past 100 years and predictions based upon "one hundred year storm-surge levels" or other such factors will be very unreliable. If we are honest, we will have to say to everyone involved in coastal engineering and the planning of coastal structures that the uncertainty is larger than might be expected by just looking at the past records. It seems inescapable that this will either increase costs or increase risks. It will be a difficult and demanding task to educate both the clients of coastal engineers and decision-makers in government about these uncertainties, which remain not only with respect to sea level but also with respect to the evolution of future climates.

None of this should be taken as inferring that there will not be a sea-level rise of considerable magnitude during the next century. Serious efforts have been made to estimate such a rise and they yield numbers of the order of 50 to 100 cm. The rise over the last century, if there has been one, is quite uncertain as the data can be interpreted in many ways. However, again, serious efforts have been made and they yield numbers in the neighbourhood of 15 cm. Over the last 15,000 years, the average sea-level rise has been of the order of 1 metre per century. However, this observation should be tempered by the fact that over the last 150,000 years sea level has never been above about six metres higher than its present level, and almost all of that time it has been below its present level. What has been done here has been to emphasize the uncertainty and to indicate that it is the uncertainty which must be planned for, rather than any particular sea-level rise.

Now let us turn our attention to interannual variation. The most important of these, from the point of view of the ocean, are variations in the monsoon and the so-called ENSO (El Niño Southern Oscillation) phenomenon. Most of recent attention has been on ENSO, not because it is more important than the monsoon variations, but because we have more data. To date, it has proved difficult to set up an adequate observing net in and around the Indian Ocean. In the equatorial Pacific zone, observations conducted under the umbrella of the international TOGA (Tropical Ocean-Global Atmosphere) programme provide a very significant quantity of data, much of which is transmitted very soon after it is collected. There has also been a great deal of theoretical attention given to tropical oceanic phenomena. The result is that for this phenomenon, the science is in that most productive of all conditions. Theoreticians are examining the data closely. Their theoretical models can reproduce these data sufficiently closely that they are able to modify them so as to improve them. At the same time, those responsible for taking observations are designing observing programmes so as to provide data needed by the theoreticians. Real time predictions are now being made, and these predictions are beginning to show considerable skill some months into the future. This predictive mode is quite a new thing for oceanography and indeed has irreversibly changed the nature of the science.

One of the important results of these studies is to demonstrate conclusively that oceanic phenomena on the western shores of the Americas are not local phenomena but are connected with oceanic changes which start in the western Pacific, move across the equatorial Pacific and propagate as waves from the equatorial Pacific into mid-latitudes. Millions of square kilometres of ocean are involved.

These results show that many very important coastal oceanographic phenomena can only be understood when examined on a nearly global scale. They emphasize the need for a global perspective even in situations where the concern for application is only local.

It must therefore be emphasized that training for oceanographers and marine scientists of all kinds must include an appreciation of ocean-wide or global phenomena, and the practical application of such knowledge must include obtaining information from many sources far beyond local boundaries. All kinds of marine science then must, per force, have an international dimension.

b. Coastal Engineering (by Prof. A. Watanabe)

The term "coastal engineering" was officially used for the first time in 1948 when the first Coastal Engineering Conference was held in Miami, U.S.A., and hence this field is regarded as a relatively new one in comparison with many other fields in engineering. In the last four decades, however, coastal engineering has achieved a considerable progress in many aspects, which is due to the increasing demand and importance of coastal zone development and protection, to a better understanding of natural phenomena taking place in the coastal zone, and to the development of various supporting technologies.

In order to demonstrate the recent tendency in coastal engineering research, the numbers of papers per subject in the 21st Coastal Engineering Conference, to be held in Spain just after the present Unesco workshop, are given here below:
Waves: wave theory (4), wave generation (4), transformation (18), breaking (14), statistics, spectra and wave groups (15), long waves (7), wave observation (7);
Currents: nearshore currents (6), wave-current interaction (15);
Structures: breakwaters (45), wave forces (10), offshore structures (7);
Sediments and beaches: sediment transport (34), wave-soil interaction (5), coastal erosion (11), shore protection (14), coastal evolution (18), scour (4), tidal inlets (3);
Others: port development (2), beach management (4), marine pollution (6).

Some of the subjects listed above will be described in a little more detail. As for the subjects related to waves and currents, much attention has been recently paid to wave transformation, breaking, random waves, and wave-current interaction. It should be noted that many studies have been conducted on mathematical modelling and simulation of wave transformation and wave-current interaction. Now we are able to calculate the nearshore wave field under combined effects of shoaling, refraction, diffraction and currents. Some models have also been proposed for wave breaking, but we need more data on breaker-induced turbulence, in the field as well as in laboratories, so as to make it possible to accurately evaluate complicated turbulence structures in the surf zone, which are related not only to wave deformation due to breaking but also to currents and sediment transport in the nearshore region. Interest of coastal engineers in random waves is increasing, particularly on directional spectra and wave grouping, both of which are important for safe and economical design of coastal structures.

With respect to the subjects on structures, many studies are still conducted on breakwaters. However, the types of breakwaters dealt with have been gradually changing from conventional rubble mound breakwaters to others such as slit-caisson type, floating type, etc. Methods to estimate wave forces and stability of structures as well as their functions have been significantly improved.

Concerning sediments and beaches, fundamental studies on mechanisms of sediment transport and beach evolution due to waves and currents are still going on. On the other hand a lot of attempts have been recently made to develop numerical simulation models of beach evolution. Now we have set up a general framework for the simulation of beach processes, though there remains much room for further improvements. Valuable experiences have been reported on countermeasures undertaken against unfavorable coastal processes such as beach erosion and harbor siltation.

In the view of the present writer, each element of coastal processes has been studied in depth, even if not sufficiently. Now we are at the stage of integrating knowledge on various elements involved in parallel to further deeper studies on some subjects in order to effectively apply outcomes from past studies and experiences to engineering practices in the future. It should be noted that numerical models have been and will be replacing physical models. However numerical models are still far from "almighty". The importance of laboratory experiments and field measurements in particular must remain. It should be kept in mind all the time that only nature can tell us its real complexity. Concerns of coastal engineers as to their works' impact, both positive and negative, on marine ecosystems have steadily increased so far and should even increase more in the future.

c. Third World Fisheries (by Dr D. Pauly)

The remarks below are my personal views, and differ in this from the paper by Cruz and Pauly (Annex 5) in which we reported the views of others.

The first point to make here is that worldwide fisheries-catch trends have flattened out in the last decades, i.e. catches are fluctuating between 70-80 million tons per annum, with no major conventional stocks left untapped and many stocks severely overfished.

In tropical Third World countries, this situation is aggravated by specific expectations connected with fishing resources, which are that:

i. production be increased to meet increasing domestic demand due to increased incomes of/or increasing populations;
ii. increasing amounts of high-quality protein become available for export (e.g. in the form of shrimps, tuna and other high value fish);
iii. opportunities for local investors are created.

The first of these expectations is constrained by the fact that fisheries yields that can be extracted on a sustained basis are always finite, and generally lower than suggested by various superficial analyses.

The second of these expectations, often driven by staggering external debts, implies that external demand prevails over internal demand, and usually implies a higher degree of dependence (not interdependence!) of Third World countries on developed countries.

The third expectation is the most common cause for conflicts between small-scale artisanal fishermen and large-scale commercial operators, who generally succeed in increasing their share of total national catch, but without necessarily increasing this catch. Put differently, "development" in the face of resource limitation is a zero-sum game, with far more losers (dispossessed small-scale fishermen) than winners (entrepreneurs with access to subsidized loans, infrastructure developments, subsidized fuel, etc.).

These expectations led to generally uncontrolled growth of fishing effort. Throughout the world, fishing effort generally stabilizes (for economic reasons) at two to three times the effort appropriate for extracting optimum yield. The excess effort is a form of economic waste, particularly costly and hurting in developing countries. This situation, incidentally, is one of the key reasons why FAO and some international development banks are increasingly reluctant to support fishery development projects across the board.

All of this occurs, in developing countries, before a background of generalized rural poverty, the main causes for rapid increase of fishing pressure on nearshore stocks. This poverty in fact is such that gradually, destructive methods that provide income even in the face of dwindling resources (e.g. using dynamite or cyanide for catching fish) replace environmentally benign fishing methods, while reckless overexploitation replaces age-old community-based management scheme. Politicians and administrators in developed countries do not handle these problems better than those of developing countries. However, given the poverty background alluded to above, the available options in developing countries are more limited, and those chosen usually reinforce the status quo, leading to more environmental degradation, overfishing and conflicts on resource use between small-scale fishermen and large-scale operators.

How does training and education in the marine science (i.e. fishery science) relate to this? Generally it does not. Indeed, very few of the responses received and analysed by Cruz and Pauly (Annex 5) even dealt with the widening problem of overfishing and resources destruction that is occurring in developing countries.

