Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change, Pilot Projects on Mangroves and Coral Reefs

Monaco, 9-13 December 1991

UNESCO

In this Series, entitled

Reports of Meetings of Experts and Equivalent Bodies, which was initiated in 1984 and which is published in English only, unless otherwise specified, the reports of the following meetings have already been issued:

1. Third Meeting of the Central Editorial Board for the Geological/Geophysical Atlases of the Atlantic and Pacific Oceans
2. Fourth Meeting of the Central Editorial Board for the Geological/Geophysical Atlases of the Atlantic and Pacific Oceans
3. Fourth Session of the Joint IOC-WMO-CPPS Working Group on the Investigations of «El Niño» *(Also printed in Spanish)*
4. First Session of the IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in relation to Living Resources
5. First Session of the IOC-UN(OETB) Guiding Group of Experts on the Programme of Ocean Science in relation to Non-Living Resources
6. First Session of the Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
7. First Session of the Joint CCOP(SOPAC)-IOC Working Group on South Pacific Tectonics and Resources
8. First Session of the IODE Group of Experts on Marine Information Management
9. Tenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies in East Asian Tectonics and Resources
10. Sixth Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
11. First Session of the IOC Consultative Group on Ocean Mapping *(Also printed in French and Spanish)*
12. Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ships-of-Opportunity Programmes
13. Second Session of the Joint CCOP/SOPAC-IOC Working Group on South Pacific Tectonics and Resources
14. Third Session of the Group of Experts on Format Development
15. Eleventh Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of South-East Asian Tectonics and Resources
16. Second Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
17. Seventh Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
18. Second Session of the IOC Group of Experts on Effects of Pollutants
19. Primera Reunión del Comité Editorial de la COI para la Carta Batimétrica Internacional del Mar Caribe y Parte del Océano Pacífico frente a Centroamérica *(Spanish only)*
20. Third Session of the Joint CCOP/SOPAC-IOC Working Group on South Pacific Tectonics and Resources
21. Twelfth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of South-East Asian Tectonics and Resources
22. Second Session of the IODE Group of Experts on Marine Information Management
23. First Session of the IOC Group of Experts on Marine Geology and Geophysics in the Western Pacific
24. Second Session of the IOC-UN(OETB) Guiding Group of Experts on the Programme of Ocean Science in relation to Non-Living Resources *(Also printed in French and Spanish)*
25. Third Session of the IOC Group of Experts on Effects of Pollutants
26. Eighth Session of the IOC-UNEP Group of Experts on Methods, Standards and intercalibration
27. Eleventh Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans *(Also printed in French)*
28. Second Session of the IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in Relation to Living Resources
29. First Session of the IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials
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31. Second IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
32. Thirteenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of East Asia Tectonics and Resources
33. Second Session of the IOC Task Team on the Global Sea-Level Observing System
34. Third Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
35. Fourth Session of the IOC-UNEP-IMO Group of Experts on Effects of Pollutants
36. First Consultative Meeting on RNODCs and Climate Data Services
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45. Ninth Session of the IOC-UNEP Group of Experts on Methods, Standards and Intercalibration
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47. First Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean
48. Twelfth Session of the Joint IOC-IHO Guiding Committee for the General Bathymetric Chart of the Oceans
49. Fifteenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies of East Asian Tectonics and Resources
50. Third Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes
51. First Session of the IOC Group of Experts on the Global Sea-Level Observing System
52. Fourth Session of the IOC Editorial Board for the International Bathymetric Chart of the Mediterranean
53. First Session of the IOC Editorial Board for the International Chart of the Central Eastern Atlantic *(Also printed in French)*
54. Third session of the IOC Editorial Board for the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico *(Also printed in Spanish)*
55. Fifth Session of the IOC-UNEP-IMO Group of Experts on Effects of Pollutants
56. Second Session of the IOC Editorial Board for the International Bathymetric Chart of the Western Indian Ocean
57. First Meeting of the IOC *ad hoc* Group of Experts on Ocean Mapping in the WESTPAC Area
58. Fourth Session of the IOC Consultative Group on Ocean Mapping
59. Second Session of the IOC-WMO/IGOSS Group of Experts on Operations and Technical Applications
60. Second Session of the IOC Group of Experts on the Global Sea level Observing System
61. UNEP-IOC-WMO Meeting of Experts on Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change
62. Third Session of the IOC-FAO Group of Experts on the Programme of Ocean Science in Relation to Living Resources
63. Second Session of the IOC-IAEA-UNEP Group of Experts on Standards and Reference Materials
64. Joint Meeting of the Group of Experts on Pollutants and the Group of Experts on Methods, Standards and Intercalibration
65. First Meeting of the Working Group on Oceanographic Co-operation in the ROPME Sea Area
66. Fifth Session of the Editorial Board for the International Bathymetric and its Geological/Geophysical Series
67. Thirteenth Session of the IOC-IHO Joint Guiding Committee for the General Bathymetric Chart of the Oceans *(Also printed in French)*
68. International Meeting of Scientific and Technical Experts on Climate Change and Oceans
69. UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System

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1. OPENING OF THE MEETING

1 The meeting was opened at 09:30 on 9 December 1991 by Dr. D. Elder, Head, Ecology Division, IUCN - World Conservation Union, on behalf of the co-sponsoring organizations. He explained that the meeting was jointly organized by UNEP, IOC, WMO and IUCN. He expressed the interest of IUCN in collaborating in efforts to establish long-term monitoring of ecosystems. IUCN has also established a global change programme, one component of which is aimed at assessing the vulnerability of coastal ecosystems to climate changes. Given the commonality of IUCN's programme with the aims of the UNEP-IOC-WMO initiative, IUCN has decided to collaborate in the further development of the monitoring programme. He then introduced Prof. F. Doumenge, Director, Musée Océanographique, who also serves as Chairman of IUCN's Commission on Ecology.

2 Prof. Doumenge welcomed the participants to Monaco and to the facility, emphasizing the support of his organization to the goals of the meeting, and to the need for long-term monitoring of reefs and mangroves in the face of global climate change impacts.

3 Dr. M. Gerges, Acting Deputy Director, Oceans and Coastal Areas Programme Activity Centre, UNEP, briefly described UNEP's regional and global activities related to climate change, including the establishment of eleven Regional Task Teams on the Implications of Climate Change in areas covered by the Regional Seas Programme, some of which are co-sponsored by IOC, and two Global Task Teams on Coral Reefs and Mangroves co-sponsored by IOC and UNESCO respectively. Based on the regional overviews prepared by the respective Task Teams, six site-specific case studies have been selected and supported by UNEP for further development.

4 Dr. Gerges further stressed the importance which UNEP attaches to the Global Coastal and Near-Shore Monitoring System, as contributing to the goals of Earthwatch, the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), as well as to the Global Environmental Monitoring System (GEMS). He also expressed the hope that the present meeting would be able to set-up the detailed operational plans for the two pilot phase activities on coral reefs and mangroves in the general framework of the Global Monitoring System established and co-sponsored jointly by UNEP, IOC and WMO.

5 Ms. M. Cole, Senior Assistant Technical Secretary, IOC, expressed the special interest of the IOC in this endeavor and indicated that the results of the week's meeting will be considered in a number of fora. The proposed monitoring system is an important and a timely one in view of international interest and efforts to address the issue of climate change and its potential consequences.

6 It was proposed and approved that Dr. J. Pernetta serve as Chairman of the meeting.

2. ADMINISTRATIVE ARRANGEMENTS

2.1 ADOPTION OF THE AGENDA

7 The proposed agenda as shown in Annex I was adopted.

2.2 CONDUCT OF THE MEETING

8 The Chairman reviewed the list of documentation shown in Annex IV made available for the meeting and the proposed timetable and working hours. He further proposed that Dr. R.W. Buddemeier act as convener of the coral reef working group; Ms. J. Ellison as convener for mangroves and Dr. H. Yap as rapporteur, for the plenary. These arrangements were agreed by the meeting.

3. LONG-TERM GLOBAL MONITORING SYSTEM OF COASTAL AND NEAR-SHORE PHENOMENA RELATED TO GLOBAL CLIMATE CHANGE

9 Ms. M. Cole, IOC Secretariat, presented a brief overview of the IOC-WMO-UNEP Global Ocean Observing System (GOOS) initiative. This system is

to be developed according to a globally-coordinated, scientifically-based strategy, and will allow for a coordinated approach to monitoring of physical, biological and chemical parameters in the ocean. The coastal component is designed to identify, understand and analyze coastal and near-shore ocean processes which may be affected by climate changes. GOOS is to be based on the results of research programmes such as TOGA, WOCE and JGOFS and will be built to the extent possible on present systems and observational activities.

10 Five modules of GOOS have been defined to meet the agreed objectives:

PROPOSED MODULES (Subsystems)

(i) coastal zone management and development
(ii) monitoring and assessment of living marine resources
(iii) climate prediction, including seasonal and interannual climate variability and long-term weather prediction
(iv) assessment and prediction of the health of the ocean
(v) marine meteorological and operational oceanographic services

Development of appropriate predictive models must be an inherent part of the system development.

11 A proposed system for long-term monitoring in the coastal zone as one component of the Global Ocean Observing System has high priority with coastal and archipelagic states due to the importance of the coastal zone for development; the present dependence of people on coastal resources; and, the potential magnitude and extent of impacts predicted to occur as a consequence of climate change. The coastal and near-shore monitoring system will draw on existing and planned data collection and exchange mechanisms, adding complementary measurements not now taken, such as biological and chemical observations.

12 An UNEP-IOC-WMO group of experts, meeting in Paris in December 1990, recommended the implementation of six pilot phase activities to measure key variables.

COASTAL MODULE
PILOT PHASE ACTIVITIES

(i) Sea level changes and coastal flooding
(ii) Coastal circulation
(iii) Assessment of organic carbon accumulation in surface coastal sediments
(iv) Changes in plankton community structure
(v) Benthic communities; coral reef ecosystems
(vi) Terrestrial vegetation; mangrove communities

13 The Sixteenth Session of the IOC Assembly, March 1991, approved by resolution XVI-10 the implementation of the proposed system in a phased manner. Likewise at its Sixteenth Session the UNEP Governing Council by decision 16/41 suggested the need for further assessments of all aspects of climate change and the Eleventh World Meteorological Congress recommended expanding ocean observing activities (Resolution 21).

14 Accordingly IOC in collaboration with UNEP, WMO and IUCN and with the assistance of consultants, and on the advice of the regional task teams, has developed an Action Plan for the implementation of the system and the two pilot phase activities concerned with the monitoring of coral reef ecosystems and mangrove communities.

15 The purpose of the present meeting was to refine the draft Action Plan in terms of defining measurement frequency, spatial resolution, sites and parameters for two of six pilot phase activities, namely coral reefs and mangroves.

