Intergovernmental Oceanographic Commission
Workshop Report No. 77

IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands

Mombasa, Kenya, 24-28 June 1991

UNESCO

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1. PREFACE

The coastal countries and islands of the Western Indian Ocean are highly vulnerable to sea-level rise, having many structural developments including major ports, cities, extensive farmlands, settlements and tourist facilities located along low-lying parts of the coast. A rise in sea-level of 3 to 10 cm per decade as predicted by the Intergovernmental Panel on Climate Change (1990) could have a devastating effect on this region, particularly when combined with other projected consequences of climate change, such as an increase in the frequency and magnitude of tropical storms. Figure 1 provides an overview of the Western Indian Ocean region and Tables 1 and 2 give information about the countries of the region.

Evaluating and planning for the projected impacts of sea-level rise in the region is difficult, due to a paucity of data and low levels of communication and awareness among scientists and policy-makers. Although 19 sea-level monitoring stations have been installed in the Western Indian Ocean region, either through Global Sea-Level Observing System (GLOSS) or through the IOCINCWIO regional component of GLOSS, much remains to be done. Many stations are currently inoperative due to lack of maintenance and repair, and certain priority stations have not yet been installed.

This Workshop was convened to review available information on sea-level measurements and analysis in the Western Indian Ocean and in particular: (i) assess the impact of sea-level changes on the coastal environment and resources; (ii) develop awareness of the implications of sea-level change; and (iii) recommend ways and means to establish links between the scientific community, carrying out sea-level measurements, and the decision makers, so as to ensure a coherent approach to coastal marine management.

The Workshop was organized as a series of 11 plenary and topical sessions (see Annex I for Workshop Programme). A total of 77 scientists, experts and policy-makers from 11 countries attended the Workshop. A list of participants is attached as Annex II.

One of the main outcomes of the Workshop was the drawing up of an outline for the IOCINCWIO regional sea-level programme. The objective of this programme is to improve the regional network of sea-level stations for long-term monitoring, both as a contribution to GLOSS, as well as for the assessment of the vulnerability of this region to sea-level changes.

2. OPENING

Dr. E.N. Okemwa, Director of Kenya Marine and Fisheries Research Institute (KMFRI), welcomed the participants and wished them a pleasant stay in Mombasa. He thanked all who provided assistance in the organization and sponsorship of the Workshop, especially the Intergovernmental Oceanographic Commission (IOC), the Swedish Agency for Research Co-operation with Developing Countries (SAREC), and the University of Nairobi (UON). Dr. Okemwa presented the main research activities conducted by KMFRI and discussed some basic problems of sea-level measurements at the Kenyan stations. He observed that concern about climate change and sea-level rise has induced many countries to monitor and review this phenomena and expressed the hope that the participants would have fruitful and stimulating discussions.

Professor R. Olembo, Chairman of the KMFRI Board, stated that evidence of sea-level rise indicated that action should be taken now, as time is not in mankind's favour. He referred to the Maldives Islands, where the

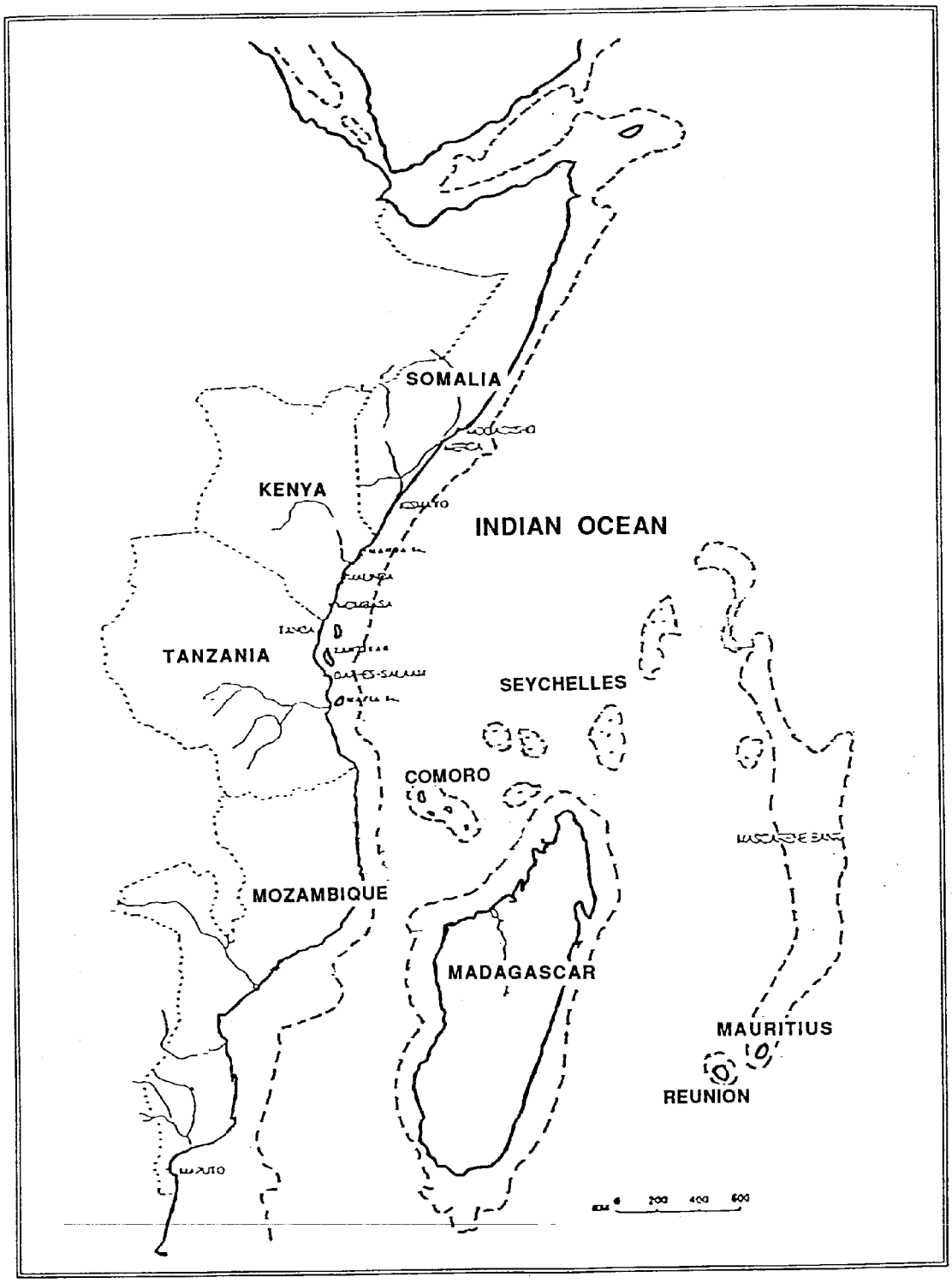

Figure 1: The East African Region. The dashed line represents the limits of the continental shelves and major banks in the Western Indian Ocean.

Table 1: The average width of the shelf is some 15 - 25 km but ranges from a few hundred metres wide to nearly 145 km (see Figure 2 for the delineation of the continental shelf).