To deal with these issues, one would expect an added emphasis on aquaculture and mariculture, which may have a potential of 10 to 20 million tons per year, and on conservation, which definitely should not be left to conservationists, but should become part of the mainstream of fisheries and marine science. Also, there should be added emphasis on resource and rural economics as well as on community development and alternative employment schemes, i.e. on working with people. Unfortunately, what the year 2000 will see, is probably more of everything else.

d. Marine Biotechnology (by Dr M. Walch)

The application of molecular biology to marine research and resource development has opened up promising new areas for research which have tremendous scientific and economic potential for all regions of the world. Marine pharmaceuticals, genetic engineering of marine and estuarine animals and plants for food production, and marine specialty chemicals offer particularly good prospects for both immediate and long-term rewards for island and riparian nations. In the short term, practical results are anticipated in improving stocks of fish and shellfish for aquaculture as well as in developing compounds of pharmaceutical value from marine sources for human and domestic animal application. Also anticipated to be of immediate benefit are vaccines produced by genetic engineering methods for prevention and control of diseases of fish and shellfish in aquaculture.

Marine biotechnology holds the greatest promise for developing countries where fish and shellfish are a major source of food, as well as an industrial commodity. Furthermore, developing countries possessing abundant marine and estuarine natural resources are ideally suited for exploration of marine biotechnology, since access to unusual and/or novel marine life permits direct utilization of new and/or unique products by genetic engineering and ensures continuous production in the laboratory, eliminating fluctuations caused by weather and climate.

Island and riparian countries should explore the potentialities of marine biotechnology unique to their regions. Existing marine laboratories should be linked with molecular genetic laboratories, if any exist within the country. If sufficient financial resources are available, investment in a genetic engineering laboratory with sufficient staff to accomplish the necessary work for genetic engineering of marine systems should be established. If financial constraints limit development, linkage of the marine facility with a molecular genetic/genetic-engineering laboratory in a developed country can be a cost-effective mechanism for establishing a marine biotechnology centre.

Workshops, seminar programmes, and short-course training for molecular biologists to become familiar with the workings of marine systems can also provide a means of technology transfer, i.e. to abbreviate the route to establishing a marine biotechnology capability. Direct linkage of a marine field station with molecular genetic facilities and staff can be established to develop a marine biotechnology capability. However, for technology transfer to industry, further direct linkage to the marine industries of the country concerned will ensure that the results of marine biotechnology research are made available to relevant and interested industries.

The organization, training and research goals of the Maryland Biotechnology Institute of the University of Maryland are presented, with special emphasis on the programmes of the Center of Marine Biotechnology. The Maryland Biotechnology Institute is composed of five centres: Center of Marine Biotechnology, Center for Advanced Research in Biotechnology, Medical Biotechnology Center, Center for Agricultural Biotechnology, Programme for Policy in Biotechnology.

The Center of Marine Biotechnology (COMB) emphasizes advanced training of marine biotechnologist through graduate students, postdoctoral fellows, and visiting scholars from the U.S. and many other parts of the world. Research programmes at the COMB include both basic and applied research in the areas of: (i) microbial processes and products; (ii) molecular ecology; (iii) reproduction, development, and growth of finfish and shellfish. A specific example of one of our aquaculture research programmes is given to illustrate how basic and applied research can be integrated to satisfy both scientific and economic goals.

A strain of marine bacteria has been isolated from the environment of the Chesapeake oyster *(Crassostrea virginica)* which has been shown to enhance the set of metamorphosis of oyster larvae. Basic research has shown that at least two types of chemical cues are produced by the bacteria: (i) a soluble cue which triggers settlement behaviour - this may be L-DOPA (dihychoxy-phenylabanine) or a derivative, which is produced by an enzyme in the organism's pigment pathway; (ii) an insoluble component of the microbial surface film (probably a polysaccharide), which cues cementation and metamorphosis.

Genetic engineering and molecular biological techniques have been used to study production of these compounds, their regulation in natural systems, and to clone the responsible enzymes in order to amplify production of important chemical cues. Important information has been gained about the ecology of this symbiosis, about molluscan developmental biology, and the physiology and secondary metabolism. In addition, applied research has shown that these microbial products can actually be used in oyster hatcheries to increase spat yield. This technology is now beginning to be used on a routine basis in both state and private hatcheries in Maryland.

This project demonstrates well that even such relatively low-tech approaches to marine biotechnological research as isolation and use of a natural microbial product, can lead to enormous applied benefits. Such work can easily be undertaken relatively quickly, even in nations without strong biotechnology research programmes.

e. Remote Sensing (by Dr I. Robinson)

The application of remote sensing techniques to marine science has developed from the 1960s, when the fundamental techniques were first explored, to the present day when remote sensing is accepted as an established method of ocean observation and measurement. 1978 was a landmark year, when three satellites were launched conveying sensors which have made a significant impact on marine science: the AVHRR on TIROS-N, the CZCS and SMMR on Nimbus-7 and the SMMR, ALT, SASS and SAR on Seasat. The exploitation of data from these sensors has led to the growth of "satellite oceanography" while at the same time other remote sensing techniques from aircraft and shore have also evolved. The emergence of the subdiscipline of ocean remote sensing implies a developing need for training in the subject.

Remote sensing should not be seen as a replacement for, but as a complement to, more conventional in-situ observation methods for marine science. From satellites it is possible to measure four fundamental properties: the brightness, temperature, roughness and height of the sea surface, and the colour of the near-surface layers. From these can be derived other useful parameters such as sea-surface temperature, wind speed and direction, wave height, wave spectrum, surface currents, tidal elevation and near-surface chlorophyll concentration. Satellites are particularly good at providing synoptic views of large areas with good spatial resolution, are able to supply data over long periods of time, and have a global sampling capability. They cannot, however, provide any information on variability with depth, nor can they sample at high frequencies. For these reasons, and because there are several ocean properties such as salinity which cannot yet be measured remotely, there is no possibility that in-situ sampling methods will be superseded.

However, remote sensing is opening up applications of marine science which hitherto could not have been considered. For the first time it is possible to study the oceans on a global scale, including problems such as

the world ocean circulation and its contribution to the poleward transport of heat, and the contribution of the ocean to global fluxes of elements such as carbon. Such studies are essential to our understanding of earth system science, with the ultimate goal of learning how to manage the environment of the whole planet. At the local scale, remote sensing is providing new opportunities for regular monitoring and scientific studies in oceanic regions which have previously not been observed in detail. This capability will be invaluable as nations seek to manage and exploit their EEZ's.
Remote sensing is already being applied to practical questions such as coastal pollution, fisheries and offshore environmental prediction and monitoring.

The next decade will see the launch of several new satellites and operational earth-monitoring satellite programmes, carrying ocean-viewing sensors. Potentially there will be an opportunity for all nations to participate in the benefits of these programmes, although it has yet to be established how access may be provided to the data. Ideally, it should be possible for all maritime nations to be able to contribute to the global study programmes planned by the space agencies responsible for the satellites, since calibration and validation will be necessary at a local scale. It is evident that if nations are to be in a position to benefit from the planned ocean satellite programmes, they must have marine scientists trained in methods of ocean remote sensing who will be able both to contribute to calibration exercises for the space agencies, and develop applications of the data to local marine science problems and coastal management issues.

Because marine remote sensing techniques differ significantly from those for land applications, it will be necessary for training programmes to be focussed specifically on oceanic applications, and be distinct from other training activities in general remote sensing. Finally, it must be noted that because the satellites will be overflying the whole world, they provide an opportunity for all nations - even those currently with the most limited observational programme - to develop a marine monitoring capability. If this opportunity is to be grasped, it will require the training of more marine scientists in some nations as well as remote sensing specialists.

The problem of the cost of using remote sensing is hampering the development of an operational tool in oceanographic research as well as in marine management. Solutions may be found in special arrangements between specific projects and activities and satellite data producers, e.g. for the global programmes such as WOCE and JGOFS.

For the teaching and training in marine remote sensing, it should be remembered that of all existing and accessible remotely sensed oceanographic data only about 5 to 10% has ever been used: a vast resource for educational purposes!

ANNEX 3

INTRODUCTORY PRESENTATIONS ON SELECTED REGIONAL PERSPECTIVES

a. Asia (by Prof. Wang Pinxian)

The role of marine resources in the economy of Asian countries will be greatly increased by the year 2000. The last couple of decades have witnessed a rapid economic development in a number of Asian maritime countries. This development is causing an enhancement in coastal and offshore activities that inevitably will lead to a concomitant development in marine science and its teaching.