ACTION PLAN FOR THE IMPLEMENTATION OF LONG-TERM MONITORING OF MANGROVE AND CORAL REEF ECOSYSTEMS

4.1 POTENTIAL IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE ON MANGROVES AND CORAL REEFS

16 Under this agenda item, summary presentations were made on results of workshops which took place in Amersfoort in connection with the Symposium on the Impacts of Climate Change on Ecosystems and Species (2-6 December 1991) (Annexes VI and VII). It was noted that an additional parameter not considered at that workshop that should be included was total irradiance which might be a more important limiting factor than temperature under certain conditions (e.g., coral reefs at high latitudes).

17 With respect to the location of sites, it was suggested that coral reefs remote from anthropogenic influence (e.g., oceanic islands, outer reef slopes) may be better in terms of yielding a clearer climate signal, than reefs flats in close proximity to centres of population. In discussion it was suggested that ecosystems existing under boundary conditions, or at the extreme ends of their ranges, would probably show change which could be more directly linked to climatic forcing, and should be included in a monitoring programme along with more "typical" habitats.

18 The group considered that it was useful to distinguish between "processes", and "parameters" that would actually be measured in the field as components of processes. In this connection, the attention of the meeting was drawn to the relevant discussions of the previous meeting of experts (UNEP-IOC-WMO/GCNSMS-I/3, Annex III, pp 5-8). The focus for the monitoring system was to measure biological variables which might indicate the responses of coastal systems to climate change. It was, however, agreed that measurements of physico-chemical parameters were essential in order to separate the "signal" of responses to climatic forcing from the "noise" of responses to other sources of change.

19 A minimum set of parameters in both mangrove and coral reef ecosystems was to be drawn up for incorporation in a universal monitoring programme focusing on agreed sites. Where resources and available expertise permit, additional regional and national sites may be included in the system which was to be open to participation by all interested institutions (see UNEP-IOC-WMO/GCNSMS-I/3, Annex III, p. 10, Item 7).

4.2 CONSIDERATION OF PARAMETERS

20 During both working group and plenary sessions, considerable discussion was devoted to the nature of parameters which might be adopted for inclusion within the framework of a global long-term monitoring system designed to detect the impacts of climatic change and sea level rise.

21 In general, it was recognized that the primary purpose of the two pilot phase activities was to put in place monitoring systems designed to detect changes in the biological components and that biological parameters should therefore receive a higher priority than physico-chemical parameters. Nevertheless the need for contemporaneous monitoring of physico-chemical variables was fully recognized by all participants if the system was to distinguish between the signal of climate change and the noise resulting from other forcing functions.

22 The parameters agreed for inclusion in the pilot phase activities are detailed in Annex III of this report.

4.3 CONSIDERATION OF METHODOLOGIES

23 It was agreed that a universally applicable manual of methodologies was required, and the meeting agreed to adopt the ASEAN-Australia Living Coastal Resources Project manual of methodologies for initial use in implementing pilot phase monitoring of mangroves and coral reefs.

24 It was agreed that the manual of methodologies would be published in its entirety by IOC in collaboration with UNEP and the ASEAN-Australia project; that the coral reef and mangrove methodologies would be published as separate issues in the UNEP Regional Seas Reference Methods for Marine

Pollution Studies series; that the coral reef volume would appear in March 1992 and the mangroves volume in April 1992. The need to have at least the coral reef methodologies manual available by the time of the Guam 7th International Coral Reef Symposium was stressed by the meeting.

4.4 RELATIONSHIP OF THE PROPOSED ACTIVITIES TO RELEVANT NATIONAL, REGIONAL AND INTERNATIONAL DEVELOPMENTS

25 The meeting noted and reaffirmed its support for the principle that the long-term monitoring system should be open ended and that any institution wishing to participate should be encouraged to do so. It was further recognized that close liaison between the development of the present system and other proposed and operational programmes and activities such as CARICOMP, PACICOMP, the ASEAN-Australia Programme and COMAR as well as other regional programmes is of vital importance to the success of the present initiative. The meeting strongly recommends to the joint secretariat that integration of the present initiative with relevant regional and international activities and programmes should be considered a high priority in future implementation of the reef and mangrove monitoring activities.

4.5 CONSIDERATION OF MONITORING SITES

26 In respect of the selection of sites the meeting noted the criteria for global, regional and national sites as detailed in the report of the UNEP-IOC-WMO expert meeting held in Paris, in December 1990. It was stressed that where possible, sites selected for mangrove or coral reef monitoring should be selected on the basis of compatibility with the selection of sites to address the other pilot phase activities.

27 The rationale for site selection and proposals based on scientific and technical criteria are provided in Annex III.

5. FUTURE IMPLEMENTATION

28 Under this agenda item an extensive and intensive discussion of the necessary elements for successful implementation of the proposed workplan was concluded which covered *inter alia* budgetary, manpower, organizational and management constraints and opportunities.

5.1 REVIEW OF THE ACTION PLAN ELEMENTS

29 Consideration was given to the necessary elements required to implement the coral reef and mangrove monitoring activities under the pilot phase of the long-term global monitoring system. It was concluded that short-term motivation for institutions and governments to participate in the programmes was required in order to stimulate initial interest and ensure participation of countries in the programme as a whole.

30 Whilst the overall goal and objectives of the monitoring system cannot, of necessity, be achieved rapidly (within only a few years) due to the nature of the problem under evaluation, it is important to recognize that there are in fact significant short-term benefits, both scientifically and for environmental management, from implementing such a monitoring programme.

31 These benefits, for both spheres of action, stem from the regional and global nature of the monitoring programme:

(i) For scientists the system represents an unique opportunity for comparative, quantitative assessment of regional variability and the status of these habitats and ecosystems. This comparative ecological assessment must be considered "cutting edge research". Within the first few years it will be possible to define (for the variables examined) the range of possible responses within entire geographical regions.

(ii) For governmental and other agencies concerned with managerial decision making in the sphere of environment and development, the data will provide an objective assessment and will define the criteria on which decisions can be made as to whether a particular system or area of interest is under threat when compared with the range of similar systems in the region. Where

systems fall outside the range of variation displayed within regions the need for specific management systems will also be identified.

32 Thus for both scientific and managerial reasons this programme will have immediate practical benefits outside the long-term goals of detecting climate change impacts.

33 The need for careful co-ordination of developments within the two pilot phase activities of direct concern to the meeting and the remaining proposed activities was recognized, as was the need to strengthen this co-ordination capability in the joint secretariat. The international agencies could potentially provide a significant component of long-term stability within the monitoring system as a whole, through the fostering of regional networks and provision of fora for co-ordination, collaboration and data exchange. Relating to co-ordination was the issue of the need for flexibility and for the system to evolve as a consequence of the participation of different institutions.

34 The participants recognized that the data management system was of utmost importance and must be developed simultaneously with the implementation of the monitoring programme. It is essential that all levels of database management be considered initially from the field collection of data, the development of data sheets through to incorporation into a global database. Participants recognized that previous difficulties in database management should be avoided by considering the end product at the same time as data gathering and entry.

35 The database management system should be provided with suitable resources in terms of both the database operators and managers, and computer hardware and software.

36 Consideration should be given to using existing regional databases such as CARICOMP and the ASEAN-Australia Living Coastal Resources systems, as regional data centres. Participants in the monitoring programme should be trained in data collection and processing at the same time as training in field methods.

37 The need for a global depository of data was considered imperative and careful consideration should be given by the joint Secretariat to providing for its maintenance over the long-term. Dr D. Elder indicated that the World Conservation Monitoring Centre (WCMC) in Cambridge, England, might well be a suitable depository for data generated through these two activities given the brief of the centre to store and manage ecosystem data. IUCN and UNEP as co-sponsors of the WCMC would undertake to investigate this possibility further.

38 The indispensability of a training component was stressed by participants who all agreed that training activities were a necessary pre-requisite to implementation of on-site activities.

5.2 REVIEW OF THE PROPOSED WORKPLAN AND TIMETABLE FOR IMPLEMENTATION OF THE ACTION PLAN

39 The Pilot Phase activities of the monitoring programme formulated by the meeting are contained in Annex III. Stage 1 represents the **minimum** commitment necessary for implementation of the monitoring networks. Stage 2 presents desirably, but **not initially** essential measurements. Participants discussed many other variables, both those used in existing monitoring programmes, e.g. the ASEAN programme and others, but agreed that the measurements described below would provide a robust, albeit limited, monitoring programme for the Pilot Study phase, given the constraints on resources and the critical need to initiate the programmes rapidly.

40 The meeting considered and approved the recommendations of the joint Secretariat that the coral reef monitoring activity of the pilot phase be initiated through preparation, publication and dissemination of the approved manual of methods and through the 7th International Coral Reef Symposium scheduled to take place in Guam in June 1992. It was felt that the programme as agreed at this meeting should be disseminated through the Guam Symposium and that indications of interest in participating should be solicited through that forum.

41 The meeting noted with regret the absence of a comparable forum through which the wider dissemination of the action plan for the mangrove pilot phase activity could be disseminated and discussed by the scientific community. It was agreed that potentially the International Society for Mangrove Ecosystems (ISME) and the global Task Team on climate change impacts and other existing COMAR, regional networks on mangroves might be suitable fora through which to achieve a wider exposure of the present proposal. It was suggested that widespread dissemination of short informative statements concerning these activities could be released to the media and to scientific journals, thus ensuring a wider review of the proposals than could be obtained solely through expert group meetings.

42 It was anticipated that following successful completion and publication of the manual of methodologies, sites could be selected and the programmes initiated in the latter half of 1992.

5.3 REVIEW OF BUDGETARY COMPONENTS OF THE ACTION PLAN

43 The meeting recognized the importance of securing the long-term commitment of governments to supporting the monitoring system, particularly in identifying and protecting sites designated as long-term monitoring sites.

44 The extremely important catalytic role of the United Nations system in stimulating the development of necessary mechanisms at regional and national level through provision of initial seed funding to ensure proper development of the monitoring system was recognized by the meeting participants.

45 The meeting discussed the need for long-term commitments on the part of participating institutions and countries in order to ensure the orderly gathering and processing of the monitoring data required to ultimately enable prediction of climate change impacts in mangrove and reef systems and hence to provide advice to governments concerning possible response options and mitigation measures.

46 The meeting participants recognized that a central core fund was required to ensure an adequate level of international co-ordination of activities; to handle and manage the data generated through the system; and to provide the necessary start-up or catalytic funds to ensure participation of less advantaged countries.

6. GLOBAL TASK TEAMS

47 Dr. M. Steyaert briefed the meeting on the formation of a joint UNEP-UNESCO Global Task Team on Impacts of Climate Change on Mangroves and informed the meeting of the outcome of a preparatory meeting held in Bangkok in conjunction with a meeting of the ISME Executive. He stated that, following an initial literature, review and preparation of a draft report the Task Team intended: (i) to refine the evaluation of climate change impacts; (ii) to select sites for case study analysis; and (iii) to ultimately produce a definitive statement concerning mangroves under changing climate conditions.