Country	Land Area Km^2	Estimated Shelf Area depth range 0-200 Km2	Length of coastline (Km)
Comoros	2,236	900	350
Kenya	582,650	6,500	500
Madagascar	595,790	135,000	4,000
Mauritius	1,865	1,600	200
Mozambique	738,030	120,000	2,500
Seychelles	443	48,000	600
Somalia	637,657	32,500	3,000
Tanzania	939,703	30,000	800

Table 2: Population Distribution (World Resource Institute, 1990)

Country	Population (Millions)	Annual Growth rate	Coastal Population (Millions)	Density (KM2)
Comoros	0.50	3.08	0.440	180
Reunion	0.51	-	0.546	205
Kenya	22.40	4.20	1.640	27
Madagascar	11.20	2.90	2.000	14
Mauritius	1.04	1.65	0.772	509
Mozambique	14.72	2.69	3.000	13
Seychelles	-	-	0.012	145
Somalia	5.36	2.80	1.600	8
Tanzania	24.19	3.65	3,690	19

highest point is only a few meters above the high water mark, as an example of a nation whose very existence is threatened by rising sea level. He informed the participants that, due to other commitments, he would designate Professor Wasawo to represent the KMFRI board at the Workshop.

Dr. G. Alcock welcomed the participants on behalf of the Secretary of the IOC, Dr. G. Kullenberg. He expressed gratitude to KMFRI and to the University of Nairobi for organizing the Workshop, and thanked SAREC for providing substantial financial support. He appreciated also the support from other organizations in providing additional funding to enable a wider participation by scientists from the region. Noting that a number of international meetings have been convened to discuss sea-level rise and its impact on coastal areas in different regions of the world, Dr. Alcock pointed out that countries of the Western Indian Ocean region have not held any such meetings, at either the regional or national level, despite the fact that these countries have many structural developments and important ecosystems located in low-lying coastal areas. The IOC therefore saw the necessity and justification for facilitating a workshop so that experts, policy-makers and entrepreneurs could come together to address the problems and suggest strategies for future planning.

Mr. S. Ragoonaden, Vice-Chairman of the IOC Regional Committee for the Co-operative Investigations in the North and Central Western Indian Ocean (IOCINCWIO), recalled that IOCINCWIO, at its second session in Arusha, Tanzania (December, 1987), had adopted a proposal for the development of a regional sea-level programme. He hoped that by the end of this meeting, the participants would develop an outline for such a programme to be presented to the Third Session of IOCINCWIO.

Prof. F.F. Ojany of the University of Nairobi welcomed the Assistant Minister for Research, Science and Technology and stated that the governments in the region should initiate the necessary steps needed to mitigate the consequences of impending sea-level rise in their respective countries. In this regard, governments will need the advice of the scientists concerned.

Dr. G. Oluoch, the Assistant Minister for Research, Science and Technology, expressed the pleasure of the Government of Kenya in hosting the Workshop. On behalf of the Minister, he thanked IOC and SAREC for their substantial support. He stressed the importance of developing regional contingency plans to address problems arising from anticipated sea-level changes and noted that the strategy chosen must be technically sound and within the economic means of the countries in the region. He hoped that at the end of the Workshop, participants would come up with an assessment of the impacts of anticipated sea-level changes on the coastal environment and resources in the region, and would provide recommendations for measures to be taken to adapt to these anticipated impacts.

3. ADMINISTRATIVE ARRANGEMENTS FOR THE WORKSHOP

Dr. E. Okemwa was designated as Chairman and Mr. M. Odido as the Secretary/Co-ordinator of the Workshop. The Chairmen and Rapporteurs of the individual sessions are given in Annex I (Programme of the Workshop). The three committees formed were chaired by S. Ragoonaden, (Regional Sea Level Programme), A.B.C. Killango (Mainland Nations Recommendations) and A.E.L. Couto (Island Nations Recommendations).

The participants considered and approved the programme of the Workshop as given in Annex I.

4. SEA-LEVEL CHANGES

4.1 PAST AND FUTURE SEA-LEVEL RISE (G. Alcock)

Most records of mean sea level show evidence of a gradual rise in global mean sea level over the last century. However, signals caused by land movements (e.g. uplift or submergence) can mask this signal due to actual changes in sea level. Correcting for the land-based signal, estimates of the actual rise in the global sea level over the last 100 years lie within a range of 10-20 cm. The Working Group I of the Intergovernmental Panel on Climate Change (IPCC) has estimated that, if the emission of greenhouse gases continues at the current rate, the level of the sea surface will rise by an additional 8-20 cm by the year 2030, 21-71 cm by 2070 and 31-110 cm by the year 2100.

A rise in sea level of this magnitude could cause major impacts in many coastal areas of the world. Consequences include: the inundation of coastal wetlands and lowlands with associated disruption of ecosystems; increased coastal erosion and breaching or destruction of coastal structures (both man-made and natural); frequent and widespread flooding of low-lying coastal areas; and contamination of freshwater supplies and agricultural land. The options available in responding to sea-level rise include fortification by building new defenses; abandonment of vulnerable areas or adaptation to new conditions.

4.2 THE IMPLICATIONS OF THE EXPECTED CLIMATE CHANGES ON THE EASTERN AFRICA COASTAL ZONE (A.L. Alusa and J. Ogallo)

In 1989, the United Nations Environmental Programme's Oceans and Coastal Areas Programme Centre (UNEP OCA/PAC) created a regional task team to evaluate the implications of climate change in the Eastern African region, including countries of Somalia, Kenya, Tanzania, Comoro, Madagascar, Mozambique, Reunion and the Seychelles. An assumed mean temperature rise of 1.5°C by the year 2025 may result in an increase in the frequency and intensity of extreme weather events and may cause changes in the monsoon winds, altering precipitation patterns over parts of the Eastern African region. Changes in precipitation patterns are difficult to predict due to topographic and geographic variations. Although rainfall activity may be intensified in currently rainy areas, an increase in temperature could lead to higher evapo-transpiration rates, with deleterious effects on crops in drier areas.

An assumed regional sea-level rise of 20 cm, by the year 2025, is not likely to cause severe impacts. However local sea-level rise may be much higher than this in areas of land subsidence. Impacts may include wave impacts on exposed wastes and on ports, and flooding of canals, estuaries, lagoons, etc. Socio-economic consequences of climate change and sea-level rise include impacts on shipping and fishing industries, agriculture and transportation.

4.3 EPISODIC SEA-LEVEL CHANGES IN THE WESTERN INDIAN OCEAN - EFFECTS ON MAN-MADE COASTAL STRUCTURES (T.S. Murty)

Episodic sea-level changes occur during specific events such as storm surges, tsunamis and water waves caused by submarine landslides. In the Western Indian Ocean there are two regions prone to tropical cyclones: the Arabian sea in the north and the region between 10°S and 30°S. Storm surges generated by tropical cyclones can cause loss of life and damage to property. Global warming is expected to intensify tropical cyclones and the wind fields associated with them. Super hurricanes or hypercanes may be experienced, in which the pressure field at the centre of the hurricane at sea level could be

800 mb or even lower. By comparison, the lowest pressure ever recorded in a hurricane is 870 mb. It is possible that the gap between the northern tropical cyclone-affected region and the southern tropical cyclone-affected region in the Western Indian Ocean may narrow or disappear completely, making all shorelines along the Western Indian Ocean subject to tropical cyclones and storm surges. Storm surge amplitudes associated with hypercanes will be significantly greater than those at present.