We might cite several examples. The mining of the enormous offshore hydrocarbon reserves in the Persian Gulf and the Southeast Asian area will continue. Japan will maintain its momentum in active exploration in the world's oceans. India will continue its investigation and exploitation of manganese nodules. In China about a third of its annual output of crude oil in 2000 is expected to be provided by offshore oilfields. All these will eventually lead to an increasing attention to marine science teaching in Asian countries. China has also become active in investigations of Antarctica and the Southern Ocean. Some countries with less extensive territory but higher speed of economic development will display growing interest in offshore activities. In general, further economic growth in Asia will increasingly depend on the utilization of offshore resources and in each case will serve as a stimulus for the contiguous countries to invest in the improvement of their own marine science programmes.

We cannot predict how Asian countries will develop their marine science training and teaching, but if we look at the past development, some major trends may be traced out which will obviously play their role in Asian countries for the forthcoming twelve years:

1. The major area of marine-related activities usually starts from the coastal zone, then extends to the nearshore continental shelf followed by the open ocean, moving to deeper and deeper waters. This tendency applies not only to industry and research, but to some extent also to teaching and training. And this implies that more countries will be involved in deep-water marine science investigations and relevant teaching towards the year 2000.

2. Development of marine science begins, as a rule, with marine biology and physical oceanography, as required by fishery, navigation and national defence. Along with the growth of economy and technology, or thanks to international cooperation, a country may start its exploration and exploitation of offshore non-living resources, especially hydrocarbons. At this stage, a need arises for expertise in marine geology, marine geophysics and offshore engineering. Therefore, it can be predicted that training in marine geology, marine geophysics and offshore engineering will be requested in countries where only training in physical oceanography and marine biology is offered at the present time.

3. As far as the level and scale of marine science teaching and training are concerned, three successive stages may be distinguished in a developing country. At an early stage, no local marine science teaching is offered and experts with marine science knowledge are educated abroad - in China this stage existed until the 1950s. Then, with the development of coastal and offshore activities, locally provided marine science training is established with an emphasis placed on technical and quantitative, rather than academic and qualitative aspects, to meet the urgent needs in trained technical personnel - in China this lasted from the end of 1950s until very recently. Later, the focus of marine science training moves to a higher level, namely to postgraduate degrees. At the second stage, a large number of marine science training centres are required, while at the later stage the quantitative expansion is replaced by qualitative improvement, as we see now in China.

Accordingly, by the year 2000 we expect that local marine science training will be offered in more Asian countries than it is now, and that the emphasis will be gradually moved to postgraduate levels. Consequently, the needs will be greater for marine geologists, marine geophysicists and offshore engineers in many countries.

As marine science training depends on many factors - not only on science itself, but also on social pressures and constraints, as well as on university infrastructure - the track of its development can never be a straight line. In China, for example, urgent needs for personnel with marine science training appeared by the end of the 1970s. Everywhere there was perceived to be a shortage of marine scientists and technicians, because of the large number of new marine-related research, industrial or administrative organizations. The three oceanographic research institutions of the Chinese National Oceanographic Administration, for instance, had tripled their staff during some ten years. Since the mid-1980s, however, all these job opportunities have been almost exhausted, and there remained a limited number of vacant positions offered to new graduates with marine science degrees.

On the other hand, problems and complications arise when political and economic reforms influence the education system. For example, when a student now graduates from university, a job will not be directly assigned to him as was the case with the previous government administration; employers can accept graduates according to their own needs. This reform does bring competition and vigour into the education system, which is a challenge to our traditional practices. The annual enrollments and job opportunities of students will no more depend on the rigid plan drawn up in the governmental office, but on the employers' needs. As a result, enrollments in marine sciences are falling. Early this year, our National Commission for Education announced the cutting of 28 undergraduate degree specializations, including marine physics, marine chemistry and marine geology. Thus we have to cut off the enrolment in marine-related sciences this year and to reorganize our undergraduate programme, replacing the narrow and rigid specialization in marine sciences by degrees with broader scope and greater flexibility, so that our graduates can adapt to jobs in marine-related, as well as non-marine occupational areas.

Concerning the teaching in marine geology for the year 2000. When this question is discussed, the two aspects of marine geology should be kept in mind. On the one hand, marine geology may be considered as a branch of oceanography known as geological oceanography, being parallel to physical, chemical and biological oceanography. The object of all these branches is the ocean system with emphasis laid on ocean water. On the other hand, marine geology is complementary to land geology, both being a part of global geology. In this case the main object is the sea floor and the earth crust beneath.

As a branch of oceanography, marine geology is faced with broader application of new and advanced techniques. Oceanographic satellites, deep-water submersibles, in-situ marine laboratories and sediment traps are just a few examples. With more and more sophisticated equipment and facilities, tremendous amounts of data will be collected, requiring proper processing and interpretation. Due to the broad nature of oceanography, multi-disciplinary approaches and implementation of large-scale regional or global scientific programmes will be emphasized in marine geology and other marine sciences. Indeed, many of the basic questions in marine geology are inherently interdisciplinary. For instance, palaeoceanography and benthic boundary studies require a close cooperation of physical, geological, chemical and biological oceanographers. The "global change" programme and climatic studies are cases in point of the global approach. All these trends will find their expression in marine geology teaching and training. Accordingly, we should strengthen the training in computer data processing, offer courses of a synthetic nature, and provide marine geology teachers with personal experience in multidisciplinary research projects whenever it is possible.

As a part of geological sciences, marine geology has been changing its role with time. Marine geology used to be a school in sedimentary geology: to provide distribution models of modern marine sediments for interpretation of palaeofacies. This is what Phillip Kuenen meant when in 1958 he entitled one of his papers: "No geology without marine geology". Since the late 1960s geology has experienced a real revolution, and the breakthrough leading to that revolution was marine geology or, to be precise, geology of the ocean. Now marine geology is penetrating into land geology and will be incorporated with it into global geology. Towards the year 2000 the statement "No geology without marine geology" will be taught to a much broader audience than it is now.

Thus marine geology teaching tends to be incorporated either with oceanography or with geology in the broad sense. At our Department of Marine Geology in Shanghai, we have outlined a new undergraduate programme to train "amphibious" geologists adapted to both land and sea, with some knowledge of geophysics, some skill in computer techniques, and adequate knowledge of a foreign language.

Looking forward to the next twelve years and beyond, considerable economic and social changes are expected in many Asian countries, and the changes will definitely influence their education systems. As the old

Chinese saying goes, it takes ten years to grow trees, but a hundred years to rear people. This applies also to marine science education. Education must be oriented to the future. We educators must be firm enough not to lose sight of the final goal due to temporary declines, and we must be flexible enough to suit all the variety of possible changes. It is certain that the role of international collaboration in marine teaching and training will significantly increase. Unesco will be able to play an important role of bridge between regions and countries at different stages in the development of marine science teaching, and to promote or organize international exchanges and collaboration.

b. Africa (by Prof. S. Diop)

Let us review briefly the present situation in Africa with respect to marine science education. Despite the existence of well trained marine scientists, many of whom were trained abroad (see COMARAF or UNEP/UN/Unesco Directory for Africa), the educational resources of our continent are not directed towards a timely development of the field of marine science for several different reasons:

1. Only a few universities have incorporated marine sciences as a full discipline in their programme. Therefore we find marine science specialities offered within different departments, such as geography, geology, biology, chemistry, and environmental studies, etc.
2. The available marine science specialists are very often scattered in separate institutions, i.e. in universities, research centers, scientific research departments, and ministries.
3. The most developed departments in nearly all African countries are the fisheries departments because of the "immediate-profit" effect that the government authorities expect to realize from their training. Fisheries departments however are, in most cases, completely separated from research centres and universities where the marine science research is normally undertaken.
4. Other drawbacks are the isolation and the lack of communication between specialists, the lack of scientific knowledge and technology skills, plus the limited funds available for marine science research and training.

As a result, on the African continent, there is a notable lack of programmes dealing with the understanding, harvesting and protection of the marine ecosystem as a resource. A view examples should be pointed out:

1. We only have few programmes against overexploitation of the resources, almost no conservation programmes, and only one or two focussed on the effects of pollution, and so on.
2. There is almost no exploitation of the deep-sea resources, except by foreign boats.
3. Despite the importance of the traditional knowledge, only a few mariculture programmes are developed on the African continent.
4. In many countries, destructive methods of marine resource harvesting are in use, such as small-mesh nets, dynamite, etc.

We feel that all marine scientists, specialists, managers and decision-makers would agree that in order to achieve significant progress in the field of marine science, cooperation and collaboration are absolutely necessary between countries, institutions, researchers, specialists and managers. Indeed, we are in a field where greater interdisciplinary interactions are needed. This aspect is realized by the Coastal Marine Project of Africa (COMARAF) which is intended to actively implement a regional network for the effective exchange of knowledge and expertise on a permanent basis among the participating African coastal countries. The corner stone of this regional network of collaborating institutions is the collection of multidisciplinary teams that are currently working on national coastal marine science programmes.

