



**SMALL STATES  
CONFERENCE ON  
SEA LEVEL RISE**  
MALE, 14 - 18 NOVEMBER 1989

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ON  
SEA LEVEL RISE**

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**REPORT**

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## CONTEXT

Industrial development and the progress of science and technology within the last one hundred years has been rapid. Paradoxically this development and progress, which has contributed so much to the welfare of mankind, has precipitated potentially disastrous changes in the Earth's atmosphere.

Development has led to the over-exploitation of the resources of the Earth, urbanization, pollution of water, air and land, immense volumes of waste, and the extinction of many plant and animal species. The consequences of the degradation of the global environment have only recently been clearly discerned.

Recent developments, including major industrial accidents, have clearly demonstrated the international nature of environmental problems: it is now obvious that environmental problems do not respect the arbitrary borders of nations. However, of the issues emerging in the international debate over the state of the environment and its link with development as a whole, the question of global warming, climate change and sea level rise was largely ignored until 1987.

The President of the Maldives, H.E. Maumoon Abdul Gayoom, following damaging high waves which hit the country in 1987, took up the issue of the vulnerability of low-lying island states to environmental hazards and called for an international response to such issues. The theme of global warming, climate change and sea level rise which he relentlessly pursued at the Commonwealth Heads of Government Meeting (CHOGM) in Vancouver, at the United Nations and at the Summit Meeting of the South Asian Association for Regional Cooperation (SAARC) in Dhaka, all within a period of less than a month, forcefully brought the issue of global warming, climate change and sea level rise to the attention of the international community.

"Climate Change: Meeting the Challenge", the report of the Commonwealth Expert Group on Climate Change and Sea Level Rise, was one of the results of his initiatives. The report emphasized the need for action now, and the especial vulnerability of the small states.

In the CHOGM in Malaysia, in October 1989, environmental issues featured prominently on the agenda. President Gayoom and his delegation took up the issue of the vulnerability of small states, particularly to sea level rise. The Langkawi Declaration adopted at the summit highlighted the vulnerability of low-lying island countries and called for international support for protecting the global environment.

It is in this context that the Government of Maldives initiated a ministerial level conference of small states on sea level rise.

## INTRODUCTION

### Aims and Objectives

It is becoming increasingly apparent that the global climate may be changing as a result of human activities. The climate changes anticipated in the next few decades are unprecedented. Human activity since the industrial revolution has seriously changed the world's atmospheric composition, causing increases in carbon dioxide and other greenhouse gases that have the potential to cause global warming and consequent sea level rise.

A significant change in sea level in the small island states will result in widespread shoreline erosion and inundation of low lying areas as well as saline intrusions into freshwater aquifers. In addition, global warming may increase the intensity of hurricane and tropical cyclones affecting these areas.

For small island nations such changes arouse particular concern. First, their often very low elevation means that for some states, their future could be in jeopardy. Second, even a small increase in sea level could result in disproportionately large land losses, since typically the length of their coastlines are very large in relation to their land area. Third, many of these states are already vulnerable to natural disasters and that vulnerability is likely to increase.

It is for these reasons, and sensing the need for action now, that the Government of the Maldives has decided to invite ministerial representatives of small states to gather at a conference to discuss appropriate actions which can be taken now and formulate policies for the future.

The Small States Conference on Sea Level Rise, hosted by the Government of Maldives from November 14-18, 1989, was an attempt at a beginning to bring together the small states of the world to discuss the problems of sea level rise and formulate an initial strategy in responding to the threats faced due to sea level rise. The Conference aimed at the assessment and exchange of available scientific information regarding sea level rise, and to endorse appropriate responses in respect of adoptive strategies and internationally agreed preventive strategies.

### Conference Participation

The Conference was attended by representatives from 14 small states in the Caribbean, South Pacific, Mediterranean and Indian Ocean regions; delegations from ten states were each led by a Minister. A number of resource persons/experts of international repute; observers from many donor countries/agencies as well as representatives from international, regional and non-governmental

organisations also participated in the Conference.

### Conference Methodology

A Senior Officials Meeting was held from 14-15 November prior to the Ministerial Meeting from 16-18 November. The Senior Officials Meeting heard various technical presentations from select experts on specific topics related to global warming and sea level rise. The Meeting also drafted the Conference Declaration which was to be presented for adoption at the Ministerial Meeting.

A number of country statements from various small states as well as some expert statements were presented at the Ministerial Meeting. These were non-technical in nature so that policy makers will have little problem in understanding the complex scientific issues involved. The Conference Declaration, known as the Male' Declaration, was adopted unanimously at the conclusion of the Ministerial Meeting on 18 November 1989. The Inaugural Address of the Conference was delivered by His Excellency Maumoon Abdul Gayoom, President of the Republic of Maldives. The Secretary General of the Commonwealth, Sir Shridath Ramphal also spoke as a special guest of the Government of Maldives at the Inaugural Session of the Conference.