48 Dr M. Gerges then drew the attention of the meeting to the developments with respect to the formation of a global Task Team on climate change impacts on coral reefs. He stated that following the agreement of the co-sponsors of the Task Team (UNEP, IOC, and Association of South Pacific Environmental Institutions [ASPEI]), UNEP proposed to support the attendance of potential members of the Task Team to enable the convening of a first meeting to be held in conjunction with the Guam Coral Reef Symposium in June 1992. He re-iterated the need for close co-ordination between UNEP and the other agencies in this regard and the present development of pilot phase activities within the framework of a long-term global monitoring system.

49 The meeting supported the view that these task teams could potentially be used as review bodies for evaluation of future products emanating from the initiation of the proposed pilot phase activities.

7. RECOMMENDATIONS TO THE GOVERNING BODIES OF UNEP, IOC AND WMO CONCERNING IMPLEMENTATION OF CORAL REEF AND MANGROVE LONG-TERM MONITORING

50 Under this agenda item the need for simultaneous development of all pilot phase activities was discussed as was the importance of the joint Secretariat to co-ordination of all activities in developing the System in an integrated manner. The meeting recognized the importance of the present initiatives in the fields of coral reef and mangrove monitoring and recommended their prompt implementation by the joint Secretariat. The meeting adopted the recommendation contained in Annex II.

8. ADOPTION OF THE REPORT OF THE MEETING

51 The report of the meeting including its substantive annexes was considered and adopted by the participants.

9. CLOSURE OF THE MEETING

52 In closing the meeting the Chairman thanked participants for their constructive comments and hard work during the week. He expressed on behalf of participants their thanks to Professor Doumenge and the staff of the Musée Océanographique, whose technical support and warm hospitality had contributed to the success of the meeting. The meeting expressed its appreciation to the Secretariat for its efforts to serve the meeting and prepare the draft report. The meeting was concluded at 17h00 on Friday 13 December 1991.

ANNEX I

AGENDA

1. **OPENING OF THE MEETING**

2. **ADMINISTRATIVE ARRANGEMENTS**

2.1 ADOPTION OF THE AGENDA

2.2 CONDUCT OF THE MEETING

3. **LONG-TERM GLOBAL MONITORING SYSTEM OF COASTAL AND NEAR-SHORE PHENOMENA RELATED TO GLOBAL CLIMATE CHANGE**

4. **ACTION PLAN FOR THE IMPLEMENTATION OF LONG-TERM MONITORING OF MANGROVES AND CORAL REEFS ECOSYSTEMS**

4.1 POTENTIAL IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE ON MANGROVES AND CORAL REEFS

4.2 CONSIDERATION OF PARAMETERS

4.3 CONSIDERATION OF METHODOLOGIES

4.4 RELATIONSHIP OF THE PROPOSED ACTIVITIES TO RELEVANT NATIONAL, REGIONAL AND INTERNATIONAL DEVELOPMENTS

4.5 CONSIDERATION OF MONITORING SITES

5. **FUTURE IMPLEMENTATION**

5.1 REVIEW OF THE ACTION PLAN ELEMENTS

5.2 REVIEW OF THE PROPOSED WORKPLAN AND TIMETABLE FOR IMPLEMENTATION OF THE ACTION PLAN

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6. **GLOBAL TASK TEAMS**

7. **RECOMMENDATIONS TO THE GOVERNING BODIES OF UNEP, IOC AND WMO CONCERNING IMPLEMENTATION OF CORAL REEF AND MANGROVE LONG-TERM MONITORING**

8. **ADOPTION OF THE REPORT OF THE MEETING**

9. **CLOSURE OF THE MEETING**

ANNEX II

ADOPTED RECOMMENDATION

Recognizing the approval of the UNEP, IOC and WMO governing bodies of the establishment of a Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change,

The **meeting recommends** that the Secretariats of UNEP, IOC and WMO request their respective governing bodies to support the development and implementation of all pilot phase activities of the system and in particular those relating to coral reefs and mangroves (Document UNEP-IOC-WMO-IUCN/GCNSMS-II/3, Annex III) and to urge the Governments concerned to facilitate their rapid implementation.

ANNEX III

ACTION PLAN FOR THE IMPLEMENTATION OF PILOT PHASE ACTIVITIES OF THE LONG-TERM GLOBAL MONITORING SYSTEM OF COASTAL AND NEAR-SHORE PHENOMENA RELATED TO CLIMATE CHANGE

INTRODUCTION

Background

In December 1990 the Intergovernmental Oceanographic Commission in collaboration with the United Nations Environment Programme, and the World Meteorological Organization convened a meeting of experts to consider a draft proposal for a Long-term Global Monitoring System of Coastal and Near-Shore Phenomena related to Climate Change. This meeting considered the draft proposal in detail and recommended its implementation in general and specifically that 6 activities be initiated during the pilot phase.

The activities recommended for development in the pilot phase were:

1. Sea-Level change and coastal flooding;
2. Coastal circulation;
3. Assessment of organic carbon accumulation in surface coastal sediments;
4. Changes in plankton community structure;
5. Benthic communities: coral reef ecosystems; and,
6. Terrestrial vegetation: mangrove communities.

The recommendations of the above joint UNEP-IOC-WMO expert meeting were subsequently approved by the Sixteenth Session of the IOC Assembly in March 1991 (Resolution XVI-10). The UNEP Governing Council in Resolution 16/41 pledged support within available resources to the creation of a Global Climate Observing System including its component parts - World Weather Watch, Global Atmosphere Watch and Global Ocean Observing System. The Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change, contributes to the coastal component of the Global Ocean Observing System.

The Global Ocean Observing System (GOOS) Support Office of the IOC, with the assistance of a consultant prepared a draft Action Plan for further development of this system and selected pilot phase activities. The joint Secretariat decided that initial emphasis should be placed on pilot phase activities 5 and 6 (coral reef ecosystems and mangrove communities respectively). The outlines for these approved pilot phase activities are contained in the report of the expert meeting held in Paris, December 1990 (UNEP-IOC-WMO/GCNSMS-I/3).

Goal & Objectives

As stated in the original proposal the goal and objectives for the long-term global monitoring system are as follows:

"The goal of the proposed coastal and near-shore monitoring system is to contribute to:

1) the global, regional and national efforts to assess climate change and environmental and socio-economic impacts of this change; and,

2) the development and implementation of policies and measures designed to mitigate the undesirable effects of the expected impacts:

Specific objectives are:

a) To provide a framework for a long-term monitoring system for coastal and near-shore observations of physical, geological, chemical and biological variables or phenomena,

with particular reference to changes which may be associated with, or attributable to, the impact of expected climatic changes;

b) to identify short and long-term changes in the variables and phenomena monitored and to forecast where possible the magnitude of future changes;

c) to obtain the data required to test models relevant to climate change in coastal and near-shore areas;

d) to serve as a timely warning mechanism for threats which may be associated with anthropogenic and climate change impacts in coastal and near-shore areas;

e) to facilitate international and intergovernmental cooperation in monitoring, assessing and anticipating environmental threats related to the impacts of climate changes;

f) to involve and assist developing countries' participation in the planning and implementation of activities carried out under the monitoring system; and,

g) to facilitate access to an exchange of data generated through other relevant programmes and activities".

Implementation of the pilot phase

Initiation of pilot phase activities requires action concerned with general development of the system as a whole and its co-ordination with other relevant programmes and activities at national, regional and international level; and actions to implement the specific activities approved under the pilot phase of the programme. The pilot phase may be expected to extend over a three year period with individual activities being developed in a sequential manner. The draft work programme presented here spans the initial actions required within the next three years.

ACTION PLAN

I. FRAMEWORK FOR ACTION

1. In order to achieve the overall goal and objectives of the long-term global monitoring system of coastal and near-shore phenomena related to climate change, specific activities will be developed aimed at:

1.1 Establishing a series of regional and global networks of participating institutions and organizations concerned with the monitoring of individual variables and phenomena forming agreed components of the overall system and of one or more of the pilot phase activities;

1.2 Providing a mechanism for co-ordination of the development of the various elements of the system and for optimum integration of joint secretariat actions, including enhanced information flow and advanced planning.

1.3 Development and implementation of appropriate standardized methods and procedures for sampling, analysis, observation, processing and exchange of data and information relevant to the pilot phase activities and the system as a whole.

2. The work programmes arising from this Action Plan should contribute not only to achieving the specific objectives and goals of the pilot phase activities and the system as a whole, but should also seek to strengthen cooperative programmes at regional and international levels, and to enhance national level capabilities in coastal zone monitoring.

3. Participation in the implementation of the Action Plan will be open to all interested institutions.

II. NETWORK FORMATION & STRENGTHENING

4. One of the major constraints facing the implementation of any global environmental monitoring programme is the problem of conflicting interests between individuals and groups concerned with research, planning and use of coastal and near-shore environments which leads to overlap and conflict in the use of scarce financial and manpower resources. This is of particular importance given the limited financial and manpower resources, particularly in developing countries, which are available for responding to the potential impacts of climate change and sea level rise.

5. Operational networks will be formed at three levels; national, regional and global. Management systems will parallel this structure ensuring appropriate and continuing dialogue between operational and policy/decision making agencies. A conceptual framework illustrating the required network components and their inter-relationships is provided in Figure 1.

6. For the purposes of the implementation of the Action Plan, the National Marine Science Committees, where they exist, will operate as the appropriate forum for national level decision making concerning the implementation of pilot phase activities and system development. The National Marine Science Committee or other designated Focal Point, should function as the national point for referral for all developments related to the implementation of the Action Plan.

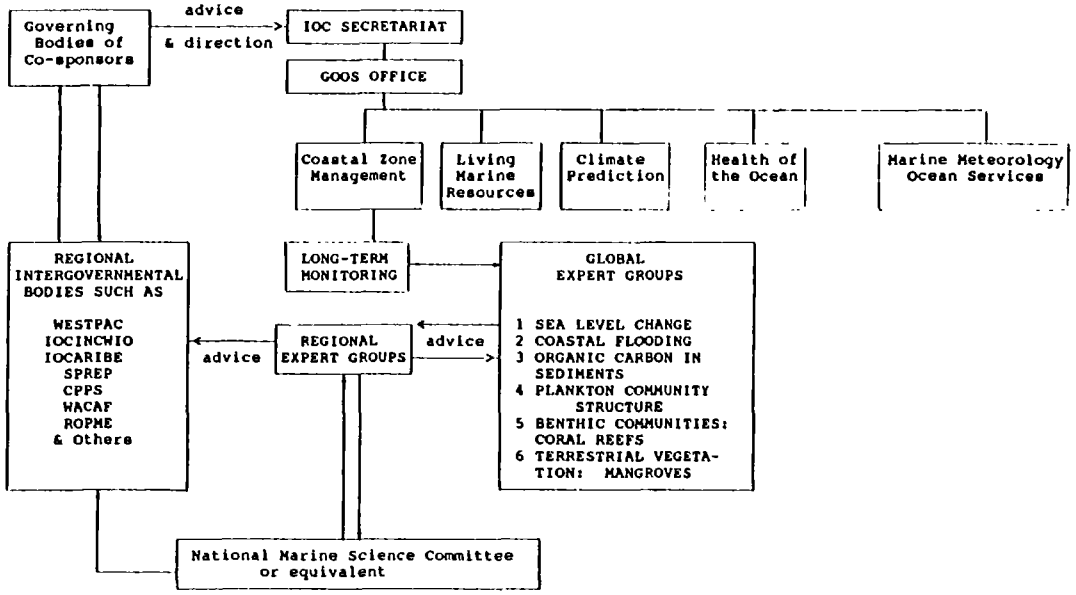

Figure 1. Basic management structures required for development of the pilot phase activities of the Long-term Monitoring System of coastal and near-shore phenomena related to climate change.