Changes in sea level associated with global warming will be slow and gradual as compared to changes in sea level associated with episodic events. Breakwaters, seawalls and mangrove forests may offer partial protection from the destructive effects of events associated with relatively fast sea-level changes. High velocity surges may result in five types of forces: buoyant forces (lifting large objects and structures from their foundations); surge forces (destroying or displacing structures at the leading edge of the surge); drag forces (displacing items or buildings in the direction of the waves and causing severe erosion and scouring of materials at the bottom of structures); hydrostatic forces (resulting in the cracking or collapse of structures); and impact forces (caused by materials carried by the surging water).

4.4 THE TOGA SEA-LEVEL OBSERVING NETWORK IN THE WESTERN INDIAN OCEAN

Dr. G. Mitchum presented the Tropical Oceans and Global Atmosphere (TOGA) Sea Level Observing network in the Western Indian Ocean. So far, fair to good data has been received from Kenya (Mombasa, Lamu), Madagascar (Nosy Be), Mauritius, and Tanzania (Zanzibar). Dar-es-Salaam data is not as good. No information is available on the status of the sea-level stations in Somalia. The University of Hawaii is willing to send and install instruments if they can be assured of local observer support. Data from the region is available, free of charge, from the TOGA Sea-Level Centre.

4.5 CONTRIBUTED PAPERS ON SEA-LEVEL STUDIES IN COUNTRIES OF THE WESTERN INDIAN OCEAN

Participants from each country summarized the work undertaken by their respective nations on sea-level studies in the Western Indian Ocean. A summary of the abstracts or presentations is provided in Annex III.

5. CONSEQUENCES OF SEA LEVEL CHANGE

Basic data pertinent to climate change and sea level rise in the region is limited and in non-standardized formats. However a rise in the region of 30-100 cm could have far-reaching consequences.

5.1 WEATHER AND CLIMATE

Changes in weather and climate patterns will affect and will be affected by sea-level changes. There will be changes in the magnitude and frequency of storm events. Cyclones and their attendant storm surges are likely to occur along tracks closer to the equator, impacting previously unaffected shorelines. Changes in precipitation patterns and the monsoon storm climate may result in higher river discharges and larger sediment loads, potentially altering coastal sediment budgets and ecosystems.

5.2 COASTAL PROCESSES

Sea-level rise, in combination with meteorological changes, will cause a change in tidal patterns, increased wave action and changes in coastal

circulation leading to altered depositional and erosional processes. Exposed shorelines are likely to experience increased erosion, and hitherto sheltered shorelines may lose their protection.

5.3 MARINE AND OCEAN LIVING RESOURCES

Coral reef communities could initially benefit from the increased area available for colonization and the increase in water temperature. However, ultimately these reefs may slowly be submerged, possibly unable to grow fast enough to keep pace with the true rate of sea-level rise. Mangroves will migrate landward to occupy newly flooded areas, while existing communities in deeper waters will be submerged. Macroalgae and sessile rocky cliff organisms will have to migrate to higher elevations on the surfaces they colonize. Seagrass growing on marshlands will benefit from increased sea level where their habitat is not completely covered.

5.4 COASTAL LOWLANDS

Coastal lowlands (eg. swamps, marshes, floodplains, deltas) will be flooded more frequently and may even be completely covered by seawater or subjected to erosion. The intrusion of sea water into estuaries and groundwater aquifers may affect the quality of freshwater supplies.

5.5 HUMAN SETTLEMENTS, INDUSTRIAL DEVELOPMENT AND GENERAL INFRASTRUCTURE

Major investments located in the coastal areas including cities, port facilities and industries will all be affected in different ways by sea-level rise. Reclaimed land currently developed or inhabited by coastal communities will be threatened by flooding. Man-made structures such as jetties, seawalls and embankments will come under increasing physical stress. Most tourist facilities are sited close to the high water mark and are already experiencing erosion problems. A rise in sea level will therefore affect them significantly. Aquaculture may initially benefit from the increased land available for fish ponds, but existing infrastructure may have to be redesigned.

5.6 ISLAND NATIONS

Islands have unique oceanographic, geomorphological and topographical characteristics. Their economies rely to a large extent on their coastal resources, including tourism. Especially small island nations are particularly susceptible to adverse impacts resulting from a significant rise in sea level. Some basic work has already been completed in Mauritius on the implications of sea level-rise on the coastal environment and socio-economic activities.

6. POLICY RESPONSES AND RECOMMENDATIONS

The policy options available to address sea-level rise include the following:

(i) protection of shores and existing coastal structures. This will involve the construction of coastal defence structures such as seawalls and embankments. Fortification of sand dunes with binding vegetation may temporarily reduce the impact of sea-level rise;

(ii) planning for development to adapt to changing sea level (e.g. establishment of buffer zones);

(iii) abandonment of vulnerable areas and relocation of affected populations. For some nations, particularly the islands, this option is not viable, as there is nowhere to transfer the displaced populations.

These are analyzed in the IPCC I Report in the global perspective (WMO-UNEP IPCC Policy-makers Summary of the Scientific Assessment of Climate Change, June 1990).

To be in a position to make correct decisions on actions to take in addressing sea-level concerns, a certain amount of baseline data is necessary, which will require a variety of research activities. These include basic measurements of sea-level change, and research on a variety of related topics such as how the combined impacts of weather, climate, coastal circulation and sea level will impact coastal systems and human settlements. In order to effectively carry out the monitoring and research activities, some training will be required to develop local scientific capabilities.

It is vital that the results of this research be communicated to managers, decision makers and the general public, and eventually be incorporated into legislation. Physical oceanographers, marine meteorologists and other marine scientists should be actively involved in monitoring and managing the coastal environment; and also in the formulation of strategies for coastal zone development and management. Coordination of activities can be facilitated through interdepartmental and interministerial co-operation.

Specific recommendations for monitoring and research activities, training, awareness legislation and co-ordination are discussed below.

6.1 REGIONAL SEA-LEVEL PROGRAMME

Sea-level monitoring and data analysis and interpretation is necessary for the development of rational management strategies. There is a need to improve the sea-level network in the region. A draft Regional Sea-Level Programme was prepared by the *Ad hoc* Committee and is provided as Annex IV. All the countries of the region are urged to do everything possible to realize this programme, in close co-operation with the Global Sea-Level Observing System (GLOSS).

Major components of this programme include the up-grading and expansion of the existing monitoring network, the establishment of a centralized data management centre, training activities and fund-raising. To implement this programme, the following actions are recommended:

(i) Each country should make efforts to ensure that the proposed sea-level stations within its jurisdiction are installed and operating;

(ii) A regional data centre should be established at KMFRI in Mombasa, Kenya and the TOGA Sea Level Centre should be requested to provide monthly and annual mean sea-level data to the regional centre for distribution;

(iii) IOC should initiate and co-ordinate training, in collaboration with national and regional institutions; and

(iv) IOC, SAREC and other organizations should be approached to assist in the realization of the regional sea level programme.

In addition to measuring the level of the sea surface, land movements (tectonics) should also be studied with appropriate equipment.

6.2 OTHER RESEARCH ACTIVITIES

Nations in the region should increase and elevate more seriously studies of their marine resources and environments by upgrading and extending the mandates of their marine and ocean research centres to support wider interdisciplinary research.