A primary objective of the COMARAF Project will be the implementation of joint research programmes oriented towards field research and training. It is felt that this will optimize the use of available funds, expertise and equipment. With these regional networks, it will be possible to create not only a pool of scientists working in marine science but also a pool of laboratory and field equipment. This approach suggests that there is less of a need to create individual centres in each country and more of a need to create regional centres and "reference centres", integrating permanent training. Interregional and international cooperation are absolutely necessary for the success of these efforts.

Looking at our continent, it seems that we need to do an inventory of the most significant problems and promote applied research programmes to address their solution. For example one might pose the problem: How can marine science research contribute to the "food self-sufficiency" of the continent? This is one question which is raised very often and which calls for a true dialogue between researchers, scientists, managers and "open-minded" politicians - a very difficult task indeed! The basis of this kind of research will necessarily be related to the natural and anthropogenic changes in coastal marine systems, and to resource harvesting, conservation, preservation and pollution problems.

In order to discuss the problem of new technologies, I will select the case of remote sensing applications in the coastal and nearshore zones of Africa. This tool can be very efficient in certain cases, despite the technical problems of data availability, hardware and software costs, and the scientific problems of the lack of specialists for the analyses, of variable data quality, and of limited coverage due to clouds and other atmospheric conditions. In other words, the application of remote sensing to African problems in marine science is a good example of how a very modern technology might be advantageously used if certain obstacles related to the developing nature of the science could be overcome.

We all know that remote sensing can be employed as a tool for coastal zone analysis and management because of the:

i. spatial synopticity and coverage;
ii. option for repetitive data;
iii. potential for quasi-real time data;
iv. variety of information offered through using different wave

lengths or sensors;

v. capacity to make observations in relatively inaccessible places.

For this tool to be more efficiently used, considering the high cost of the technology involved, a means must be set up to share the existing equipment and facilities between different laboratories. An emphasis should be placed on the standardization of the methodology to facilitate an inter-laboratory sharing. As it is now, even within the same country where certain remote sensing capability does exist, the cooperation and the common use of this equipment remains difficult.

Another point relevant to remote sensing applications in our countries is that the use of microcomputers (pc's) is certainly more efficient than the integrated sophisticated computer systems which raise great difficulties of maintenance, qualified personnel and cost of computer use. The microcomputers are more flexible with relatively easy software. As an example, the Unit for Satellite Imagery Processing (UTIS) in Senegal has different applications in oceanography and coastal research: fisheries, climate forecasting and other possibilities in meteorology and climatology.

Image processing from METEOSAT and NOAA satellite data are now being used to provide sea-surface temperature maps for the upwelling areas which are important to fisheries. Colder subsurface waters are brought to the surface by an offshore transport produced by the local wind regime. The subsurface waters are sufficiently rich in nutrients to maintain large phytoplankton populations, which are evident also by remotely sensed color imagery. Correlation analysis with data obtained in the field provides a means to evaluate the primary production. This in turn is a mechanism to estimate the higher pelagic biomass, vital for example to the pelagic fisheries, the tuna fisheries, or to the localization of the fish larvae.

We cite another example of a problem applicable to the coastal zone: How to explain the very quick degradation of the mangroves areas when linked with increasing acidity and salinity of the waters and soils? The biomass and index of vegetation succession are clearly showing this degradation. The thematic cartography and diachronic mapping from SPOT satellite imageries give very good correlations with field measurements: radiometric transects with determination of chlorophyll in the vegetation, decrease of the water-table, hypersalinity and appearance of bare, salty surfaces.

In both cases, the results are providing useful maps for management purposes. However, we must insist on the importance of the ground-truth correlation and the calibration of the equipment. Further, the use of microcomputers should be expanded, depending of course on the telephone-line quality, through the establishment of a microcomputer network between different countries for scientific exchange, documentation and coordination of regional activities. A feasibility study on this has been undertaken for the East African region.

In the third part of this presentation, I will emphasize that the international programmes have to play an important role in improving marine science research, teaching and training in our countries.

We all know about the International Geosphere-Biosphere Programme(IGBP), a most important programme launched by ICSU last year. Four coordinating panels and four working groups have recently been set up. Our present workshop would be mostly interested in the panel on marine biosphere-atmosphere interactions. Its central theme concerns the dynamics of the euphotic zone and the consequences of its response to atmospheric forcings on its primary production and structure of its local ecosystem. The feedback between the organisms and the physical system is also stressed. One of the programmes felt to be relevant to the IGBP goals, is the JGOFS programme, which includes the following items to be studied:

i. rate of air-sea exchange of gases;
ii. dependance of the rate of primary production on ocean circulation and nutrient dynamics;
iii. dependance of air-sea gas exchange on characteristics of the marine ecosystem;
iv. decomposition of biological matter below the euphotic zone;
v. oceanic sedimentation processes and biological dynamics at the sea bottom.

The central theme of the planned study conference of the IGBP panel will be the "modelling of the physical, chemical and biological processes in the euphotic zone of the ocean".

I would like to once again insist that the regional component of the IGBP must be stressed in order that the African continent, but also Asia and Latin America for example, be able to fully participate in this programme. We have to bear in mind that in all these continents, which mainly concern the tropical belt, major interregional marine science activities with research and training components, particularly in the coastal marine systems, have now commenced in the COMAR programme. If the principle of including the response of coastal zones to the effects of global environmental changes has been considered as important, we will have to identify precisely the coastal zone issues relevant to the broader goals of the IGBP.

It is sure, however, that a realistic strategy, particularly in our continent, must be adopted for a maximum efficiency of this kind of very broad and worldwide programmes. When important but fundamental research is involved, such as solar-terrestrial models, measurements of solar flux, ozone depletion, air-sea exchange of gases, etc., it will be difficult to fully involve the African community because of the scarcity of scientists in these fields. Furthermore, there is no direct and immediate interest and application of these subjects for the African people. However, other questions concerning, for example, in-situ observations, standardization of measurements, monitoring of coastal ecosystem modifications, watershed modelling, etc., would be much more easily accepted by the scientists of our continent. Also for these subjects, an interdisciplinary approach as part of joint research projects is important, and international collaboration is needed.

c. Small Islands (by Dr W. Hunte)

Small islands have two general characteristics that make them unique with regard to their needs for expertise in marine science:

1. The ratio of their coastal area to land mass is much higher than for coastal nations or even large islands. This factor makes their coastal zones particularly important as a food resource, touristic attraction and waste recipient.

2. Due to the UN Law of Sea treaty, small islands are responsible for large areas of oceanic resources. Therefore, education, research and application of marine science are important to national development, yet this importance is not proportionally reflected in the allocation of funds in national budgets.

Six interrelated issues are relevant to the needs of small islands in the field of marine science:

1. Fisheries and Marine Resource Management. Two primary questions that must be answered are: For any particular marine resource what is the appropriate level of exploitation? Is the stock/resource island-specific or is it shared with other islands or nations? The characteristics of marine resources relevant to their exploitation differ greatly. Therefore, marine management must be resource-specific. In the Caribbean, coastal resources are now fully or overexploited. Oceanic resources further offshore may offer, a limited but typically unknown, potential for increased exploitation. There is often considerable variation in abundance of these oceanic resources due to the influence of large-scale climatic processes. Understanding these effects will improve the predictive capability of those concerned with the oceanic fisheries.

2. Deterioration of Coastal Marine Habitats. The problem of over-exploitation of coastal resources is aggravated by the vulnerability to environmental change of many of the coastal habitats, such as coral reefs, seagrass beds and mangroves. Deterioration in coral reefs, for example, is caused by sewage discharge, often aggravated by tourism, and by land run-off in the form of erosion products and chemical fertilizers and pesticides. Run-off is aggravated by vegetation clearance for housing and hotels and by inappropriate agricultural techniques. Studies are needed to determine which organisms are sensitive to what components of the discharge/run-off and at what concentration, and to determine the pathways and residence times of these contaminants in the environment. In particular, the role of agricultural pesticides in coastal deterioration is poorly known.

3. Monitoring Programmes. Both fisheries management and coastal zone management require comprehensive monitoring programmes to quantify the current state of the coastal resources and environment, to assess the rate of change, and to evaluate the impact of any management activity implemented. It is important that these monitoring programmes be appropriately designed and implemented. The monitoring programmes and supporting research will generate information which must be stored, retrieved and disseminated.

4. Management of Information. The obtaining and handling of information relevant to resource management is essential for effective management. The scientific and management data should be archived as part

of a marine database. Specialist advice may be required at any or all stages of the processing, storage, dissemination and interpretation of the data.