7. At a regional level, co-ordination between national level activities undertaken under this Action Plan will occur via the inter-governmental level meetings of IOC Regional Bodies and UNEP Regional Seas Action Plans and Regional Associations of WMO and appropriate collaborating regional agencies (such as SPREP and CPPS). Such regional bodies may seek to establish regional level expert advisory groups composed of national level action agencies implementing the monitoring activities.

8. Where they are formed regional level expert advisory groups will be responsible for the provision of scientific and technical advice to the regional level decision making body concerning the implementation of the Action Plan. Such expert advisory groups will also liaise with global expert groups concerned with system implementation, standardization of methodologies, data handling and exchange.

9. At an international level the governing bodies of the agencies co-sponsoring the monitoring system will advise and direct the joint Secretariat on implementation of the monitoring system. While the IOC Secretariat will be responsible on behalf of the joint Secretariat for the day-to-day management and operation of the system.

III. CO-ORDINATION MECHANISMS & INSTITUTIONAL ARRANGEMENTS

10. The Joint UNEP-IOC-WMO Secretariat shall be responsible for reviewing periodically the content of the Action Plan; reviewing the substantive progress of activities and work programmes initiated under it; and for advising on the nature and mechanisms required for implementation of the various pilot phase and other activities. Such advice and reviews shall be reported to the Governing Bodies of co-sponsoring agencies via the joint Secretariat.

11. The GOOS Support Office of the IOC Secretariat shall be responsible for co-ordinating the implementation of the work programme agreed by the joint Secretariat and ensuring that mechanisms are developed for the quality control, handling and timely exchange of data arising from the monitoring system.

12. Mechanisms shall be instituted by member states which will ensure timely and efficient decision making in implementing the Action Plan.

13. Individual member states will retain responsibility for the collection of monitoring data relating to their participation in activities initiated under the Action Plan, and shall make such data freely available on a timely basis through approved data handling and exchange mechanisms.

14. In principle each of the activities agreed upon as part of the work programme will be considered as contributing to the regional collaborative effort among member states.

IV. MONITORING AND DATA MANAGEMENT METHODOLOGIES

15. In accordance with the principles detailed in the proposed system document, standard methodologies for data collection will be adopted or developed for implementing activities under the Action Plan. Any newly developed methodologies shall be adopted following advice of appropriate expert groups.

16. The Secretariats of UNEP and IOC shall be responsible for the preparation, editing, publication and distribution of manuals of approved methodologies.

17. On the advice of appropriate experts and in collaboration with established data handling and exchange mechanisms, procedures for the quality control, handling and exchange of data generated under the system will be developed during the pilot phase.

V. FINANCIAL ARRANGEMENTS

18. The activities arising from this Action Plan should be financed by member governments; by international agencies; by non-governmental organizations; and through bilateral agreements between member states.

VI. WORK PROGRAMME 1991-1992

19. To ensure smooth development of pilot phase activities there exists a need to strengthen the planning, management and co-ordination capacity of the GOOS Office and to stage the implementation of approved pilot phase activities.

BENTHIC COMMUNITIES: CORAL REEF

Background

Coral reefs have a pantropical distribution and are ideal indicators of climate change since their major components, the benthic corals are highly sensitive to environmental forcing. A number of agencies and organizations are currently involved in initiating proposals for monitoring of reef ecosystems for various purposes, in the Caribbean and Indo-West Pacific. A network of institutions reporting bleaching events already exists in the Caribbean, and a Global Task team on the impacts of Climate Change on Coral reefs is in the process of being established by UNEP, IOC and ASPEI.

These pilot phase monitoring programmes were formulated by a group of experts as the minimum commitment necessary to implement a monitoring network (Stage 1). Desirable, but not initially essential measurements, are presented in Stage 2. Many other variables were discussed, such as those measured in the ASEAN-Australia Living Coastal Resources project, but the following programmes were agreed as the minimum monitoring programme that would provide robust assessment of coral reef status. The experts recognized the constraints on resources and the need to initiate the programme rapidly over a wide geographic scale.

It must be recognized, however, that distinguishing the noise of natural environmental variability and the effects of anthropogenic stress in reef environments from the signal due to climate change and sea level rise, will only be possible following extended monitoring based on replicable and widely applied monitoring techniques.

Aims

1) To secure commitment of member states to the initiation of this pilot phase activity.

2) To ensure co-ordination between on-going and planned coral reef monitoring activities.

3) To implement initial monitoring of selected sites in the Caribbean and Indo-Pacific regions.

4) To extend the existing Caribbean network of institutions and individuals collecting coral bleaching observations to the Pacific and Indian Oceans.

5) To strengthen the existing regional networks of institutions collecting coral reef monitoring data by providing facilities for inter-regional and global collaboration in data handling and exchange.

Methodology and workplan

Following the expert meeting in Monaco in December 1991 the approved monitoring methodologies will be edited and published in their entirety by IOC in collaboration with UNEP and the ASEAN-Australia project. The coral reef and mangrove methodologies will be published as separate issues in the UNEP Regional Seas Reference Methods for Marine Pollution Studies series in 1992. The work plan and timetable will be presented to the IOC Executive Council and at an IOC Co-sponsored workshop to be held as part of the 7th International Coral Reef Symposium, Guam, June 1992. The report of the expert meeting will be circulated to all IOC Member States, Regional Bodies, collaborating agencies and the UNEP/IOC Regional Task Teams for comment and indications of interest in participation.

Existing sites of reef monitoring and sources of data will be identified. Where necessary to ensure global coverage of the proposed system, additional monitoring sites will be established in each of the Pacific, Caribbean and Indian Oceans and initial surveys will commence in the last quarter of 1992 and throughout 1993. A network of institutions to monitor bleaching events in the Pacific and Indian Oceans will be established during the 7th Coral Reef Symposium in Guam, 1992 and support provided to existing networks in the Caribbean.

Outputs

1. Manual of approved monitoring methodologies for mangrove communities (mid-1992).

2. Catalogue of existing mangrove monitoring sites, institutions and data sources and establishment of a global network of participating institutions (1993).

3. Compilation of initial site survey data and development of standardized formats for data handling and exchange (1993).

Budget

For the coral reef monitoring programme, a minimum of 60 sites is necessary, distributed across all ocean regions. The following table contains indicative estimates of the establishment cost for a coral reef monitoring site. The budget will vary depending on in-country costs and the level of current coral reef and environmental data gathering activities.

Cost per site		UNEP-IOC-WMO (US $)	Host country local rates
Recurrent			
Personnel		0*	
Communication		1,000	
Consumables		5,000	
	Sub-total	6,000	
Establishment costs			
Equipment		7,000	
Travel		5,000	
	Sub-total	12,000	
Total		$ 18,000	

* Indicative figures are not included due to the extreme variation in salaries worldwide. It is estimated that operation of a single national level monitoring site would involve no more than 3 man-months per year.

Countries that have poorly developed infrastructure may need up to an additional $ 30,000 for initial startup costs, e.g. boat, field vehicles, field facilities. However, it is the responsibility of the individual country to assess their requirements and negotiate them with the sponsoring agencies and potential donors.

Sites

The outline for this pilot phase activity states that a number of sites covering the Caribbean, Indian and Pacific Oceans should be selected, spanning the range of reef types and degrees of anthropogenic impact. Criteria for site selection should include the existence of infrastructure which could immediately implement a long-term monitoring programme; the sensitivity of particular reef locations to climatic forcing; and minimal additional anthropogenic sources of change which might obscure the climate signal. Additionally, historical monitoring data from coral cores or slabs should provide information on interannual variability and trends in anthropogenic influence. The possibility for such studies should be included in the criteria for site selection.

The recommendations of the expert meeting include the distinction between global, regional and national sites. Global and regional sites should ideally be located in far-field environments where direct anthropogenic influences and the influence of factors other than climate change are reduced to a minimum. National sites could serve as short- and medium-term stations spanning the full range of near and far-field conditions.

A full matrix of reef types and degrees of existing anthropogenic impacts would result in too many individual sites being required during the pilot phase. However, it is critical that the initial sites be selected with reference to a conceptual framework that provides both specific and general guidance for the staged incorporation of additional sites and that maximizes the potential for co-ordination with existing programmes.

After a comprehensive review of the guidelines provided by UNEP-IOC-WMO/GCNSMS-I/3 and the draft action plan, the working group of experts on coral reef monitoring integrated the major climate and reef ecosystem factors into a nested sampling design to identify the major criteria for site selection.

This design considers the primary scientific dimensions of the programme as follows:

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* biogeographic/biodiversity;
* latitudinal;
* longitudinal;
* geomorphologic;
* land/anthropogenic vs. clean oceanic influence

The following dimensions are expected to be addressed at other stages of the activity:

* socio-economic;
* policy;
* conservation;
* feasibility.

The sampling design is tabulated as:

GEOGRAPHIC/BIOGEOGRAPHIC PROVINCE

Indian Ocean (including Red Sea, Persian Gulf)
South East Asia
Central and West Pacific
East Pacific
Broader Atlantic/Caribbean

LATITUDE

High
Low

LAND EFFECTS

Absent/low (oceanic/insular settings)
Present/significant (continental/high island

ENVIRONMENTAL FACTORS

Ocean climate/circulation patterns
Major storm patterns
(presence/absence/frequency)
Atmospheric climate patterns (rainfall, clouds, etc.)
Temperature range and variability

Within the above listing there are potential sites which meet the stated criteria of Global, Regional, or National sites. Some individual countries contain reefs which span the full range of criteria for different sites.

It is recommended that the sampling design, site selection

criteria, and list of priority candidate sites be subject to scientific review on a 5 year cycle, with input from the climate modeling and detection community and climate-oriented physical oceanographers. It is further recommended that the representatives of the sponsoring agencies and co-ordinating bodies maintain continuity of communications and credibility with the coral reef scientific community as well as with governments and agencies through a single point of contact.

The Group of experts discussed which countries might be considered to represent possible locations for a pilot phase programme covering the full range of reef types and environmental variables. A possible list is appended as Appendix A to this annex. The countries listed in the Appendix represent a scientifically selected set of representatives coral reef types and environmental variables reflecting the criteria discussed above. Many other countries could be included in this list as substitutes or additions depending upon government interest in participation. The listing does not reflect priority nor a commitment to participation by the countries listed.

A consistent terminology is recommended to distinguish between the areas chosen for study.