A wide range of research activities are needed in order to predict the possible consequences of climate change and sea-level rise on the coastal regions of the Western Indian Ocean.

Weather and climate: Meteorological observations of air movements, temperatures and cyclones should be improved. There is also a need for studies on the effect of monsoons on sea-level changes. National climate committees should be established, as recommended by the Second World Climate Conference (Oct./Nov. 1990), to develop the national climate programmes. A list of the members of these national committees should be made available to facilitate person-to-person consultations on specific matters. A regional marine forecasting centre should be set up to provide timely warnings of possible storm surges or abnormal sea-level fluctuations caused by meteorological or geological phenomena.

Coastal Processes: Modelling should be used to predict how different shorelines will be affected by sea-level rise and tidal waves, in order to come up with geopotential maps (hazard maps). Sediment budgets at river mouths vis-a-vis land use practices upstream should be studies, as should the effect of sediment dynamics on jetties and beaches.

Coastal ecosystems: Further studies should be conducted on how different ecosystems, particularly corals, mangroves and marine algae, will be affected by sea-level rise.

Human settlements, industrial development and general infrastructure: An assessment of the long-term impacts of sea level changes should be carried out for existing structures. The effect of coastal dynamics on man-made structures should be studied so that the effects of sea-level changes can be predicted. To lessen the adverse impacts of sea-level changes on the coastal environment and infrastructure, coastal structures should be constructed in close consultation with scientists and engineers.

Case studies: Case study proposals should be prepared on how sea-level changes will affect vulnerable areas of the island nations and mainland coasts.

Of the island nations, vulnerable areas include the islands of Comoro and Mauritius. Pilot projects should be initiated in Comoro and Mauritius to assess their vulnerability because of the erosion they are already experiencing and the investments and developments along their coastlines. The island nations have expressed the need for the development of numerical models to assist in the management of their coastal environments. To be able to run these models, the countries will need microcomputers. Dr.I. Fagoonee will provide guidelines for standardized data collection and for the preparation of background documents for national committees.

On the mainland, vulnerable areas identified in Tanzania include Mtwara, Dar-es-Salaam, Tanga and the Ruvu river mouth. In Kenya, Mombasa, Malindi and Lamu have been identified. Other countries should also identify appropriate sites for case studies, particularly in areas with large

populations or substantial investments.

A team of scientists should be established to ensure proper steering and co-ordination of the case study programmes. To review progress and consolidate the case study programme, a regional workshop should be convened in conjunction with IOCINCWIO-III.

6.3 TRAINING

In order to effectively carry out monitoring and research activities, there is a need to develop local scientific capabilities. This can be done through short-term training and attachments and/or through long-term training at the undergraduate and graduate levels in marine meteorology, physical oceanography, coastal zone management and other aspects of marine science.

In this regard, IOC, SAREC, UNEP, UNESCO, UNDP and WMO are invited to assist in the provision and funding of these training activities.

6.4 AWARENESS

The coasts are a natural heritage that must be conserved and maintained for future generations. The attention of leaders and policy makers should be drawn to the causes and consequences of sea-level changes, in particular to the effects this phenomena will have on coastal settlements, development and infrastructure. Workshops and seminars should be held at national and regional level to improve the awareness of policy makers and planners about sea-level concerns.

Planners, architects and engineers should be made aware of inherent problems related to the construction of structures in the coastal environment and should be sensitized to the precautions that must be taken to preserve the shores, especially beaches. For future developments in the coastal zone, mandatory independent environmental impact assessments should be required.

Investors and users of the beaches (in particular hoteliers and tourists) should be informed of the problems related to sea-level changes and the best strategies for accommodating them. These problems should be demonstrated by experts during their meetings, and through illustrated manuals and brochures detailing areas most susceptible to sea-level rise. Coastal communities and society at large should be educated on the consequences of sea-level change and the need for rational use of the coastal environment. This can be done through dissemination of accurate information using mass media, brochures and bulletins. Press conferences with expert panels discussing the consequences of sea-level rise should be organized. Sea level information should also be built into the school and college curriculum.

Countries in the region are urged to provide information on their environmental vulnerability to the upcoming United Nations Conference on Environment and Development (UNCED), Brazil, June 1992.

6.5 LEGISLATION

Governments should be involved in the planning of coastal developments. To this end, legislation on coastal zone management should be further developed and enforced, and where legislation does not exist, it should be enacted. Conventions on environment management should be reinforced in the region.

6.6 CO-ORDINATION

National co-ordination of coastal management and protection so as to base it on scientific knowledge is important. There is a need for better co-ordination between scientists and engineers so that, in solving problems related to sea-level changes, new problems are not created. A regional research centre associated with a university should be established. This centre should be able to provide facilities to all scientists in the region.

An active user community for sea-level data is necessary to ensure that the data and products are of high quality. The RECOSCIX-WIO Regional dispatch centre should co-ordinate the exchange of information among users.

7. CLOSURE

Dr. W.K. Ngala, the Director of Research Development in the Ministry of Research, supported effort made by the country. Mr M.W. Dunford of the Mombasa and Coast Tourist Association said he would present the problems related to sea-level change to the Association and expressed the hope that some of the speakers present at the Workshop would be able to address the Association at its annual meeting. He noted that the information presented was very important and should be widely circulated in an easily readable format. Dr. G. Mitchum thanked all those who attended the Workshop on behalf of the TOGA sea-level Centre. He said the Workshop had enabled him make contacts in countries where he did not have any before, thus opening the possibility of an improved TOGA network coverage in the region. He hoped that efforts would be made to ensure that all tide gauges in the region are operational. Dr. G. Alcock thanked all those who contributed to the success of the Workshop and was pleased that the Workshop had been interesting, stimulating and also productive. He hoped this Workshop would open up avenues for co-operation in the development of a viable regional sea-level observing system. In his closing speech, Mr. S. Mung'ala, the provincial commissioner of the coast province, noted that this Workshop had brought together scientists, entrepreneurs and policy-makers to address a subject of importance to the coastal communities. These communities are very interested in the results and recommendations of the Workshop, as they will be directly affected by sea-level rise. He hoped that the information presented during the Workshop would be widely circulated in an easily readable format.

ANNEX I

PROGRAMME OF THE WORKSHOP

June 24, 1991.

0800-1000 Registration

1000-1100 OFFICIAL OPENING
Director KMFRI
Graham Alcock (IOC)
S. Ragoonaden (IOCINCWIO)
F.F. Ojany
Hon. G. Muhoho EGH.

1100-1130 BREAK

Chairman sessions 1 and 2: S. Ragoonaden
Rapporteur: A. Muzuka.

1130-1230 SESSION 1: Plenary session
Past and future sea level rise (G. Alcock)

1230-1400 LUNCH

1400-1500 SESSION 2: Plenary session
Episodic sea level changes in the Western Indian ocean (T.S. Murty.

1500-1520 BREAK

1520-1700 SESSION 3:
Chairman: Prof. L.J. Ogallo
Rapporteur: A.B.C. Killango
Theme:- Causes of sea level changes
- Determination and prediction of sea level change
- Evidence of sea-level changes in the Western Indian Ocean.

1520-1540 Changes in sea level in the region of Mauritius (S. Ragoonaden)

1540-1600 The Western Indian ocean sea-level observing system (M.O. Odido)

1600-1620 Seasonal variation in mean sea level at Zanzibar Island (J. Francis and A.M. Dubi)

1620-1700 DISCUSSIONS

1900 RECEPTION

June 25, 1991.