5. Implementing and Enforcing Management. The implementation and enforcement phase of a management programme on marine resources and/or on the coastal zone habitat is critical. Two points are stressed:

i. An appropriate administrative infrastructure for managing marine resources and the coastal zone must be developed. In addition, this body could negotiate with foreign nations that are exploiting national resources.

ii. The enforcement of management will be enhanced by cooperation of the resource users and the public. Public and political environmental awareness programmes are required. Resource users should be encouraged to be partners in management. Traditional knowledge of marine organisms should be incorporated into the management schemes, and traditional approaches to management should be considered wherever appropriate.

6. Education and Research. Education and research in basic marine science should be emphasized. There is inadequate understanding of the population dynamics of tropical marine organisms and of the functioning of tropical marine ecosystems. Basic and applied marine science are closely integrated. In an attempt to appear "useful" to the public, to the government and to the agencies, the objectives and quality of our basic marine science should not be sacrificed. It must be remembered that basic science is the foundation on which we can successfully apply our understanding to national needs.

A central constraint on the quality of marine science education and research is the funding required to attract and retain high quality staff, to support research programmes and to support research students within the programmes. Students will become increasingly computer literate, computer-assisted learning will increase, but this must not replace direct interaction between student and lecturer. Developed countries can best assist others by offering short-term training in the context of clearly defined specialist skills. The higher degree programmes for M.Sc. and Ph.D. should typically be conducted in the ecological and social circumstances in which the student will subsequently function.

ANNEX 4

PRESENTATION AND DEMONSTRATION OF EXAMPLE MATERIALS

a. Remote Sensing (by Dr I. Robinson)

Seven lessons have been written as the first of a series to guide oceanography students at senior undergraduate and postgraduate level into the oceanographic interpretation and application of remotely sensed image data. The lessons have been supplied under the terms of a Unesco contract with the UK Open University, and are built around the image processing toolkit "Bilko", created for Unesco under the same contract by Dr R. Callison of Dundee University. This software operates on personal computers with MS-DOS, which also support the EGA (Enhanced Graphics Adaptor) and high resolution color monitor.

The lessons are intended to provide self-paced tuition and experience to students as a supplement to a more formal course in the principles and applications of ocean remote sensing. Each one is focussed on a set of aims, which are build up cumulatively to lead the student into familiarity both with the image analysis toolkit and with the principles of image interpretation. Several image datasets are supplied with each lesson, covering sea-surface temperature and ocean colour data of north-western European sea locations from satellites and aircraft. Most of the data have been preprocessed to apply geometric and atmospheric corrections and much stress is placed upon using the data to make measurements of ocean properties, such as temperature, at particular geographic locations. The student is encouraged to appreciate that the image dataset is not simply a picture to be enhanced, but represents many thousands of individual, accurate, ocean measurements.

It is anticipated that further lessons will be produced, covering different ocean areas, and these could provide the foundation for a worldwide network of cooperation in ocean remote sensing training. Lessons could be contributed by educators from many oceanic regions, based on their local seas, if relevant images can be provided for them by those who have the advanced computing facilities necessary for preprocessing procedures.

Some outstanding issues facing the development of training programmes in marine remote sensing are:

1. Training can be developed in collaboration with remote sensing and space agencies, but it must be noted that marine applications of remote sensing require a different approach from other remote sensing applications. It is vital that marine science agencies are also driving the training programmes for marine remote sensing. In the past there has been a tendency for ocean application to be treated only as a part of the training of broadly-based remote sensing specialists, who may lack a proper understanding of ocean science. It is essential that those remote sensing scientists responsible for developing marine application programmes are also trained in marine science. Better still, marine scientists should be

trained in the relevant methods of remote sensing so that they car take the lead in marine remote sensing.

2. Training in remote sensing requires access to satellite data. Some agencies have an "open skies" policy of access to data at minimum cost, but others charge high prices to all users for the provision of data. Because effective marine remote sensing requires multitemporal image data of a particular location it can become far more expensive in data costs than the study of land applications. It is important that satellite agencies be made aware of the severe limitations to training which are being imposed by high costs. It should be pointed out to them that in the interests of furthering the use of remotely sensed data, and indeed of encouraging the future growth of commercial markets for remotely sensed data, easy and cheap access to data should be provided for education and training purposes. Otherwise the growth and development of the marine applications of remote sensing could be seriously restricted.

b. Computer-assisted Learning (by Dr A. Edwards)

The aim of this presentation is to give a very quick introduction to the potential for the use of computers in the education of marine scientists, seen from the viewpoint of an educational technologist, *not* a Marine Scientist.

One important topic is the possible role of computer-assisted learning or CAL. This can be set into context through a brief history. The basic building block of a CAL lesson is the frame. Taking a CAL lesson involves navigating through a set of frames. The simplest form of a CAL lesson is the *linear programme*, in which the student is led through the same set of frames in a linear manner. This form of lesson is based on behaviourist psychology and is now rarely used. It is no longer considered an appropriate way of teaching complex material to people.

The next form of CAL is the *branching programme*. This gives the student corrective feedback and is adaptive to student responses. The main problem with this kind of lesson is that it rapidly becomes very complex. Even with the aid of tools, such as *authoring systems*, it is beyond the capabilities of most teachers to create such complex programmes.

Generative CAL allows students to work on problems generated by the computer. This makes lessons better adapted to individuals. However it can only be applied in fields in which it is easy to generate problems, which really implies limiting it to arithmetic.

Simulation is another very important use of computer, which can be classed as a branch of CAL. Simulation can be used when it is too expensive or dangerous to teach students through direct experience.

Given this brief introduction to the nature of CAL, the reader is referred to the summary of its features which appears in section VII of the

Synthesis Chapter.

Another use of computers in education can be called *emancipatory*. That is where the computer is used as a tool. It may, for example, give access to databases, or be used to do calculations. One should also not neglect the need for education in the use of computers themselves. Most jobs- including those done by marine scientists - involve the use of computers in some way.

It is possible to speculate about how computers will be used in education in the year 2000 and beyond. There will be increased use of interactive video. Significant developments in Intelligent Computer-Assisted Instruction (ICAI) can also be anticipated. An intelligent tutoring system is essentially two expert systems: one which knows about teaching and one which knows about the subject to be taught. There will also be increased concern with the design of the student-computer interface. One example currently being researched is the Alternative Reality Kit, a direct manipulation interface that has been used so far to teach physics, but which can be expected to be used much more widely in future.

I have brought an example CAL lesson with me today to demonstrate. It is known as the "Water Disk", and I would say that it represents the current state-of-the-art in frame-based, branching CAL with interactive video. It allows the user quite extensive control over the lesson and hence achieves a degree of individualization. The lesson is taken from an Open University undergraduate science course, not a marine science course. However, I hope participants will be able to see how their own subject might be taught in a similar manner. The disk was produced by a course team and the University's Academic Computing Service, and special credit is due to John Bolton, the course-team chairman and sciptwriter for the disk.

c. <u>World Maritime University Instruction</u> (by Prof. A. Couper)

The presentation of simulation material from the World Maritime University took two forms: (i) explanation of 13 overhead-projector transparencies used for the simulation, and (ii) a video recording of the presentation and debate by WMU students in plenary session.

The objectives of the simulation were outlined. These were to allow government administrators and commercial managers to adopt various procedures in determining a policy for an EEZ. The game required the integration of many possible sea uses. Working groups from ministries were expected to apply their knowledge of basic science, economics, law, etc. to produce policy options which would give maximum net-benefit to the nation rather than maximizing any particular concern, e.g. employment, environmental protection, fish catch, balance of payment, local food supply, etc. It was nevertheless expected that priorities would be stated and supported. The use made of data and the transparencies for correlations as a basis for working group deliberations were outlined.

The organization of the simulation was described. Initially, working groups followed the standard-bureaucracy model and thus were constituted on the basis of ministries and reported as such. Following this, they were reconstituted on an "adhocracy" model forming interdisciplinary task forces. The successful EEZ/Ocean plans emerged from the latter. The merits of simulation conducted in this way were stated, and the policy of the WMU and its sponsors of refining this method for distribution more widely outlined.

d. North Sea Pollution Model (by Prof. J. Backhaus)

As a specific example of the use of a numerical model for public education and resource/pollution management, I would like to present the results of an oceanographic model of the North Sea. This experiment was designed to determine subseasonal, seasonal and interannual fluctuations of the circulation, and to simulate its effect on the transport of discharges into the North Sea.

A scenario of fourteen years (1969-1982) was simulated, including the tides, the seasonal means of temperature and salinity, and the local wind forcing. The results were condensed on to a floppy disk and a video cassette, that illustrate:

1. On the Floppy. An overall mean of the simulated flow and its effect on the transport and dispersal of the pollutant load from several of the major rivers. To estimate cause and effect relationships, the rate of volume discharge can be manipulated by the operator. Consequently, the use of the North Sea floppy by non-experts provides insight into both the circulation and the (mean) fate of pollutants within the sea. In this way the floppy presentation points out the potential of the use of models in marine planning and management of resources.