Country
Location
Monitoring Area
Site
Transect or Quadrat No. or replicate

Definitions

Location: General geographic area (scale 100s km)
Monitoring Area: Focus area for the Programme (scale 10s km) including islands, major reefs
Site: Sub-set of the Monitoring Area where studies are undertaken (scale 1 km)
Transect or Quadrat: Number of the replicate survey

Baseline survey

Each Country or Location selected will require designation of a Monitoring Area or areas for which baseline surveys will be required and from which monitoring Sites will be selected. These Monitoring Areas are the basic units of the monitoring study. The major factors influencing the selection of Monitoring Areas are:

(i) limited influence from confounding effects (e.g. anthropogenic alteration); and
(ii) sensitivity to environmental influences reflecting the global or regional climatic factors.

Additional factors influencing the selection of Monitoring Areas and Sites may include availability of pre-existing baseline or survey data, existing scientific facilities and operational convenience as discussed above.

Once Monitoring Areas have been identified, baseline surveys are required. At the most basic level these may consist of a literature and data review resulting in assembly of the available information on:

1) Local oceanographic conditions, their patterns and variability and their relation to larger regional circulation and productivity patterns;

2) Local and regional meteorological conditions and data sources;

3) The physical parameters specified below including methods, frequencies, and reliability of past and present data;

4) Present and planned land use activities that influence the areas;

5) Present, planned and expected marine resource exploitation patterns that could influence the proposed areas;

6) Sources of survey, research, or assessment data related to the proposed areas;

7) Available maps or charts, including satellite images of the proposed Monitoring Area;

8) Manta tow surveys to select representative areas.

Baseline survey data will be used to select specific sites and to prepare a Site Monitoring Plan specifying observations to be made, methods, and the rationale and protocols for any site-specific observations or modifications to the general monitoring program procedures. Procedures will have to be varied to accommodate differences in Monitoring Areas e.g. low vs high energy Sites.

Where existing data are inadequate to establish a reasonable relationship between conditions in the Monitoring Area and regional or global trends in climate, surveys should planned for incremental accomplishment during the pilot phase of the monitoring program. Survey datum points should be established to provide topographic and sea level control for the proposed Monitoring Areas.

Secondary and tertiary levels of survey data acquisition (desirable but not initially required) will include satellite and aerial photography surveys to identify geomorphic and ecological features in a larger geographic context.

Survey activities on the area scale should be augmented or repeated as recommended by periodic program and monitoring data reviews or as established by the site program plan.

The strategy and parameters chosen to assess the status and stability of coral reefs are based on an 8 year project covering the regional scale of south-east Asia and the Great Barrier Reef. The data from these surveys are contained in relational databases either at Chulalongkorn University, Thailand for the ASEAN-Australia Living Coastal Resources project or at the Australian Institute of Marine Science in Townsville as a result of the extensive surveys for the crown-of-thorns starfish.

PARAMETERS

Biological Parameters

The parameters chosen for the Global Climate Change monitoring of reefs have been selected at three incremental levels:

Stage 1: Basic Parameters to be undertaken at all sites;

Stage 2: Advanced Parameters for greater detail;

Stage 3: Research Parameters which require high level technology and training (not considered for the pilot study programme).

Stage 1: Basic Parameters

These provide a rapid and unambiguous assessment of the status of the benthos on a coral reef. Emphasis is on the cover and form of corals relative to algal growth and bare substratum over relatively wide areas of a coral reef. These parameters can be assessed after a minimum of training and require a minimum of equipment for data collection and processing.

The following quantitative estimates are recommended as the minimum necessary for participation in Stage 1 of the Global Monitoring Project:

Percent cover of Corals - scleractinian
non-scleractinian
soft corals
gorgonians
zoanthids
Algae - *Halimeda*

calcareous reds
macroalgae
turf alga
Other - sponges
ascidians
Sand, rubble and bare dead coral

Significant features - e.g. recently dead coral indicative of crown of thorns (COT) and coral death through bleaching or disease.

Other conspicuous organisms of interest:
Acanthaster
Diadema
Echinometra etc
Tridacnids
Holothuroids

Methods

Line Intercept Transect and Manta-tow (Manual of Survey Methods prepared by the ASEAN-Australia Living Coastal Resources project).

These basic parameters are currently measured on the Great Barrier Reef and in 5 ASEAN countries participating in the ASEAN-Australia Living Coastal Resources project funded through the Australian aid agency AIDAB. The techniques for assessment have been developed and tested by scientists in the ASEAN countries in association with Australian scientists, principally from the Australian Institute of Marine Science.

The Line Intercept Transect (LIT) survey method was chosen as the fundamental basic method. This method provides a rapid estimate of percent cover of corals based on the growth form of the colony, algal cover and other prominent organisms as well as bare substratum.

The line transect method can be modified by increasing the taxonomic level of identification of the prominent organisms, especially corals, to Genus level (Stage 2) and Species level (Stage 3). These modifications, however, do not invalidate comparisons between the results of Stage 2 and Stage 3 surveys and the basic method.

The transect pattern can also be used to assess fish abundance, species diversity and approximate biomass. These surveys are more appropriately in Stage 2.

A minimum transect of 100 m (5 x 20 m transects) should be undertaken at each **Site** within the **Monitoring Area** at a minimum of two depths. It is recommended that 3 and 10 m be chosen on low energy reefs and two deeper depths on higher energy reefs to include a zone of maximal coral cover. Primary sites should be chosen on the fore-reef slope facing the predominant oceanic influence. During Stage 2 coral cover to windward and to leeward may be compared.

It is recommended that several Sites should be examined in the Monitoring Area. Countries are encouraged to include additional Sites on reef-flats, back-reef slopes and lagoonal reefs to fulfil national needs.

Broadscale surveys using the manta-tow method should be undertaken to select the above sites within the **Monitoring Area** along reef slopes or around the perimeters of reefs. A minimum of 15 tows, each of 2 min duration should be undertaken near the crest to assess coral cover and status over an area covering several hundred square metres. Conspicuous macrofauna and zonation patterns should be noted.

The surveys of the above parameters should be undertaken at a minimum of annual periods, preferably at six monthly intervals when there are two distinct seasons, or whenever there has been a significant disturbance impact. Where feasible the surveys should be conducted when the water temperature is near the predicted maximum.

Stage 2: Advanced Parameters

* variation of the Line Intercept Transect method to

identify corals to Genus level;

* the use of permanent 2 m x 2 m quadrats to measure coral growth rates;

* surveys of fish populations on 150 m by 10 m belt transects.

These may be inappropriate for the pilot phase study unless there is existing expertise and in-country willingness.

Episodic Events

Annual or biannual surveys of coral reef **Monitoring Areas** are unlikely to capture the occasional episodic events such as major storms (cyclones, hurricanes, typhoons), shipwrecks, unpredicted emergent events and severe temperature induced bleaching events. Annual surveys may also miss episodic outbreaks of Acanthaster planci. Where these events occur in **Monitoring Areas** adjacent to active teams of coral reef workers, it is recommended that immediate and frequent Line Intercept Transect Surveys be undertaken during and immediately after the event until the effects of the change have stabilized. Some extreme events, such as those associated with ENSO phenomena, are somewhat predictable; general and site-specific monitoring protocols should provide for planned responses to such occurrences.

Where survey teams are not resident close to the **Monitoring Area**, it is recommended that monitoring for these episodic events be based on "informal" networks of tourist operators or dive clubs that already exist in some **Countries**. Local populations should be encouraged to report significant changes to the Monitoring Areas.

Physical parameters

Key environmental variables should be considered for monitoring at or near each coral reef site. The particular needs for localized on-site monitoring, which will be site-specific, should be identified as part of the baseline survey, and should be documented as site-specific procedures. Parameters that should be considered for each site include:

Oceanographic data

1) Water temperature
Surface maxima and minima -- preferred frequency daily (longer intervals can be adopted as a temporary expedient or out of logistic considerations, but frequencies greater than weekly are not recommended). Temperatures should be taken from water representative of the shallow transect site.

Temperature/depth profiles -- to be taken on the oceanic side of the monitoring site monthly, or at more frequent intervals if predictions or daily temperature observations indicate that an extreme event is imminent or in progress.

2) Salinity -- A primary observation only for sites with known or expected land run-off effects or where salinity may be expected to fall outside the range of 25-38 o/oo. At such sites a weekly profile and/or event-triggered measurements (e.g., based on rainfall, runoff or streamflow, or other water quality observations) should be established based on background information. At oceanic sites salinity should be measured during the baseline survey or as a component of secondary or tertiary level studies of environments (reef flats or lagoons) likely to reflect local rainfall or evaporation effects.

3) Sedimentation -- a primary variable only for sites with expected terrestrial or relevant anthropogenic effects. At such sites a cumulative monthly sediment trap collection is the minimal requirement. More extensive collections or analyses should be part of a designed secondary-level programme.

4) Sea level -- for sites measuring only the primary biological and ecological variables and having short-term tectonic stability, regional sea-level network observations are adequate. Local measurements will

be required only if secondary- or tertiary-level studies involve characterization of shallow water or intertidal communities, or utilize high-precision control of transect depths or quantitative determination of wave energy regimes. Installation of a high-quality local datum (high precision Global Positioning System) will facilitate addition or interpretation of local measurements related to water level.

5) Storm -- observations as a primary variable should include estimates of oceanographic features (wave height and run- up, sea state) as a supplement to meteorologic observations.

6) Meteorological data-- unless stated, the following observations relevant to Sites should be made. Acceptable distance from the site should be considered as part of the baseline survey; in oceanic regimes where spatial coherence is high, separations on the scale of kilometers may be acceptable. In cases of uncertainty an extended baseline study (e.g. one year of observations) should be made near the site to test for equivalence to or correlation with more distant stations.

   a. Temperature -- daily maximum and minimum (hourly or more frequent digital records preferred).

   b. Barometric pressure -- daily, with option of 4-6 times per day during major storms or extreme events.

   c. Wind speed and direction -- hourly (more frequent digital records preferred).

   d. Light-related measurements -- sunlight hours (daily) at the site and/or cloud cover 4-6 times per day during peak photosynthetic period (0800-1600). Direct irradiance measurements desirable.

   e. Rainfall -- daily total; in areas of significant runoff or fluvial influence this should be supplemented with data on watershed rainfall totals and streamflows, if available.

   f. Relative humidity -- a secondary or tertiary variable unless local conditions dictate otherwise.

Other variables -- in addition to the above variables, water quality (nutrients, pH/alkalinity) and community metabolism measurements (productivity, calcification, photosynthesis, respiration) may be considered for expanded programs or for National-level sites where anthropogenic stress factors must be considered and where expertise and scientific infrastructure are available.

DATA MANAGEMENT

It is essential that establishment of the database design and structure be considered prior to the development of any monitoring scheme. The recommended structure is a central database with a network of in-country databases.

It is essential that sufficient resources in terms of trained personnel and computing facilities be provided at the commencement of the programme. Where possible Countries should be connected by electronic mail to other countries and the central database.

All participating scientists should be trained early in the Programme on data collection, encoding, entry and the preparation of summaries. This will impress on participants the necessity for collecting the data carefully to arrive at the final product.