Chairman sessions 4 and 5: Prof. D.P.S. Wasawo
Rapporteur: Saeed Mwaguni

0900-1000 SESSION 4: Plenary session: Effects of sea-level changes on man-made coastal structures (T.S. Murty)

1000-1300 SESSION 5:

Theme: Effects of sea-level changes on beaches and low lying shores.

1000-1020 Implications of sea-level rise in North Eastern and Eastern African coastal region (M. Kh. El Sayed)

1020-1040 Coastal sediment dynamics in a changed climate (M.P. Tole)

1040-1100 Rapid method of determining the susceptibility of shore line to erosion due to a change in the sea: a case study (K.K. Kairu)

1100-1120 BREAK

1120-1140 Some preliminary observations on the possible impacts of a 3-5 meter (10-15ft) sea-level rise on the coastal landform and structures along the Kenyan coast (F.F. Ojany)

1140-1200 UNEP activities on the implications of the expected climate changes on the Eastern African coastal region (L.J. Ogallo)

1200-1220 The effects of sea-level changes on geomorphological processes along the coast (D.E. Kapule)

1220-1300 DISCUSSIONS

1300-1400 LUNCH

1400-1620 SESSION 6

Chairman: Luc chang-to

Rapporteur: G.O. Guya

Theme: Impacts of sea-level changes on the small island nations.

1400-1420 The rising level of the sea and implications to construction (low lying islands such as Lamu) (C.K. Kabubo)

1420-1440 Sea level, coastal erosion and management in Madagasikara (R.L. Ranaivoson)

1440-1500 Rates and causes of coastal erosion on the Zanzibar Island (Nyandwi N. and A.N.N.Muzuka)

1500-1520 BREAK

1520-1540 Potential impact of sea-level rise in Mauritius (I. Fagoonee)

1540-1620 DISCUSSIONS

1620-1640 EXCURSION BRIEFING

June 26, 1991.

0800-1800 EXCURSION

June 27, 1991.

0900-1100 SESSION 7
Chairman: Dr. E.N. Okemwa
Rapporteur: Julius Francis
Theme: Impacts of sea-level changes on marine and ocean living resources.

0900-0920 Possible effect of a 20-140cm seawater rise on the East African coast (W.M Kudoja)

0920-0940 Vertical distribution of Kenya's intertidal seaweeds as related to patterns of submersion and emersion (G.M. Wamukoya)

0940-1000 Modelling the effects of sea-level rise on intertidal populations with fixed individuals (E.V. Berghe)

1002-1020 Impacts of sea-level rise on Kenyan coastal reefs (J.C. Mutere)

1020-1100 DISCUSSIONS

1100-1120 BREAK

1120-1300 SESSION 8:
Chairman: Prof. J. Kokwaro
Rapporteur: Peter Ochumba
Theme: Effects of sea level changes on agriculture, mariculture and mangrove ecosystems.

1120-1140 Implications of sea level rise on rocky cliffs and mangrove macroalgae in Kenya (H.A. Oyieke)

1140-1200 Sea level rise: Its impact on mangrove ecosystems in Tanzania (Y. Mgaya)

1200-1220 Effect of sea level changes on aquaculture, development in Kenya (J.R. Radull)

1220-1300 DISCUSSION

1300-1400 LUNCH

1400-1620 SESSION 9:
Chairman: Michael W. Dunford
Rapporteur: Phillip Mwanukuzi
Theme: Effects of sea level changes on coastal human settlements and socio-economic activities especially tourism.

1400-1420 Effects of sea level changes on coastal human settlements: Examples from Tanzania (J.A.R. Wemba-Rashid)

1420-1440 Effects of sea level fluctuations on ground water along the Kenyan coast (Mailu G. and Muturi H.R.)

1440-1500 The cost implications of rising level of sea: marine structures (G.O. Guya)

1500-1520 BREAK
1520-1540 Eroding Kenyan coastline: The need for geological input into shoreline management decisions and strategy (E.O. Odada)
1540-1620 DISCUSSIONS
1620-1700 EXCURSION REPORTS

June 28, 1991.
0900-1100 SESSION 10
COORDINATOR: DR. E.O. Odada
Theme: Preparation of (1) Case study for mainland; (2)Case study for island; (3) Regional sea level programme
Each group will have Chairman and Rapporteur.
0900-1100 Meeting of Adhoc committees
1100-1120 BREAK
1120-1220 SESSION 11
Chairman: Prof.F.F. Ojany
Rapporteur: Dr. W.M. Kudoja
Policy options.
1220-1400 LUNCH
1400-1500 Discussion of *Ad hoc* committee reports
Chairman: Dr. E.O. Odada
1500-1540 Conclusions and Recommendations
Chairman: Prof. F.F Ojany
1540-1600 BREAK
1600 CLOSING SESSION

ANNEX II

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ANNEX III

SUMMARIES OF ABSTRACTS OF CONTRIBUTED PAPERS ON SEA-LEVEL STUDIES IN COUNTRIES OF THE WESTERN INDIAN OCEAN

COMORO

Sea-Level Studies in Comoro (A.B.P. Mahamoud)

Not much work has been done in the field of sea-level studies in Comoro. Mr. Mahamoud informed the participants that there is already serious erosion on some beaches of Comoro which could be aggravated by a rise in sea level. A tide gauge, previously operating in Dzaoudzi, is no longer there.

KENYA

(a) Sea Level Observing Network in Kenya (Mr. O. Odido)

Mr. Odido outlined the proposal for a national sea- level network. This will consist of five observing stations located at Kilunga, Lamu, Malindi, Mombasa and Shimoni. Two of these stations are already operational at Lamu and Mombasa, however, bench marks have not yet been established for the Lamu station. It is possible that another station will soon be installed soon.

(b) The Projected Effect of Sea-Level Rise on the Biodiversity of the Malindi-Watamu Biosphere Reserve (Dr. J. Mwanje)

Dr. Mwanje examined the projected effect of sea-level rise on the biodiversity of the Malindi-Watamu Biosphere Reserve. The coastal tourism infrastructure, Mida Creek mangroves, alluvial deposits of the Sabaki estuary, herbs and plants (which may be of medicinal value) in the littoral zone and fauna species may be gradually destroyed following a rise in sea level. As sea level rises, the fluvial and littoral environment would be inundated, and there would be a commensurate and sustained successional change in flora and fauna communities in a dynamic framework, generating an ecological response characterized with minimal loss in biodiversity/genetic resources. This scenario would only be possible if the change is gradual, thus permitting homeostatic controls in the natural communities. Eventually a somewhat steady-state climax system may be achieved when sea-level rise reaches a certain threshold, hence allowing for a new apex of high species diversity.

(c) Coastal Sediment Dynamics in a Changed Climate (Prof. M.P. Tole)

Prof. Tole indicated that sea-level changes will influence and be influenced by the distribution of sediments along the coast. A number of rivers and streams discharge water and sediment into the Indian Ocean along the Kenyan coast. These include the Tana and Sabaki rivers and to a lesser though extent, the Rare, Ndzovuni, Nyore, Mwachi, Mambone, Cha Simba, Ramisi, Mwena and Umba rivers. The rates of sediment input are likely to increase in a warmed climate due to increased precipitation.