2. On the Video. An animation provides insight into the temporal and spatial fluctuations of pollutants in the sea. It relies on the simplifying assumptions that there is a constant discharge, that the pollutant substances are passive, and that no biological or chemical processes are affecting them. The result is therefore an estimate of the variability of substance concentrations in the sea based solely on the variability of the physical environment.

The video movie was produced solely by digital electronics. It demonstrates the potential of time-dependent model simulations; the clear visualization of model results represent a valuable didactical tool for explaining complex processes to non-experts.

As a point of caution, both examples of the display of model results rely on simplifying assumptions; in the first case solely mean conditions were assumed, in the second case mean emission rates were prescribed (due to lacking data). The latter, however, points at the likelyhood of peak events which were caused by the time-varying flow. It is near at hand to assume that variable discharge rates as well as biological and chemical processes may coincidently induce peak events which are even more drastic than shown in the video. Therefore estimates and decisions which are solely based upon mean conditions are dangerous - they exclude peak events. Environmental catastrophies are peak events which may cause a severe damage to the environment. Therefore they should not be excluded in decision-making.

Training and Education in Marine Science: the Views of 130 Members of ICLARM's Network of Tropical Fisheries Scientists*

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Abstract

A questionnaire on the teaching and training of marine science for the year 2000 and beyond was sent to the 732 members of ICLARM's Network of Tropical Fisheries Scientists. There were 130 responses, which were analyzed using X^2 tests for differences between geographical regions. Significant regional differences occurred with reference to the following areas: that mariculture, resource assessment and management, computer applications, and environmental impact and monitoring, will be important occupational areas towards the year 2000; that none of the present areas in marine science education will decline in importance; that computers and ecological modelling will complement the new areas of emphasis; that teaching methods will eventually change and be more applicable to each country's natural resource endowment; and that the NTFS presently plays an important role in marine science education and research.

Introduction

As a contribution toward the "UNESCO Workshop on Teaching and Training in Marine Sciences for the Year 2000 and beyond", the authors distributed questionnaires prepared by the staff of the UNESCO Marine Science Division to the 732 members of ICLARM's Network of Tropical Fisheries Scientists (NTFS). The questionnaire had been slightly expanded through the addition of a question pertaining to the role of the NTFS (see Appendix I). This contribution presents the results of a statistical analysis of the 130 responses received up to March 1988, by regions, defined in Table 1.

Table 1. Basic statistics of survey of NTFS numbers, as used in this contribution.

Item	Asia-Pacific	Africa and West Asia	Area Latin America and Caribbean	Europe, USA and Canada	Total
Number of countries	28	27	26	13	94
Number of NTFS members	370	129	83	150	732
Number of respondents	57	19	15	39	130
% response	15	15	18	26	18

*ICLARM Contribution No. 469.

The reasons for creating the NTFS were that "fisheries scientists in the tropics tend to work in far greater isolation than those in temperate regions and the lines of communication, such as they are, often run north-south instead of equatorially. The result is that scientists in adjacent countries or even in the same country can quite often be unaware that they are working on parallel tasks. Scientists of the Indo-Pacific and of the Atlantic seas have similar problems and similar fisheries but minimal contacts, particularly if they do not rank high in seniority [...]. The principal vehicle for communication in the Network [is] a newsletter [called "Fishbyte", now in its fifth year] for exchanges of informal notes, news and views on stock assessment and management" (Munro and Pauly 1982).

Membership of the NTFS is now 732; Table 1 gives a regional breakdown. Funding for the NTFS activities comes from ICLARM, the FAO/DANIDA (Danish International Development Agency) Training Course in Tropical Fish Stock Assessment, the FAO regular program and NORAD (Norwegian Agency for International Development) (through the R/V Fridtjof Nansen Project).

Materials and Methods

The modified UNESCO questionnaire was mailed to members of the NTFS during November 1987, with a cover letter requesting answers to be returned no later than the end of December 1987. However, answers were received well into 1988 and the cutoff date was extended to 31 March 1988; altogether 130 answers were considered, of which 90% consisted of filled questionnaires, and the rest of informal letters. Some questionnaires were completed by groups, but these were treated as individual answers.

Since the questionnaires were open-ended, the responses received were divided into subsets (see Table 2 where the number to the left refers to the original number of each question). This increased the number of "questions" from 7 to 14. All responses provided by respondents were included in the tabulation. Thus, the least frequency per response is 1. This implies that for any question with *n* number of alternative responses, one respondent may have from 1 to *n* responses. Thus, the total number of responses per region may exceed the number of respondents. For example, Question #1 has 11 possible responses. For the Asia-Pacific region, which includes a total of 57 respondents, this implies an expected total of 627 responses (see Table 2).

Table 2. Summary of responses to UNESCO questionnaire (questions 1-6) with X^2 for significance of regional differences computed as explained in the text (see also Table 3); • refers to $P < 0.9$; •• to $P < 0.95$ and ••• $P < 0.99$.

	Respondents: Asia-Pacific	Africa and West Asia	Latin America and Caribbean	Europe, USA and Canada	Total	Computed X^2
1A. WHAT NEW OCCUPATIONAL AREAS THAT REQUIRE EXCLUSIVE OR ACTUAL EXPERTISE SEEM TO BE INCREASINGLY IMPORTANT TOWARDS 2000?						
a. Mariculture/Marine Aquaculture (genetics, disease, ocean ranching, coastal aquaculture)	20	10	8	18	56	25.82•••
b. Marine Engineering/Electronics	6	1	1	2	10	
c. Resource assessment and management/coastal management	27	6	4	8	45	8.02••
d. Mineral deposits/energy sources	7	2	2	2	13	
e. Social sciences (economics, politics)/Marine policy	4	1	2	14	21	
f. Computer applications such as acoustics, GIS, remote sensing, automated monitoring)	8	3	2	12	25	8.70••
g. Environmental impact and monitoring	12	3	3	18	36	9.68••
h. Mathematics and statistics	1	2	1		4	
i. Resource bioeconomics	1	1		2	4	
j. Ecology/ecosystem approach	9	4	4	4	21	2.67
k. Gear technology		1	1		2	

Continued

Table 2. Continued

	Asia-Pacific	Africa and West Asia	Respondents Latin America and Caribbean	Europe, USA and Canada	Total	Computed X^2
1B. WHAT AREAS WILL SIGNIFICANTLY DECREASE IN IMPORTANCE?						
a. None	5	2	5	8	20	6.76*
b. Descriptive marine biology (taxonomy)	8	3	1	2	14	2.69
c. Descriptive ecology (biochemistry)	4	1	3	3	11	3.01
d. Research vessel surveys	1	1		1	3	
e. Physical oceanography	6		1	3	10	
f. Fishing gear technology				1	1	
g. Baseline data gathering	2				2	
h. Classical population dynamics	1	1		1	3	
2. WHAT KEY KNOWLEDGE AND SKILLS WILL BE REQUIRED AT THAT TIME?						
a. Computer applications	19	3	8	18	48	7.12*
b. Basic sciences (physics, mathematics, chemistry, biology)	8	1	3	4	16	2.01
c. Social sciences (economics, politics)	5		1	3	9	
d. Cost-effective research	1			1	2	
e. Technical skills and extension work	4	1	4	3	12	6.24
f. Environmental conservation and management	3	1		2	6	
g. Improved assessment/monitoring skills	9	4	1	1	15	6.12
h. Ecological approach/modelling	17		1	10	28	9.68**
i. Applied science	4	1		2	7	
j. Genetics				1	1	
k. Aquaculture engineering				1	1	
3A. WILL TEACHING METHODS USED TO IMPART KNOWLEDGE AND SKILLS CHANGE?						
a. Yes; (have to be changed)	27	10	13	22	72	7.5*
b. No	7	2	2	3	14	0.62
c. No idea	1				1	
HOW:						
a. Shift from theoretical to applied (on-the-job training)	16	4	4	14	38	1.64
b. Post-educational training	5	1		4	10	
c. Computer-based and audio-visual methods	22	4	6	10	42	3.33
d. Re-education	2				2	
3B. HOW CAN DEVELOPMENTS IN TECHNOLOGY IMPROVE THE METHODS TO ACQUIRE KNOWLEDGE AND SKILLS FOR THOSE HAVING FINISHED THEIR FORMAL EDUCATION?						
a. Ability to teach specialized marine science	4	1		5	10	2.89
b. Post-educational training	3			2	5	
c. Computer-based, audio-visual teaching methods	7	2		5	14	2.12
d. Application of techniques	2	1	1	5	9	
e. Multidisciplinary approach	3	1		3	7	
f. More effective information dissemination	4				4	
g. Upgrade teaching skills	4				4	