In depth discussion of the database was considered inappropriate as the pilot study has not been finalized and the available resources not determined.

The ASEAN-Australia Living Coastal Resources project has established functional regional and in-country databases for the ASEAN region. This database is currently being reviewed and restructured and can serve as the model for the Global Monitoring Programme for other regions.

TERRESTRIAL VEGETATION: MANGROVE COMMUNITIES

Background

Mangroves are economically significant in tropical and sub-tropical regions since they serve as breeding/nursery ground for commercial and subsistence fish and penaeid prawn stocks, as a valuable source of timber and charcoal, and for mariculture development. It is expected that these communities will respond to climate forcing and they are already subject to other sources of anthropogenic change, hence they were included in the pilot phase of the Long-term Global Coastal and Near-Shore Monitoring System.

Mangroves have a pantropical distribution limited in the North and South by the occurrence of ground frost. Mangrove communities are subject to varying degrees of anthropogenically induced stress in different regions, ranging from total clearance for land reclamation and mariculture to changes induced by altered sediment flux in coastal areas.

It must be recognized that distinguishing the noise of anthropogenically induced stress in mangrove communities from the climate signal, eg. increase in CO_2 concentration, temperature and eustatic sea level rise will only be possible following extended monitoring based on replicable and widely applied monitoring techniques.

Aims

1) To secure commitment of member states to the initiation of this pilot phase activity.

2) To ensure co-ordination between on-going and planned mangrove monitoring activities.

3) To implement initial monitoring of selected sites in the mangrove areas worldwide.

4) To strengthen the existing regional networks of institutions collecting mangrove monitoring data by providing facilities for inter-regional and global collaboration in data handling and exchange.

Methodology and workplan

Following the expert meeting in Monaco in December 1991 the approved monitoring methodologies will be edited and published in their entirety by IOC in collaboration with UNEP and the ASEAN-Australia project. The coral reef and mangrove methodologies will be published as separate issues in the UNEP Regional Seas Reference Methods for Marine Pollution Studies series in 1992. The work plan and timetable will be presented to the IOC Executive Council. The report of the expert meeting will be circulated to all IOC Member States, Regional Bodies, collaborating agencies, the UNEP/UNESCO Global Task Team on Climate Change Impacts on Mangrove Ecosystems and the UNEP/IOC Regional Task Teams for comment and indications of interest in participation.

Existing sites of mangrove monitoring and sources of data will be identified. Where necessary to complete coverage of the proposed system, additional monitoring sites will be established in each of the Pacific, Caribbean and Indian Oceans and initial surveys will commence in the last quarter of 1992 and throughout 1993.

Outputs

1. Manual of approved monitoring methodologies for mangrove communities (mid-1992).

2. Catalogue of existing mangrove monitoring sites, institutions and data sources and establishment of a global network of participating institutions (1993).

3. Compilation of initial site survey data and development of standardized formats for data handling and exchange (1993).

Budget

For the mangrove monitoring programme, a minimum of 60 sites is necessary, distributed across all ocean regions. The following table contains indicative estimates of the establishment cost for a mangrove monitoring site.

Cost per site	**UNEP-IOC-WMO**	
Recurrent	(US $)	Host country
Personnel *	0	local rates
Supplies and Maintenance	7,000	
Communication	3,000	
Sub-total	10,000	
Establishment costs		
Travel to workshop	5,000	
Consultants (sample analysis)	3,000	
Equipment	2,000	
Sub-total	10,000	
Total	$ 20,000	

* Indicative figures are not included due to the extreme variation in salaries worldwide. It is estimated that operation of a single national level monitoring site would involve no more than 3 man-months per year.

Countries that have poorly developed infrastructure may need up to an additional $ 35,000 for initial capital expenditure in establishment of the monitoring station; purchase of equipment; baseline survey; analysis of satellite imagery and local transport.

Sites

The outline for this pilot phase activity states that a number of sites covering the Caribbean, Indian and Pacific Oceans should be selected spanning the range of mangrove community types and varying degrees of anthropogenic impact. Criteria for site selection should include the existence of infrastructure which could immediately implement ground truth surveys to accompany mapping of zonation and extent based on remotely sensed data. In addition, the existence of historic time sequences of satellite images or aerial photographs should be used as a criterion for site selection.

The recommendations of the 1990 expert meeting include the distinction between global, regional and national sites with the former being located in far-field environments where direct anthropogenic influences and the influence of factors other than climate change are reduced to a minimum. Existing mangrove management programmes have tended to concentrate on nationally important mangrove areas which are subject to stress resulting from encroaching development. The COMAR programmes operating in the Asia-Pacific, Caribbean and African regions provide one base on which to build a monitoring network whilst the ASEAN-Australia Marine Science Project forms another. The COMAR programme of UNESCO could assist in network development. It is suggested therefore that regional networks be established based on existing national sites involved in regional mangrove monitoring programmes where these currently operate. Within each region a minimum of two regional sites should be selected, which fulfil the conditions detailed in Item 7.1 of the system plan.

The following general conditions are desirable for selected sites:

(i) Previous research or monitoring at the site, for example aerial photographs or records of human uses, or intensive stratigraphic or ecological scientific studies.

(ii) Proximity to a GLOSS tide gauge.

(iii) The size of the site should relate to the contextual geomorphic setting, such that the site is a unit with respect to important processes.

The scientific guidelines for site selection can be separated into factors relating to:

a) Biogeographic differences in community structure
b) Environmental setting
c) Relative sea-level trends
d) Latitudinal gradients of light and temperature
e) Tidal amplitude

It is considered that these factors will cause different responses of mangrove ecosystems to climate change and sea-level rise. Examples of localities at the extremes of these ranges are discussed below, and these limits should be infilled by monitoring sites at a density of about one every 500 km of latitude on mangrove coastlines. Given the variance in biogeographic range, environmental settings, tidal regimes and latitudinal gradients of mangrove communities it will be necessary to establish sites that reflect these differences.

Biogeographic considerations

Climate change should alter the community structure of mangroves through relative dominance of different species, and extension of ranges of species into higher latitudes. It is possible that communities with lower diversity will have reduced ability to adjust to the stresses of climate change and sea-level rise relative to communities with higher diversity. Hence it is important to select and compare sites at the Indo-Pacific and East-Pacific/Atlantic centres of diversity, the west and east limits of these, and the north and south limits, as well as systematic sites along the interim gradients. North and south limits in this case should be continental shorelines, where fewer limits to dispersal exist than for island locations.

The far extremes of mangrove distributions are by definition the climatic limits of successful growth, limited by temperature, ground frost and light. It is possible that these communities on the limits will be the first to show responses to disturbance by sea-level rise. For climate change they are of interest because they may show a clear signal of changes in community productivity and structure. Independent of biogeographic region, it is desirable to include oceanic islands near latitudinal limits, because they may provide a clearer signal of climate change.

Environmental settings

It is likely the mangrove response to climate change and relative sea-level rise will vary according to environmental setting, as this controls the degree of influence of external marine and fluvial factors, and the sedimentation rate.

Relative sea level trends

Stratigraphic analysis combined with isometric dating, and long-term tide gauge records have established trends in sea-level change for certain locations of the world that may provide analogues for global sea-level trends of the future. Trends in secular sea-level are indicated in analyses such as Barnett (1983, 1984), Gornitz and Lebedeff (1987), and Pirazzoli (1986, 1989). Trends in palaeo-sea level are synthesized by Devoy (1987). Sites with relative sea-level rise (submergent coasts) should be compared with those of relatively stable sea-level and those of relative sea-level fall (emergent coasts) for identification of ecosystem responses and forcing processes. Sites with variables sea-level owing to factors such as seasonal steric changes or ENSO events should also be considered.

Tidal regime

It is possible that sea-level rise will have a greater impact on areas of small tidal range relative to those of large tidal range. Hence comparison of sites is desirable.

The sampling design based on the scientific dimensions discussed above is tabulated as:

BIOGEOGRAPHIC PROVINCE
- Indo-Pacific
- East-Pacific/Atlantic

LATITUDE
- North-South
- Centres of diversity

LONGITUDE
- East-West
- Centre of diversity

ENVIRONMENTAL TYPES
- Deltas
- Arid coasts
- High islands
- Low islands

RELATIVE SEA LEVEL TRENDS
- Emergent coasts
- Submergent coasts
- Stable coasts

TIDAL REGIME
- Large
- Small

The list of countries in Appendix B represents a scientifically selected set of representative mangrove community types and environmental variables reflecting the criteria discussed above. Many other countries could be included in this list as substitutes or additions depending upon government interest in participation. The listing does not reflect priority nor a commitment to participation by the countries listed.

Measurement requirements

Biological variables initially proposed for inclusion in the monitoring programme by the expert meeting at monitoring sites included species composition and zonation. Such characteristics are sensitive to changes in seawater temperature, salinity, sediment inputs, beach composition and coastal dynamics in terms of offshore-bottom profile, long-shore drift, erosion and accretion.

The most appropriate and cost effective mapping and monitoring technique for analysis of plant community structure is digital image technology from satellites and aircraft combined with ground measurements of secondary variables, and is suggested that a 5-year time interval between mapping period may be sufficient.

Baseline survey

Each selected site will require an initial detailed survey and vegetation map based on either suitable satellite imagery and/or aerial photography detailing major zones and vegetation formations within the monitoring area. Based on recognizable divisions of the site a suitable programme of quantitative biological survey is required, sufficient to describe the components and characteristics of each vegetation formation. A detailed on-site topographic survey is also required to determine the elevation of the mangrove substrate with respect to the tidal spectrum. Such surveys should be made with respect to fixed survey points which remain in position between surveys and should include a sea level recording station established to GLOSS standards.

The baseline survey should also include an off-shore physical oceanographic description of the site including: major current patterns; depth profiles of physical variables and benthic substrate types. Where sites are subject to marked seasonal changes, a minimum of two surveys will be required to describe seasonal differences in physical oceanographic conditions.

Benthic substrate data should include grain size composition and organic content.

Such generalized surveys should be repeated at a minimum frequency of five years.

PARAMETERS

The main priority is the determination of the response of biological communities to climate change. This will involve measurement of some of the physical variables leading to these responses. Parameters are listed as either being of primary or secondary importance. The primary parameters represent the minimum required set for measurement.

Measurement of biological parameters (listed below) and certain physical parameters will be made along a transect across the intertidal slope, as close to the center of the area as possible. Sampling frequency along this transect will be site dependent according to the scale and characteristics of the site.

Further to the systematic study specified below, resurvey should be made immediately following an extreme event (cyclones etc.).

Minimum Parameter Set (Stage 1)

The following biological parameters are the minimum necessary to assess the impact of possible climate change on mangrove ecosystems. The interval between monitoring periods is envisaged as being 5 years during the operational life-span of the system. During the pilot phase a shorter interval of 3 years is recommended to provide adequate data flow for calibration, testing, and establishment of necessary data management systems.

Because of the diversity of mangrove environments and in order to distinguish between the effects of climate and anthropogenic and other non-climatic impacts the following physical parameters are the minimum required.