(d) Rapid Method For Determining the Susceptibility of Shore Lines to Erosion due to Level Rise: A Case Study (Mr. K.K. Kairu)

Mr. Kairu pointed out the urgent need to forecast the response of different shorelines types to changing sea level. A rapid method for predicting the impacts of sea-level rise on coastlines was presented which is based on the geology and geomorphology, especially the elevation, degree of cementation, weathering, texture and the local coastal processes.

(e) Modelling the Effects of Sea-level Rise on Mangroves (Dr. E. Vanden-Berghe)

Dr. Vanden-Berghe presented a basic theoretical model to simulate the growth of mangroves and the effect of sea level-rise on their biomass. The behavior was modelled as a function of growth rate, fecundity and survival rate. Under constant sea level, the total biomass reaches a steady-state equilibrium. The level of equilibrium depends on survival and growth rated, not fecundity. In response to rising sea level, the biomass drops to approximately one third of the former biomass, for a wide range of growth and survival rates. The reason for the drop is that as old individuals in the lower part of the transect die, newly available areas are colonized by young, small individuals. The model assumes that there is only one species and that land area upshore will become available as sea level rises.

(f) Some Preliminary Observations on the Possible Impacts of Sea-level Rise on Coastal Landforms and Structures along the Kenyan Coast (Prof. F.F. Ojany)

Prof. Ojany outlined some possible impacts of sea-level rise on coastal landforms and structures along the Kenyan coast. Kenya's coastline is about 580 km long which is developed with luxury homes, hotels, beach resorts, large coastal settlements and ports. Much of the coast is flanked by Pleistocene coral rock and crag which constitutes a relatively resistant material to marine erosion. Thus, Kenya would not be as adversely affected as other low-lying countries.

Kenya experiences a semi-diurnal tide, with a maximum tidal range of 4 to 8 meters. Rising sea level could have a number of effects, including an increased tidal range, accelerated coastal erosion and more frequent floods and storm events. An increased tidal range will intensify the strength of coastal waves and adding to their erosive power. Man-made structures below 3 to 7 meters may be affected by flooding and cracked through strong vibrations generated by waves pounding the cliffs. Popular options for mitigating sea-level rise include beach nourishment, construction of coastal defenses (sea walls) and the abandonment of threatened areas. It is recommended that Kenya form a sea-level Monitoring Agency consisting of the Survey of Kenya, Kenya Ports Authority, universities and research institutes. This agency would work in close collaboration with other international bodies doing similar work and avail itself of the services of UNESCO, WMO, UNEP, HABITAT, FAO and the Regional Centre for Services in Surveying Mapping and Remote Sensing.

(g) The Effects of Sea-level Changes on Geomorphological Processes along the Coast (Dr. D.E. Kapule)

Dr. Kapule discussed the effects of sea-level changes on the geomorphological processes along the coast. Biological, geological and climatic factors all influence coastal landforms and will be affected by sea- level changes. In particular, intensified wave forces will increase weathering and erosion of coastal landforms. Geological mapping, terrain analysis and

aerial photography are useful methods in determining how coastal landforms are affected by sea level changes.

(h) Implications of Rising Sea Level for Construction on Low-Lying Islands such as Lamu (C.K. Kabubo)

Mr. Kabubo summarized erosional effects of sea-level rise on low-lying areas. Causes of shoreline erosion may be natural or man-made. Natural causes include sea-level rise, changes in sediment supply, storm waves, deflation, longshore sediment transport, sorting beach material, and wave and surge overwash. Man-induced causes of erosion include removal of subsurface resources (oil, water or minerals), interruption of littoral transport, reduction of sediment supplied by rivers due to construction of dams, construction of structures which interfere with wave energy, navigation improvements such as widening and dredging of harbours, and the destruction of natural vegetation cover (eg. mangroves).

(i) Possible Effects of a 20-140cm Sea Water Rise on the East African Coast (Dr. W.M. Kudoja)

Dr. Kudoja informed the participants that an increase in sea level of 20 to 140 cm will have far-reaching effects on marine organisms, human structures and settlements.

(j) Impacts of Sea-Level Rise on Kenyan Coastal Reefs (J.C. Mutere)

Miss Mutere outlined the effects of sea-level changes on Kenyan coastal coral reefs. The coral reef community structure will change, primarily in the back reef region, where there will be increased wave energy and less exposure during low tide. More of the continental shelf area will be available for colonization, resulting in an increase in the width of active back reef area. The typical pocilloporid and portid assemblages will give way to new species assemblages which will be either of mixed or monospecific stands. These would lead to increased habitat diversity. Sea-level rise would also increase and stabilize the rate of sedimentation and encourage the development of a soft substrate associated with burrowing.

(k) Implications of Sea-level Rise on Rocky Cliffs and Mangrove Macroalgae in Kenya (H.A. Oyieke)

Ms Oyieke made a presentation on the effects of sea-level rise on rocky cliffs and mangrove macroalgae in Kenya. In the event of a sea-level rise, the ecological niches of the various species will shift vertically upwards along the cliff or mangrove trunk. For this vertical shift to occur, a continued substrate must be available.

(l) Effect of Sea-level Changes on Aquaculture Development in Kenya (J.R. Radull)

Mr. Radull summarized the effects of sea-level changes on mariculture development in Kenya. Prawns, brine shrimp (Artemia) and oysters are the main farmed species on the Kenya coast with prawns and artemia raised at Ras Ngomeni, and oyster at Gazi. The farming is done in a semi-intensive fashion, using ponds, cages and hanging rafts. Sea-level changes could adversely affect the collection of seed from the wild, threatening prawn and oyster culture. The existing 52,900 ha of mangroves in Kenya will be affected and this may increase the potential for mariculture area off Ungwana Bay. Sea water intrusion into rivers may result in the contamination of freshwater aquifers, adversely affecting aquaculture, as freshwater is essential in hatchery operations.

(m) Effects of Sea-Level Fluctuations on Groundwater Quality along the Kenyan Coast (Mr. H. Muturi)

Mr. Muturi presented a paper on the effects of sea-level fluctuations on groundwater quality along the Kenyan coast. He noted that the main factors that control water quality along the Kenyan coast are the permeability of the rock types and the effective recharge, which facilitates efficient flushing of salts associated with the depositional environment. However, satisfactory studies have not been carried out to ascertain the influence of sea water intrusion into the aquifers. Investigations should be done to establish groundwater potential of lagoonal sands and sand dunes, and also to determine the pumping rate necessary to prevent salt water intrusion into aquifers.

(n) The Cost Implications of Rising-Sea Level: Marine Structures (Mr. O. Guya)

Mr. Guya discussed the projects launched by the Kenya Government to preserve land from destruction by the sea. This includes shoreline protection infrastructure, such as jetties and sea walls. Most protective structures along the coast have been damaged by misuse by individuals, corrosion, marine boring animals, wave action and lack of maintenance. Damage to marine structures will increase when sea level rise as a result of increased loading, strong currents, waves and wind. The increased temperature of the sea water will also accelerate the rate of corrosion of the structures, consequently increasing maintenance costs.