Continued

Table 2. Continued

	Respondents					
	Asia-Pacific	Africa and West Asia	Latin America and Caribbean	Europe, USA and Canada	Total	Computed X^2
3C. WHAT IS THE ROLE OF DISTANCE LEARNING AND COMPUTER-BASED EDUCATION?						
a. None/not effective	1			1	2	
b. Complementary (used as tools only)	14	2	3	11	30	2.41
c. Very important	2	3	2	4	11	3.74
3D. HOW CAN METHODS BE ADAPTED TO DEAL WITH ENORMOUS GROWTH IN INFORMATION AND SPECIALIZATION?						
a. Specialization (smaller groups)	1	1		1	3	
b. Use of computers	6	2	4	2	14	5.24
c. Training of personnel	5			1	6	
d. Workshops/seminars/networks	4	2			6	
e. Standardize methods	3		1		4	
4A. WHAT ARE THE MAIN OBSTACLES TO APPLY SUCH INSTRUCTIONAL METHODS, PARTICULARLY IN COUNTRIES DEVELOPING THEIR MARINE SCIENCE CAPABILITIES AND WHAT IS NEEDED TO OVERCOME THEM?						
a. Funds (equipment, training, technical capability)	39	10	8	21	78	3.01
b. Lack of appropriate primary education	3	1	1	3	8	
c. Politics, traditional/cultural barriers (e.g., language)	12	1	5	12	30	5.72
d. Lack of qualified teaching staff	13	5	6	16	40	4.4
e. Technology, e.g., computer literacy		1			1	
4B. HOW TO OVERCOME THESE BARRIERS?						
a. Government to government approach	2	2			4	
b. Symposia	3	2	2	1	8	
c. "Open-mindedness"	3	1	1	1	6	
d. Scientists from developed countries to act as "experts"			2		2	
5A. WHAT WILL AND SHOULD BE THE MAIN DIFFERENCES IN EDUCATIONAL REQUIREMENTS IN MARINE SCIENCE BETWEEN REGIONS AND COUNTRIES?						
a. Education should be dovetailed to suit the country's resource endowment and potential	24	14	8	15	61	7.36*
b. Export of professionals from developed to developing countries rather than offer scholarships to developing countries	2	1		1	4	
c. Export of personnel from developing to developed countries						
d. Shift to practical approach (technical and management)	5	2	2	1	10	2.43
e. None	4	1		3	8	
f. Export of scientists from developed to developed countries		1			1	
g. Difference in national objectives	3		1		4	
h. Developed countries to rely on technology				1	1	

Continued

Table 2. Continued

	Asia-Pacific	Africa and West Asia	Respondents Latin America and Caribbean	Europe, USA and Canada	Total	Computed X^2
5B. TAKING INTO ACCOUNT CERTAIN NEGATIVE IMPACTS OF NATIONAL DEVELOPMENT STRATEGY OF THE 70S AND 80S, WHAT EXPERIENCES FROM COUNTRIES WITH A LONG TRADITION IN MARINE SCIENCE TEACHING AND TRAINING ARE AND WILL BE RELEVANT FOR COUNTRIES DEVELOPING SUCH CAPABILITIES AND VICE VERSA?						
a. No value for those just starting	1				1	
b. Gap between LDC and OECD to widen				2	2	
c. Degradation experience	3			1	4	
d. Export of skilled personnel from developed countries	2			1	3	
6. HOW CAN MARINE SCIENCE TEACHING AND TRAINING BE MADE MORE EFFECTIVE IN ACHIEVING THE PERCEIVED GOALS FOR THE STATE OF THE ENVIRONMENT AND THE MANGEMENT OF MARINE RESOURCES FOR YEAR 2000 AND BEYOND?						
a. Improve local training capacity/ manpower planning	9	6	3	6	24	2.71
b. Improve undergraduate level teaching e.g., by periodic review of curricula	11	3	1	5	20	1.75
c. Regional/global research centers to permit more contact among scientists	10	2	2	3	17	2.1
d. Training of decisionmakers	4	1		7	12	5.76
e. Link-up with economic goals	4	1	2	2	9	
f. Interdisciplinary approach	2			1	3	
7. ROLE OF THE NTFS						
a. Education and research	3	3	3	9	18	6.84*
b. Information dissemination with regard software case studies, translations, critical reviews of papers, scientific publications	8	3	3	3	17	1.8
c. *publication of journal/newsletter	5	2		3	10	
d. Extension work	2	1			3	
e. Submit position papers	9		2	10	21	6.35*
f. Roster of personnel/profile of researches	3	1	1	2	7	
g. Curator of data center	2				2	
h. Assistance in securing funds	6	1	3	1	11	4.89
i. Assisting interns in participating in training programs/workshops	7	2	5	3	17	6.65*
j. Establishing geographical units/ meetings	11	7	2	6	26	4.32
k. Expand scope, e.g., to aquaculture; network of marine scientists	1			1	2	
8. NON-RESPONSE						
a. Irrelevant study				2	2	
b. Already received a copy	1				1	
c. Passed to another	1				1	
d. No experience in marine science	3			1	4	
e. Late; busy	1			1	2	

Inferences based on simple frequency analysis are not affected by this because the importance of a particular response is evaluated on the basis of absolute and not of relative frequencies and because the regional totals and the number of responses per category can be treated as independent.

The chi-square test was applied to learn whether regional differences in attitude, stage of economic development, etc., influence response.

The chi-square value provides an estimate of the significance of any differences between the observed and expected frequencies, the expected frequency being a function of the row and column totals. Since the resulting row and column totals do not represent the actual number of responses, no valid generalization about a particular question can be made using this test. This inconsistency was remedied here by applying the chi-square to every response with 10 or more occurrences, and not to the whole response block (all responses pertaining to one question).

For example, for Question #1, 20 out of the 57 respondents from the Asia-Pacific region perceived mariculture/marine aquaculture to be an increasingly important occupational area requiring expertise towards the year 2000. This implies that the remaining 37 of the respondents did not consider mariculture as important. The chi-square table used would then have 4 columns, representing the 4 regions and 2 rows, representing either an affirmative or negative response. (See Table 3 for an illustration of this example). The same procedure was applied to all responses listed in Table 2 for which 10 or more responses were available.

Table 3. Illustration of arrangement of responses and computation of X^2 values for a given question (here: No. 1a, significance of aquaculture). The i refers to rows (i.e., response) and the j to the column (i.e., region).

	Area				
Item	Asia-Pacific	Africa and West Asia	Latin America and Caribbean	Europe, USA and Canada	Total
Observed values = O_{ij}					
Total number of respondents	57	19	15	39	130
Important	20	10	8	18	56
Not important	37	9	7	21	74
Expected values = E_{ij}					
Important	24.55	8.18	6.46	16.80	
Not important	21.06	5.12	3.98	11.95	
$(O_{ij} - E_{ij})^2$					
Important	0.84	0.4	0.37	0.09	
Not important	12.06	2.93	2.28	6.85	

$$X^2 = \sum_j \sum_i \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Results and Discussion

The NTFS members considered marine aquaculture, resource assessment and management (including coastal zone management), computer applications (Geographical Information Systems or GIS), remote sensing, automated monitoring, acoustics, environmental impact and monitoring, and ecology/ecosystem approach to be increasingly important as new areas requiring expertise by the year 2000 (Table 2). Some members believed that the areas of descriptive marine biology including taxonomy and ecology will decline in significance, but the dominant view is that none of the areas now important in marine science education will wane - at least up to year 2000.

As a complement to the new areas of emphasis, the NTFS members felt that skills in computer applications, ecological modelling, the basic sciences including mathematics, physics and chemistry, improved technical extension work and monitoring should be upgraded.

An overwhelming affirmation of the eventuality of change in the methods used to impart knowledge and skills, if not an actual and urgent need for it, was expressed by the NTFS members. Changes should occur by employing computer-based and audiovisual methods and shifting, as one respondent put it, "from theoretical to practical training".

"Distance learning" and computer-based education were judged important but most of the respondents considered these more as tools and complements to existing educational methods rather than as major methods. This "tool/complement" nature is again highlighted by the respondents' perceived importance of computers (as against training of personnel through workshops, etc.) in handling the enormous growth in information and specialization.

NTFS members pointed to the scarcity of funds as the greatest obstacle to the application of improved instructional methods. Scarcity of funds affects recruitment of trained personnel, improvement of technical capability, and purchase of equipment. The absence of qualified teaching staff figured prominently as an obstacle although it was also mentioned as a consequence of scarce funding. To a lesser extent, political and cultural barriers were also regarded as obstacles to efficient implementation of modern instructional methods.

To overcome these barriers, some respondents suggested bilateral and/or multilateral agreements between governments, the holding of symposia (e.g., to foster "open-mindedness"), and "transfer of technology" from developed to developing countries.

The majority of respondents believe that marine science education should be tailored to suit the country's resource endowment.

In order to upgrade teaching and training, the NTFS members believe the following should be achieved: improve local training capacity/manpower planning; improve undergraduate level teaching; establish regional/global research centers to permit more contact among scientists; and train decisionmakers.