Parameter	Minimum Frequency	Methodology
BIOLOGICAL		
Forest structure	5 years	ASEAN-Australia Manual or USM Manual
Tree size	5 years	ASEAN-Australia Manual or USM Manual
Density	5 years	ASEAN-Australia Manual or USM Manual
Tree growth	5 years	DBH increment (USM Manual)
Leaf area index	5 years	Light attenuation: ASEAN-Australia Manual with modifications
Interstitial macro-fauna	2 years	Holme & McIntyre, 1971; Hullings & Gray, 1971
Species composition of macrofauna	1 year	Burrow density
PHYSICAL		
Relative sea level change	Continuous	GLOSS or tide gauge part of met. station
Topography	5 years	EDM survey, relative to datum
Stratigraphy	Baseline	Coring and radiometric dating
Sedimentation rate	5 years	Inserted stakes, remain *in situ*
Meteorological data	Continuous	Automated meteorological station
Total radiation		to WMO standards
Air temperature		
Rainfall		
Wind Speed and direction		
Relative humidity		
Atmospheric pressure		
Evaporation		Evaporimeter, WMO standards

Desirable additional parameters (Stage 2)

Further to these minimal requirements, it would be desirable where possible to monitor the following indicators, to allow assessment and interpretation of biological responses to global change.

A more complete analysis including the following parameters could assist in interpretation of the biological responses.

Parameter	Minimum Frequency	Methodology
BIOLOGICAL		
Analysis of leaf pigments & tannins	5 years	Tannin analysis of treetop leaves
Height of pneumatophores	5 years	Ruler with EDM survey
PHYSICAL		
Sediment particle size	5 years	Sieve cascade, ASEAN-Australia Manual
Redox potential	5 years	Inserted iron stakes, removed
Soil salinity	Seasonal	Squeeze cored sediment
Surface water	Seasonal	Maximum/minimum recorder

Additional optional parameters (Stage 3)

Routine long-term measurements of these parameters may aid in the interpretation of the causes of observed change in mangrove communities.

Parameter	Minimum Frequency	Methodology
BIOLOGICAL		
Plant ecophysiology	seasonal	Pearcy, et al., 1985
Age distribution of macrofauna	5 years	ASEAN-Australia Manual
Predawn water potential	5 years	Scholander pressure bomb
Wave conditions		Derive from meteorological data
PHYSICAL		
Water circulation		GCNSMS Activity 2
Sediment ash free dry weight	5 years	Loss on ignition
Trace metals	5 years	To international standards
Pesticides	5 years	To international standards
Root flora	1 year	Qualitative observation
Carbon partitioning	5 years	To be determined
Rate of turnover of biomass	5 years	To be determined
Litter breakdown	5 years	To be determined

DATA MANAGEMENT

The data during the initial phase (2-3 years) will be produced and included in a base-line status report for mangrove ecosystems at selected sites. Such base-line data will be of value to coastal zone managers in

localities where mangroves form a major coastal habitat and consequently a source of renewable resources. These data will provide quantitative estimates of total levels of stress in different mangrove ecosystems. In a number of instances, many parameters, e.g., sedimentation rates, which are considered of importance for inclusion in the global monitoring effort are not currently measured using standardized methodologies. To develop, test, and adopt appropriate methodologies will therefore be an initial phase priority.

During the initial phase, development of standardized formats for data exchange will be emphasized. Whilst existing data handling mechanisms remain appropriate for regional and national programmes, it is clear that considerable effort will be required to develop globally applicable data handling mechanisms. It is anticipated that during the second year of the initial phase, a major symposium and a workshop will be needed to analyze the base-line data, to prepare a comprehensive report on the status of mangrove ecosystems, to evaluate and modify data handling methodologies, and to develop optimum data exchange mechanisms. It is envisaged that the baseline data will be exchanged readily, freely, and in a timely fashion between participating countries but that a need for real-time data exchange will not arise during the 1990's.

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APPENDIX A

EXAMPLES OF POSSIBLE COUNTRIES FOR INCLUSION IN PILOT PHASE MONITORING OF CORAL REEFS

The following list of countries represent a scientifically selected set of representatives coral reef types and environmental variables reflecting the criteria discussed in this annex. Many other countries could be included in this list as substitutes or additions depending upon government interest in participation. The listing does not reflect priority nor a commitment to participation by the countries listed.

INDIAN OCEAN (including Red Sea, Persian Gulf, etc.)
- Mauritius @
- Maldives #
- Jordan, Gulf of Aqaba (special case) @
- Thailand, Phuket @
- Kenya #
- W. Australia, Houtman Abrolhos Is **
- Somalia and Cocos Keeling **

SOUTH EAST ASIA
- Philippines @
- Malaysia (e.g. Sabah) @
- Indonesia @
- Thailand @
- Papua-New Guinea, New Britain/New Ireland are associated with the Pacific, but have land interaction effects and climate similar to SE Asia with less anthropogenic disturbance.
- [Singapore is a resource of expertise but not a Location]

PACIFIC
- French Polynesia, Moorea, Takapoto @
- Australia, Great Barrier Reef, Lord Howe Id @
- Hawaii #
- Fiji #
- Panama #
- Belau (Palau) **
- Kiribati, equatorial atoll site **
- Solomon Is. **
- PNG [see above] **
- Galapagos **

ATLANTIC/CARIBBEAN
- Bermuda #
- Panama #
- Barbados &/or Tobago #
- Bonair #
- Cuba #
- Belize **
- Brazil (Abrolhos, Fernano de Noronha) **
- W. African reef systems **

(@) = Countries with existing monitoring programmes
(#) = Countries with existing on-site scientific facilities and staff
(**) = Remote locations that fulfil the criteria for Global Climate Monitoring but would require expeditionary-type studies, until such time as indigenous capabilities have been developed.

APPENDIX B

EXAMPLES OF POSSIBLE COUNTRIES FOR INCLUSION IN PILOT PHASE MONITORING OF MANGROVES

The following list of countries represent a scientifically selected set of representative mangrove community types and environmental variables reflecting the criteria discussed in this annex. Many other countries could be included in this list as substitutes or additions depending upon government interest in participation. The listing does not reflect priority nor a commitment to participation by the countries listed.

BIOGEOGRAPHIC CONSIDERATIONS

BIOGEOGRAPHIC REGION	INDO-PACIFIC	EAST PACIFIC/ATLANTIC
Centre of species diversity	Malesia	Caribbean Panama
Eastern limit	Samoa/Fiji	Nigeria
Western limit	East Africa	N.W. Mexico
Northern limit	S. Japan	Florida
Southern limit	Victoria, Australia	Brazil

ENVIRONMENTAL SETTING

DELTAS	ARID FRINGE	HIGH ISLANDS	LOW ISLANDS
Amazon	Senegal	Fiji	Cayman Is.
Sunderbans, Bangladesh	KAP region (Gulf)	Jamaica	Tongatapu, Tonga
Irian Jaya, Papua New Guinea	Pakistan	Mauritius	Bermuda, Maldives
Daintree, N. Queensland	W. Australia	Guam, Kosrae	Low Is., GBR

RELATIVE SEA LEVEL TRENDS

SUBMERGENT COASTS	EMERGENT COASTS	STABLE COASTS
Samoa/S.Fiji	Tonga	Queensland
Bermuda	North Papua New Guinea	West Africa
Sunderbans,	Bangladesh	Sunda Shelf
Andaman Islands	Madras, India	

TIDAL REGIME	LARGE RANGE	SMALL RANGE
	N.W. Australia	Cayman Is., Jamaica
	N.E. Brazil	Sri Lanka

LATITUDINAL EXTREMES

LIMIT	NORTH	SOUTH
	Bermuda	S.E. Brazil
	N. Senegal	Namibia
	Aquaba, Red Sea	Mozambique
	Ryukus, Japan	S.E. Australia
	N. Micronesia	New Zealand
	N.W. Mexico	Peru

ANNEX IV

LIST OF DOCUMENTS [1]

Document Code	Title
WORKING DOCUMENTS	
UNEP-IOC-WMO-IUCN/GCNSMS-II/1	Agenda
UNEP-IOC-WMO-IUCN/GCNSMS-II/1 Add.	Timetable
UNEP-IOC-WMO-IUCN/GCNSMS-II/2	Annotated Provisional Agenda
UNEP-IOC-WMO-IUCN/GCNSMS-II/3	Summary Report
UNEP-IOC-WMO-IUCN/GCNSMS-II/4	List of Documents
UNEP-IOC-WMO-IUCN/GCNSMS-II/5	List of Participants
UNEP-IOC-WMO-IUCN/GCNSMS-II/6	Action Plan for implementation of long-term monitoring of coral reefs and mangroves in respect of predicted impacts of climate change and sea level rise
INFORMATION/REFERENCE DOCUMENTS	
UNEP-IOC-WMO/GCNSMS-II/Inf.1	Pernetta, J.C. and Elder, D.L. Climate, Sea Level Rise and the coastal zone: Management and planning for global changes. IUCN 1990
UNEP-IOC-WMO/GCNSMS-II/Inf.2	Ellison, J. Climate Change and sea level rise impacts on mangrove ecosystems. Paper presented to IUCN/WWF/US-EPA/Netherlands RIVM Symposium on Impacts of Climate Change on Ecosystems, 3-6 December 1991
UNEP-IOC-WMO/GCNSMS-II/Inf.3	Buddemeier, R.W. Climate Change and sea level rise impacts on coral reef ecosystems. Paper presented to IUCN/WWF/US-EPA/Netherlands RIVM Symposium on Impacts of Climate Change on Ecosystems, 3-6 December 1991
UNEP-IOC-WMO/GCNSMS-II/Inf.4	Draft Manual of Methods. ASEAN-Australia Marine Living Resources Project
UNEP-IOC-WMO/GCNSMS-II/Inf.5	D'Elia, C.F., R.W. Buddemeier and S.V. Smith. Workshop on Coral Bleaching, Coral Reef Ecosystems and Global Change: Report of Proceedings. Maryland Sea Grant College Publ. 1991
UNEP-IOC-WMO/GCNSMS-II/Inf.6	Kjerve, B. Mangrove Hydrology Manual
UNEP-IOC-WMO/GCNSMS-II/Inf.7	CARICOMP Monitoring Methodologies
UNEP-IOC-WMO/GCNSMS-II/Inf.8	Relationship of GCNSMS (COOS) to the Global Ocean Observing System (GOOS)/Global Climate Observing System (GCOS) and related IOC initiatives (to be distributed at the meeting)
UNEP-IOC-WMO/GCNSMS-II/Inf.9	UNESCO Publication on Coral Reefs and Mangroves. Summary List

[1] This list is for reference only. No stocks of these documents are maintained, except for the Summary Report.