(o) Eroding Kenyan Coastline: the Need for Geological Input into shore line Management Decisions and Strategy (Dr. E.O. Odada)

Dr. Odada stressed the need for geological input into shoreline management decisions and strategies. Widespread erosion is attributed to development pressures, sea-level rise, mining of sand, dam construction on rivers and destruction of mangroves. Unplanned protective structures are aggravating the erosion rather than alleviating it. The public must be made aware of the causes of erosion. Proper beach management and planning are necessary. Buffer zones should be created between the shoreline and stable upland areas.

MAURITIUS

(a) Changes in Sea Level in the Region of Mauritius (Mr. S. Ragoonaden)

Mr. Ragoonaden presented the data on sea-level observations in Mauritius. Information available indicates that the earliest levelling survey was conducted in 1881, however no details on the benchmark references have been found. Benchmarks dating back to 1915 have been identified at the Port Louis harbour. Other information indicates that a tide staff was installed in 1929. However the earliest sea-level data available at PSMSL date from the 1942-1947 and 1953-1963 periods. Levelling based on this data was carried out in 1964 and the National Primary Levelling network is now tied to the 1964 mean sea level. No other tide data is known to exist between 1964 to 1986. In 1986 a tide gauge was installed at Port Louis with the assistance of the University of Hawaii. According to the data available from these gauges, monthly sea level varies significantly with a maximum elevation in February/March and a minimum elevation in August/September corresponding to the maximum and minimum sea surface temperatures observed in the region. Comparing the 1964 data with the 1987-1989 data, a relative change of 30 cm

in the mean sea level is observed.

(b) Potential Impact of Sea Level Rise in Mauritius (I. Fagoonee)

Dr. Fagoonee outlined the potential impact of sea-level rise in Mauritius. Erosion will be more acute where it was benign. Coastal roads are at risk and many jetties, ship ways, breakwaters and groynes, which were not properly designed, are showing signs of collapse. Wave impacts on sand dunes and berms will cause erosion and loss of coastal vegetation and sand materials. Lagoonal sediments will become mobile and may shift positions. Bays will change shapes, some becoming less important, and new ones will be formed elsewhere. Estuaries will be flooded, causing erosion at river mouths, and the upstream migration of brackish and marine flora and fauna. Coastal marshes will be flooded, becoming saltier. The biotope will change, possibly causing serious modification of the feeding and resting habit of some avian fauna. Dump sites situated near wetlands will be encroached upon, causing toxic leachates to flow more readily into lagoonal systems. Mangroves will move inland where possible. Existing fish reserves may increase, however the fate of corals is debatable. In the short-term, a rapid rise in sea level may be beneficial to corals, rather than deleterious. In the long-term coral reefs may be slowly submerges and unable to grow fast enough to keep pace with predicted rates of sea-level rise.

MADAGASCAR

(a) Activities of the Institut Géographique et Hydrographique (FTM) in Sea-level Activities (Mr. R.N. Raharijaona)

Mr. Raharijaona outlined the activities of the Institut Géographique et Hydrographique (FTM) in sea-level activities. Two sea-level stations have been installed at Nosy Be and Fort Dauphin in collaboration with the Centre National de Recherches Océanographiques (CNRO). There is a need to study the effect of the sea-level rise on coral reefs, littoral erosion, and coastal fisheries.

(b) The Sea-Level Rise, Coastal Erosion and Management in Madagascar (Mr. L. Ranaivoson)

Mr. Ranaivoson presented a paper on coastal erosion and coastal zone management in Madagascar. Not much work has been done in this regard. Significant erosion has been noted in the towns of Toamasina and Morondava. The wide beaches which previously fronted Morondava have already disappeared. A boulevard, houses and a lighthouse have also been affected. Frequent cyclones have accelerated the erosion process. In spite of this, many structures are still being constructed close to the beach, disregarding the evidence of the instability of the beaches.

MOZAMBIQUE

A Proposal for a Sea-Level Network in Mozambique (Mr. A.E.L. Couto)

Mr. Couto presented a proposal for a sea-level monitoring network in Mozambique, consisting of 5 sea level stations at Pemba, Inhambare, Nacala, Beira, Quelimane and Maputo. One gauge is already operating at Maputo. Not much work has been done in studying the impact of sea-level changes.

SEYCHELLES

The Sensitivity of Seychelles Coastal Areas to Possible Significant Sea-Level Changes (Mr. Luc Chang-Ko)

Mr. Chang-ko described the sensitivity of Seychelles coastal areas to significant sea-level changes. Seychelles has three main islands: Mahe, Praslin and La Digue, which are characterized by concentration of human settlement and roads along the coast. Flash floods, caused by isolated severe thunderstorms, have always occurred at low tide. Due to a shortage of land, land reclamation has been done in Mahe using dredged materials. The airport and Port Victoria are built on a reclaimed area, which is barely three meters above mean sea level. Granite has been used to form artificial barriers on reclaimed land. The government maintains a strict control on the removal of sand from beaches for construction purpose; and requires that silt screen be used to contain sediments and prevent them from flowing into the reef during dredging operations. No residential houses are allowed on reclaimed land.

TANZANIA

(a) Seasonal Variation of Mean Sea Level at Zanzibar (Mr. J. Francis)

Mr. Francis presented the seasonal variation of mean sea level at Zanzibar. Based on seven years worth of data collected from the tide gauge at the Zanzibar harbour, monthly mean sea levels were computed. Low values were observed during the northerly monsoons and high values during the southerly monsoons. Contributing factors to sea-level variations include atmospheric pressure, wind, and coastal currents. The effect of atmospheric pressure and wind is insignificant. Coastal currents appeared to be the main controlling factor on the seasonal variation of mean sea level. Based on seven years worth of data, mean sea level has been rising by average at an average rate of 0.4 cm/year.

(b) Rates and Causes of Coastal Erosion on Zanzibar Island (Mr. A.N.N. Muzuka)

Mr. Muzuka presented a paper on the rates and causes of coastal erosion on Zanzibar Island. Estimates of coastal erosion at Zanzibar were made through field measurements, analysis of aerial photographs and interviews with communities in the eroding areas. Aerial photographs indicate high annual erosion rates of up to 40 m between 1947 and 1977. Recent field measurements at Maruhubi, north of Zanzibar township, indicate annual erosion rates of 3m. These high rates of coastal erosion were caused by high wave activity during some periods of the monsoons, amplified by a high tidal waves. The unconsolidated nature of the rock formations on the western coast were found to be the cause of the comparatively intensive erosion in this area, as compared to that on the east coast.

(c) Effects on Sea-Level Changes on Coastal Settlements: Examples from Tanzania (Dr. J.A.R. Wemba-Rashid)

Dr. Wemba-Rashid said that comparatively large-scale settlements of the East African coast began approximately 2000 years ago. During this period, the original inhabitants, the proto-Bantu, came into contact with the ancestors of the current Bantu speakers. By about 800 AD, traders from parts of present day Middle East, the Indian subcontinent and South East Asia also visited and settled along the coast. Available records point to the presence of settlements on the East African coast, some of which have since disappeared. A few of these settlements have been identified and excavated by

archaeologists. Sea-level changes may be one of the principal causes for the disappearance of settlements along the coast of mainland Tanzania. Such changes would have adversely affected security, economic viability and continued contact with external people, among other things.

ANNEX IV

REGIONAL SEA LEVEL PROGRAMME

Sea-level data has many practical applications. These include the immediate operational requirements of ship navigation, harbour design and coastal zone management, as well as long-term prediction of global sea-level changes due to climate variations.