The responses to Question #7 highlight the achievement of the NTFS in the field of education and research, specifically in information dissemination. However, NTFS members perceive the need to create more impact in the field of marine science education by: preparing/submitting position papers; establishing geographical groupings and organizing regular meetings; and, assisting members in securing funds for training and workshops.

Table 2 shows the results of the chi-square tests. The following statements relevant to marine science education were observed to be associated with significant regional differences:

a) that mariculture, resource assessment and management, computer applications, and environmental impact and monitoring will become increasingly important occupational areas by the year 2000;

b) that none of the present areas in marine science education will decline in importance;

c) that use of computers and ecological modelling will complement the new areas of emphasis;

d) that teaching methods will or have to change;

e) that education should be adapted to suit a country's resource endowment, thus leading to the differences of the educational requirements among countries;

f) that the NTFS contributes usefully to education and research, but that it also should assist with preparation/submission of position papers, and provide assistance for interns to participate in training workshops.

The method of analysis we used here, however, does not straightforwardly allow for identification of possible causes for these regional differences.

Overall, the responses received correspond to the general recommendations in ACMRR (1981), Chia (1984), Chua (1987) and Agüero and Costello (1987) and with the results of UNESCO/ROSTEA (1988).

We intend to refine our analysis in a future contribution, by matching the responses we received with specific characteristics of the respondents (e.g., their educational levels and type and number of publications), such as to be able to identify causes for the observed regional differences. Such detailed analysis may yield insights concerning improvements capable of implementation, e.g., through the NTFS or as part of some activity on Training, Education and Mutual Assistance in the Marine Sciences (TEMA) (UNESCO 1984).

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Appendix I: Modified UNESCO Questionnaire, as Sent to NTFS Members

1. What new occupational areas that require exclusive or partial expertise in marine science can be foreseen as developing towards the year 2000? What areas will significantly decrease in importance?

2. What key knowledge and skills will be required at that time and how will these differ from today's?

3. What will the university teaching methods used to impart the knowledge and skill change? If so, how? How can developments in technology improve the methods to acquire knowledge and skills for those having finished their formal education?

   What will be the roles for distance learning and computer-based instruction?

   How can methods be adapted to deal with the enormous growth in information and specialization?

4. What are and will be the main obstacles to applying such instructional methods, particularly in countries developing their marine science capabilities, and what is needed to overcome them?

5. What will and should be the main differences in educational requirements in marine science between regions and countries? What will this mean for national teaching and training programs?

   Taking into account certain negative impacts of the international development strategy of the 70's and 80's, what experiences from countries with a long tradition in marine science teaching and training are and will be relevant for countries developing such capabilities and vice versa?

6. How can marine science teaching and training be made more effective in achieving the perceived goals for the state of the environment and the management of marine resources for the year 2000 and beyond?

7. What role could the Network of Tropical Fisheries Scientists of ICLARM play in tackling the issues raised in points (1) to (6)?

ANNEX 6

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(items with computer or video material are marked with an *)

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ANNEX 8

ACRONYMS

ALT	Altimeter
AVHRR	Advanced Very High Resolution Radiometer (TIROS-N)
CAL	Computer-assisted(aided) Learning
CD-ROM	Compact Disk - Read Only Memory
CD-WORM	Compact Disk - Write Once Read Many times
COMAR	Coastal Marine Project (Unesco)
COMARAF	Coastal Marine Project of Africa (Unesco/UNDP)
CZCS	Coastal Zone Colour Scanner (Nimbus-7)
EARN	European Academic and Research Network
EC	European Community
ECA	Economic Commission for Africa (UN)
ECOR	Engineering Committee on Oceanic Resources
EEZ	Exclusive Economic Zone
EGA	Enhanced Graphics Adapter
E-mail	Electronic-mail (other than Tmail, e.g. EARN)
ENSO	El Niño Southern Oscillation
ESA	European Space Agency
FAO	Food and Agriculture Organization (UN)
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution (IMO, FAO, Unesco, WMO, WHO, IAEA, UN, UNEP)
GOES	Geostationary Meteorological Satellite (NOAA)
IAEA	International Atomic Energy Agency (UN)
ICES	International Council for the Exploration of the Sea

ICLARM	International Centre for Living Aquatic Resources Management
ICOD	International Centre for Ocean Development (Canada)
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme (ICSU)
IMO	International Maritime Organization (UN)
IOC	Intergovernmental Oceanographic Commission (Unesco)
IODE	International Oceanographic Data and Information Exchange (IOC)
IT	Information Technology
IUCN	International Union for Conservation of Nature and Natural Resources
JGOFS	Joint Global Ocean Flux Study (SCOR-IOC)
METEOSAT	ESA geostationary Meteorological Satellite
MS-DOS	Microsoft - Disk Operating System
NGO	Non-governmental Organization
NIMBUS	US Meteorological Satellite
NOAA	National Oceanic and Atmospheric Administration (USA)
NORAD	Norwegian Agency for International Development
NTFS	Network of Tropical Fisheries Scientists (ICLARM)
OCE	Division of Marine Sciences (Unesco)
SAR	Synthetic Aperture Radar
SASS	Seasat-A Scatterometer System
SCOR	Scientific Committee on Oceanic Research (ICSU)
SMMR	Scanning Multichannel Microwave Radiometer (Seaset & Nimbus-7)
SPOT	Système pour l'Observation de la terre (France)
TEMA	Training, Education and Mutual Assistance in the Marine Sciences (IOC)

TIROS	Television Infra-Red Observation Satellite
TOGA	Tropical Oceans and Global Atmosphere
Tmail	Telemail-Omnet (Sciencenet, ocean subdivision)
UN	United Nations
UNCLOS	United Nations Conference on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USP	University of South Pacific
WHO	World Health Organization (UN)
WMO	World Meteorological Organization (UN)
WMU	World Maritime University (IMO)
WOCE	World Ocean Circulation Experiment

UNESCO REPORTS IN MARINE SCIENCE

No.		Year
42	The application of digital remote sensing techniques in coral reef, oceanographic and estuarine studies. Report on a regional Unesco/COMAR/GBRMPA Workshop, Townsville, Australia, August 1985 English only	1986
43	Quaternary coastal geology of West Africa and South America. Papers prepared for the INQUA-ASEQUA Symposium in Dakar, April 1986 Available in English only	1987
44	Physical oceanography of the Eastern Mediterranean (POEM): Initial Results Unesco/IOC First POEM Scientific Workshop, Erdemli, Turkey, 16-20 June 1986 English only	1987
45	Marine science teaching and training at first degree (undergraduate) level. Recommended guidelines from a Unesco workshop on university curricula Paris, November 1986 Available in Arabic, Chinese, English, French, Russian and Spanish	1987
46	Comparison between Atlantic and Pacific tropical marine coastal ecosystems: community structure, ecological processes, and productivity. Results and scientific papers of a Unesco/COMAR workshop. University of the South Pacific. Suva, Fiji, 24-29 March 1986 English only	1987
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Title of numbers which are out of stock

No.		Year
1	Marine ecosystem modelling in the Eastern Mediterranean Report of a Unesco workshop held in Alexandria, Egypt, December 1974 English only	1977
2	Marine ecosystem modelling in the Mediterranean Report of the Second Unesco Workshop on Marine Ecosystem Modelling English only	1977
3	Benthic ecology and sedimentation of the south Atlantic continental platform Report of the seminar organized by Unesco in Montevideo, Uruguay, 9-12 May 1978	1979
7	Coastal ecosystems of the Southern Mediterranean: lagoons, deltas and salt marshes. Report of a meeting of experts, Tunis, 25-27 September 1978	1979
11	Programa de Plancton para el Pacífico Oriental Informe final del Seminario-Taller realizado en el Instituto del Mar del Perú,	
12	Geología y geoquímica del margen continental del Atlántico Sudoccidental Informe final del Taller de Trabajo organizado por la Unesco en Montevideo Uruguay, 2-4 de diciembre de 1980	1981
13	Seminario Latinoamericano sobre Enseñanza de la Oceanografía Informe final del Seminario organizado por la Unesco en São Paulo, Brasil, 17-20 de noviembre de 1978	1981
16	Marine and coastal processes in the Pacific: ecological aspects of coastal zone management Report of a Unesco seminar held at Motupore Island Research Centre, University of Papua New Guinea, 14-17 July 1980	1981
17	The coastal ecosystems of West Africa: coastal lagoons, estuaries and mangroves. A workshop report, Dakar, 11-15 June 1979	1981
18	Coral reef management in Asia and the Pacific: some research and training priorities. Report of a Unesco workshop held in Manila, Philippines, 21-22 May 1981 English only	1982
	El Callao, Perú, 8-11 de septiembre de 1980	1981