Document Code	Title
UNEP-IOC-WMO/GCNSMS-I/3	UNEP-IOC-WMO Meeting of Experts on Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change, Paris, 10-14 December 1990
UNESCO Reports in Marine Science No. 54	Stewart, R.W., Kjerve, B., Milliman, J. and Dwivedi, S.N. 1990. Relative sea-level change: a critical evaluation
IOC Manuals and Guides No. 14	Manual on Sea Level Measurements and Interpretation
IOC Technical Series No. 35	Global Sea Level Observing System (GLOSS) Implementation Plan
UNEP-SPC Ref. Methods for Marine Pollution Studies No. 25	Coral Reef Monitoring Handbook. 1984
Bernal, P., Holligan, P.M. 1991	Marine & Coastal Systems. International Conference on an Agenda of Science for Environmental and Development into the 21st Century, Vienna, 24-29 November 1991

ANNEX V

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ANNEX VI

POTENTIAL IMPACTS OF CLIMATE CHANGE ON CORAL REEFS

Background

At the IUCN-WWF-US/EPA-Netherlands Government sponsored Symposium on the Impacts of Climate Change on Ecosystems and Species held in Amersfoort from 3 to 6 December 1991 a subgroup of the working group on marine/coastal systems was convened to discuss issues relating to climate change impacts on coral reef systems. The conference charge to the sub-group was to:

(i) identify key factors and precesses governing responses to climate change in coral reef ecosystems;

(ii) identify the main features of ecosystems and species responses; and,

(iii) to determine the maximum rates of change which coral reef ecosystems can withstand.

Discussion

Member of the working group agreed that time was inadequate to respond to all aspects of the charge, and chose to consider global level relationships between probable reef responses and seven environmental forcing functions related to global change. It was recognized that this very large scale view necessarily results in generalized classifications that may be inapplicable to individual locations or reef systems, and that regional or site specific assessments are still required to evaluate the vulnerability of individual reefs or reef systems. The evaluation scenario used was the IPCC business-as-usual scenario for the year 2100, with the recognition that this scenario does not specify tropical sea surface temperature, which is a critical variable.

Evaluation was done in an iterative fashion; first the environmental variables were evaluated as to whether their individual effects and their effects in combination with other probable environmental changes would be positive or negative in terms of overall reef welfare on a global average basis in a pristine world (i.e., no other anthropogenic environmental changes). The process was then repeated for the "dirty world" case - additional consideration of the probable effects of non-climate, anthropogenic environmental change and their interactions with climate related variables. Finally, the same environmental variables were specifically addressed in terms of their probable overall effects on four broadly defined biological variables - biomineralization (primarily calcification at the organism level), species diversity; community structure (with physical and biological complexity treated as a positive factor); and primary productivity and/or community metabolism (e.g., P/R, community calcification).

The environmental variables considered and their probable effects were as follows:

1) Sea level rise - as a single factor, its effects are expected to be positive because of increased colonization of sea-level limited reef flats and ventilation of "stagnant" ülagoon systems. It interacts with all other variables, and since most of those produce negative effects the combined value for sea level rise is uncertain. It is expected to have no effect on biomineralization and positive effects on the other biological variables.

2) CO_2 concentration increase - surface ocean equilibration with the increasing atmospheric concentrations will result in lowered pH, lowered carbonate mineral saturation states, and increased availability of dissolved CO_2 (as opposed to bicarbonate ion). This may reduce both biomineralization and community calcification, and increase organic

productivity, but the available data are so limited that the group noted this as a highly uncertain but possibly significant variable in terms of both individual and net effects, as well as influences on community structure and biodiversity.

3) Temperature - May be expected to have different effects at different scales; in the near term, increases in sea surface temperature may be expected to increase the frequency and/or magnitude of high temperature stress events. On a longer scale, warming trends in higher latitude oceans could have a modest positive effect by increasing the area suitable for coral habitat. Interactions will be with UV and nutrients. Effects are negative for community structure and metabolic factors, negative for diversity over present ranges, but possibly positive in marginal or new areas, and negative for coral biomineralization but uncertain for algae.

4) UV radiation increase - Overall effects are uncertain because of limited data, but there is concern about possible effects on reproduction (i.e., larval mortality or genetic damage). Interactions with temperature and nutrients for an overall negative impact. Biological effects are expected to be primarily on species diversity, with uncertainty or no effects related to other variables.

5) Storms - the postulated increase in major storm frequency or intensity was expected to have both an individual and a net negative effect on reefs through the average effect of impacts on community structure and metabolism. Effects on biological diversity will continue to be positive, and biomineralization will not be affected.

The foregoing variable had no strong local or regional anthropogenic sources; however, the following variables had significantly different "dirty world" outcomes.

6) Sediment dynamics - Sedimentation was seen as negative for all biological variables; for convenience, this category was used as a proxy for hydrology and land use effects and toxic compound transport as well as strict sedimentation processes. In the pristine world there was expected to be a modest negative effect as a result of erosion from sea-level rise and possibly increased rainfall intensity. However, local anthropogenic sources due to land use (e.g., deforestation) and coastal modification are major reef stresses in some areas at present and may be expected to increase with growing population. The resultant interactions resulted in a strongly negative net assessment in the real world.

7) Nutrients - In the pristine world, sources of nutrient stress are limited to those associated with sedimentation increases or possible (currently unpredicted) changes in upwelling; it was therefore assigned an effect rating of zero to slightly negative. However, nutrient loading (e.g., as a result of agricultural practices, sewage disposal, etc.) is considered a major contemporary coral reef stress, and one that may interact with UV and CO_2 effects. It was therefore given one of the strongest negative "dirty world" ratings, both individually and as a net effect. Biological impacts are complex; nutrient stress is negative for biodiversity and community structure, as well as for community calcification and coral biodemineralization; however, it is positive for organic productivity, and may enhance algal calcification. Its effects are therefore to shift competitive advantages away from coral reef communities, and chronic nutrient stresses inhibit recovery from acute community stresses caused by storms, high temperature events, etc.

As a result of their consideration, the group assembled a list of key research needs:

(a) The effects of increases in dissolved CO_2 concentration on calcification rates and organic productivity in reef and competing organisms/communities.

(b) Mechanisms and rates of stress adaptation, with emphasis on the physiological and genetic components.

(c) UV effects, particularly on the various aspects of the reproductive process.

(d) The broad issues related to the subject of restoration ecology, ranging from "replanting" of damaged reef areas to research on genetic strains and characteristics most suitable for such uses.

(e) Better ocean and coastal climate models at the regional and subregional scale.

The group also identified specific policy issues derived from the above results:

1) Although the method used for assessment does not permit ranking of vulnerability relative to other ecosystems, it is clear that most of the environmental factors suggest negative effects of climate change on coral reefs, and immediate efforts should be made to reduce the threat of global climate change to reef systems.

2) Two of the factors (sediment dynamics and nutrient loading) that represent the greatest present threat to reefs on local/regional anthropogenic basis also present some of the greatest combined threats when interacting with climatic variables. It was considered both urgent and completely consistent with climate change initiatives to reduce and mitigate these present threats as a matter of highest priority. A strong programme of integrated coastal zone management would be one effective and appropriate way to achieve this as well as the larger issues of climate change protection.

3) In view of the many uncertainties, many of them in potentially critical areas, strong, integrated, long-term programmes of coral reef monitoring and research are needed.

ANNEX VII

POTENTIAL IMPACTS OF CLIMATE CHANGE ON MANGROVES

Background

At the IUCN-WWF-US/EPA-Netherlands Government sponsored Symposium on the Impacts of Climate Change on Ecosystems and Species held in Amersfoort from 3 to 6 December 1991 a subgroup of the working group on marine/coastal systems was convened to discuss issues relating to climate change impacts on mangrove systems. The conference charge to the sub-group was to:

(i) identify key factors and precesses governing responses to climate change in mangrove ecosystems;

(ii) identify the main features of ecosystems and species responses; and,

(iii) to determine the maximum rates of change which mangrove ecosystems can withstand.

Discussion

The main impacts of climate change that can be expected to affect mangrove ecosystems and species are sea level rise, climate warming, changes in precipitation and changes in frequency or intensity of hurricanes as well as changes in productivity caused by higher levels of atmospheric carbon dioxide. To date, there has been very little research that directly addresses these issues. These changes will occur in combination with each other as well as with stresses on mangrove communities consequent from sharing the tropical coastal zone with the majority of the world's human population.

Sea-level rise is likely to be the most significant of these impacts, in several ways.

Mangrove species feature zonation according to elevation, owing to varying tolerance of salinity and frequency of inundation. With sea-level rise landward migration can be expected, with seedlings of seaward zones establishing in landward species assemblages, and expansion of mangrove landward zones onto fringing land previously unoccupied by mangroves. Established trees may become stressed by increased salinity and frequency of inundation, with reduced growth and early death.

The Bruun model of beach erosion with rising sea-level has been shown to be also appropriate for mangrove swamps. Sediments from mean to high tide levels, which is the range of mangroves, is eroded and deposited sub-tidally. Erosion could be of three types, low cliffed erosion at the seaward edge, sheet erosion of the entire mangrove surface, and creek bank erosion. Trees could be undercut and more prone to windthrow, and enhanced litter loss could impact the faunal food chain utilizing mangrove detritus. Mangroves with low rates of sedimentation, such as low island autochtonous systems can be expected to be more impacted by sea-level rise than those of sediment rich locations, such as deltas.

Correlation has been shown between mangrove distributions and areas where mean monthly water temperature exceeds 24°C, excepting locations too distant to be colonized by mangrove propagules. While most GCM's predict limited warming around the equator relative to high latitudes, the predicted sea-surface temperature increase of 1.5°C by 2025 can be expected to affect sub-tropical mangroves, causing increased diversity of higher latitude marginal mangroves, and some expansion of the ranges of mangroves into salt marsh environments.

Thermal stress affecting root structures and communities and mangrove seedling establishment has been shown in sea temperatures above 35°C. It is possible that increased temperatures in some areas may reach this limit.

Diversity of mangroves is greater in areas of higher rainfall, owing to availability of fluvially-derived nutrients and sediments. Hence changes in diversity, extent and biomass of mangroves can be expected to show positive correlation with changes in rainfall.

As well as changing climate, increased CO_2 directly affects plant growth and development. Mangroves have a C_3 pathway of carbon fixation in photosynthesis, where metabolic response to increased CO_2 has been shown to be increased productivity, and more efficient water use due to reduced stomatal conductance. It is possible that reduced transpiration will cause changes in salt regulation, particularly in salt secreting species.

There is an evident inverse correlation between yield and latitude in mangrove litter production, broadly between 5-10 t/ha/a across the range of mangroves. This implies a marginal increase in productivity with increased temperature and CO_2 concentrations. It is possible that some ecosystems may find limits in nutrient supplies not previously realized.

No data exists on effects of increased UV light on mangrove plants.

Modelling studies suggest an increase in the destructive energy and frequency of tropical hurricanes, as a result of increasing sea-surface temperatures, and changes in spatial frequency. From combinations of other factors of sea-level rise, and changes in ecophysiology and community composition relative to climate change may be prone to damage in lesser magnitude storms than has been shown previously. This concept may extend to all natural and anthropogenic stresses: mangroves will become far more fragile as ecosystems, hence justifying stronger conservation measures and increased research and management activity.