Sea level has risen by 20-40cm over the last 100 years. Projections have been made for an increase in the earth's mean temperature of 1.5-4.5°C before the end of the 21st century.

According to the report of the Working Group 1 of IPCC, if emissions of greenhouse gases continue at the current rate, the global mean sea level could rise at a rate of about 6 cms per decade over the next century (with an uncertainty range of 3-10 cm per decade). The predicted rate is about 8-20 cm in global mean sea level by 2030 and 31-110 cm by the end of the next century (IPCC). However there will be significant regional variations. The 13th session of the IOC Assembly approved a proposal for the development of a Global Sea-Level Observing System (GLOSS). This will comprise a global network of about 400 tide gauges for monitoring sea-level changes. At its second session in Arusha, Tanzania in 1987, the Regional Committee for IOCINCWIO adopted a proposal for the development of a regional sea-level network as a component of GLOSS and also to address sea level related regional concerns.

Over 15 sea-level stations have been installed in the region to date. The University of Hawaii, through IOC's Tropical Ocean And Global Atmosphere (TOGA) experiment have assisted in the installation of a number of gauges since 1986. However, not all these gauges are in operation for various reasons. Benchmarks at some of the sea-level stations in the region are not levelled regularly, while at other stations there are no benchmarks.

In developing a regional sea-level programme we therefore need to address the following:

(a) Repair of and Maintenance of Tide Gauges

The reasons why some of the installed gauges are not operational should be investigated and appropriate actions taken to have them working again. For this, qualified personnel are needed. Spare parts and consumables are not easily available in the region. A technician should be based in the region to ensure that the gauges are working. This technician will also be responsible for training technicians in each of the countries.

(b) Benchmarks and Levelling Information

Benchmarks should be established for all tide gauges in the region. These benchmarks must be levelled regularly so that accurate information is available to assist in the analysis and interpretation of data.

(c) Installation of New Tide Gauges

Several locations, not identified in the GLOSS Implementation Plan, are of regional interest and were proposed for inclusion in a regional sea-level observing programme (Table 1). A feasibility study should be undertaken to identify suitable sites for the gauges at these places. There should be agencies in all the countries committed to operating each of the tide gauges and providing information for international exchange.

(d) Upgrading of the Network

Gradually, the regional network should be upgraded and automated gauges should be introduced with the ultimate goal of providing real time data and products.

The agencies responsible for operating the tide gauges should be encouraged and assisted in the collection of additional information on currents, storm surges, salinity, sea surface temperature, atmospheric pressure and wind data at the tide gauge locations.

(e) Data Management

Scientists in the region should have access to readily available sea-level data, collected within the regional sea-level programme. To facilitate this, sponsorship should be sought, to provide agencies responsible for the tide gauges with equipment for digitizing analogue charts and with computers for analyzing the data.

A regional data centre, for collecting, analyzing and archiving the information should be established at KMFRI. This centre will also be in charge of quality control. RECOSCIX-WIO, with its experience in scientific information exchange, should be requested to assist and collaborate in the establishment of the centre. IOC should be requested to consider including sea-level data analysis software in the OCEAN-PC project. Institutions already having computers and sea-level data are encouraged to make use of software available on request from the TOGA Sea Level Centre for processing their data.

(f) Research Activities

To ensure availability of high quality data, sea-level-related research activities should be initiated. These include the development of case studies on the impacts of sea-level changes on coasts and the projection of actual sea-level rise.

(g) Training

Technicians should be trained for servicing and maintaining the tide gauges. This training should consist of attachments and workshops. Longer-term courses leading to the awarding of diplomas or degrees will be useful in enabling the technicians to maintain other oceanographic instruments within their institutions.

Data management is another area where training is needed. This can be in the form of attachments,training workshops and long-term training leading to BSc, MSc and PhD degrees.

IOC should consider sponsoring students from the region to conduct studies on data from the region available at the PSMSL and TOGA Sea-Level Centre as a project for a higher degree.

Interface workshops should be held for scientists and technicians on sea-level data management.

(h) Publicity

The development and maintenance of a good network will depend on support from policy makers and the general public. These individuals should be made aware of sea-level concerns through conferences, seminars and workshops at which sea-level-related information is disseminated. In addition, brochures, stickers and bulletins with similar information should be produced. Education on sea-level changes should be built into the school and college curriculum so that the youth are made aware of the problems.

(i) Funding

Countries in the region should make a concerted effort to develop their national sea-level observing network, and in particular, to ensure that the regional sea-level stations within their jurisdiction are installed and operational. Considering the limitation of expertise and resources to do this, the international community should be requested to assist through bilateral and multilateral arrangements. In particular, IOC and SAREC should be approached in this regard.

Scientists in the region should be assisted in attending sea-level training programmes currently offered by several countries, some of which are sponsored by IOC.

TABLE 1: PROPOSED REGIONAL SEA LEVEL OBSERVING NETWORK

STATION	COUNTRY	POSITION		
Djibouti	DJIBOUTI	11-36N 043-09E	I	G (#2)
Hafun	SOMALIA	10-27N 051-15E		G (#6)
Mogadishu	SOMALIA	02-01N 045-20E	I	G (#7)
Kismayu	SOMALIA	00-25S 042-31E	I	
Kiunga	KENYA		P	
Lamu	KENYA	02-17S 040-54E	O	
Malindi	KENYA		P	
Mombasa	KENYA	04-03S 039-40E	O	G (#8)
Shimoni	KENYA		P	
Tanga	TANZANIA		P	
Dar-es-Salaam	TANZANIA	06-51S 039-18E	I	
Zanzibar	TANZANIA	06-09S 039-11E	O	G (#297)
Mtwara	TANZANIA	10-18S 040-07E	P	G (#9)
Port Victoria	SEYCHELLES	04-40S 053-28E	*	G (#273)
Praslin	SEYCHELLES	04-18S 055-45E	O	
Aldabia	SEYCHELLES	09-30 046-20		G (#14)
Farquar	SEYCHELLES		P	
Pemba	MOZAMBIQUE	12-58S 040-29E	P	G (#11)
Inhambane	MOZAMBIQUE	23-55S 035-30E	P	G (#10)
Nacala	MOZAMBIQUE		P	
Beira	MOZAMBIQUE		P	
Quelimane	MOZAMBIQUE		P	
Maputo	MOZAMBIQUE		O	
Dzaoudzi	MAYOTTE (France)	12-47S 045-10E	*	G (#96)
Moroni	COMORO		P	
Nosy Be	MADAGASCAR	13-24S 048-17E	O	G (#15)
Tulear	MADAGASCAR		P	
Majunga	MADAGASCAR		P	
Fort Dauphin	MADAGASCAR	25-01S 047-00E	I	G (#271)
Port Louis	MAURITIUS	20-09S 057-28E	O	G (#18)
Agalega	MAURITIUS	10-26S 056-45E	P	G (#16)
Rodrigues	MAURITIUS	19-41S 063-25E	O	G (#19)
Pointe des Galets	REUNION(FRANCE)	20-55S 055-18E	I	G (#17)

O: operational
I: installed but not operational
P: not yet installed
G: GLOSS station

In addition, Tanzania will identify two other sites close to the mouths of Ruvu and Rufiji rivers which are of national interest.

(end of document)