### Organisational Matters

Both the Senior Officials Meeting as well as the Minister's Meeting were chaired by the Head of the Maldivian delegation. Representatives of Antigua & Barbuda, Tonga and Cyprus were elected as Vice Chairmen of the Senior Official Meeting with Mauritius as the Rapporteur. The Vice Chairmen for the Ministerial Meeting were representatives of Brunei Darussalaam, Antigua & Barbuda and Tonga. A representative from Mauritius was again elected as the Rapporteur for the Ministerial Meeting.

## SYNTHESIS OF COUNTRY STATEMENTS

Delegates from the following small states presented country statements: Antigua and Barbuda, Barbados, Cyprus, Fiji, Grenada, Kiribati, Maldives, Malta, Mauritius, Trinidad and Tobago and Vanuatu.

An outstanding feature of the statements was the vulnerability of the small states - most of which are low-lying island nations - to adverse global climate change and sea level rise. The countries are finding themselves increasingly prone to natural disasters and expressed grave concern that global climate is changing as a result of human activities that are altering concentrations of greenhouse gases in the atmosphere and the characteristics of the earth's surface.

### Impacts

Should the predicted changes in climate and sea level rise occur, the impact on the lives of the people of small states will be enormous. However, the possible impact on various countries will vary according to their size, geographic location and other factors including the type of island (coralline or volcanic). Potential impacts include:

- widespread shoreline erosion and inundation
- loss of coastline, beaches and wetlands and severe disruption of coastal industries (especially fisheries)
- an increasing inland penetration of saline water affecting drinking water and coastal ecosystems and salt water intrusions in coastal fresh water aquifers.
- a higher frequency and greater intensity of hurricanes especially for the small states located in the "hurricane belt".
- displacement of fishermen and villagers living in coastal areas which is likely to seriously affect the social and economic structures of the countries concerned.

### Actions Taken

Being increasingly aware of the potential problems of sea level rise, small states have taken wide range of actions to meet the possible impacts. Small states are playing greater and more prominent roles in international conferences and are advocating global action. They are also becoming party to international conventions such as the Vienna Convention on the Protection of the Ozone layer and the Montreal Protocol. Some small nations have initiated pre-feasibility and feasibility studies to examine the possible impacts of sea level rise. Others have installed electronic tide and water level meters to monitor sea level rise. National environmental action plans have been drawn up by some countries while others have set up ministries charged with the

responsibility of providing basic essentials and rehabilitation facilities. The most obvious and cost effective area where efforts must be directed, it is felt, is the reduction of greenhouse gas emissions by all states.

#### Perspectives for the future

For future action, the states have unanimously endorsed regional, international and global programmes related to climate change and sea level rise. International meetings and conferences provide an important mechanism to share experiences and take joint action. The need to mount a campaign to increase awareness of the international community to the vulnerability of small states was strongly emphasized. International cooperation for development of alternative sources of energy, waste minimisation and recycling are suggested. Efforts will be made to convince industrial countries to accept their particular responsibility in the reduction of greenhouse gas emissions and the need to develop "trans-national ethic" and "mutualism" at the global level are recognised. The necessity for adequate training of the personnel who could be dealing with disaster situations is also emphasised. Construction of major sea wall defences are envisaged. The need for the international community, comprising both the developing and the developed nations, to take up the challenge of mean sea level rise as a global threat is emphasised. Small states will continue to be dependent upon the reports and findings of international conferences and meetings of technical groups such as the IPCC, as they lack necessary expertise and personnel. The importance of an international network for sea level monitoring (e.g. GLOSS), detailed dissemination of weather records and the setting up of a new body to collate and undertake research are also suggested. One country, offered to be a focal point for a monitoring network in the Caribbean region as it has the necessary capabilities.

#### 4. SYNTHESIS OF TECHNICAL PAPERS

Twelve international experts presented technical papers at the conference. The papers have been synthesised under the following themes:

1. Scenario Setting
2. Vulnerability of Small States to Sea Level Rise
3. Effects of Sea Level Rise on Ecosystems
4. Effects of Sea Level Rise on Resources
5. Perspectives for the Future

Abstracts of papers under each sub-heading is followed by a summary of the discussions of the presentations.

##### 1. Scenario Setting

- 1.1 "Evidence of Climate and Temperature Change and Sea Level Rise".....Dr. Richard Warrick.

The atmospheric concentrations of carbon dioxide, methane, nitrous oxide and the CFCs - the principal greenhouse gases - have been increasing. For example, CO<sub>2</sub>, the main greenhouse gas, has increased by about 25% over the last 200 years. The record of global-mean temperature changes indicates that the world has warmed by about 0.5° C over the last 100 years. Although there is no direct evidence that this is due to the "greenhouse effect", this observed warming is not inconsistent with climate model predictions of warming over the same time period.

There is considerable uncertainty regarding future global warming. The "best estimate" is that, by the year 2030, the world will be 1-2 ° C warmer than today (a full range of uncertainty gives 0.5-2.5° C). It is generally agreed that, as a result of global warming, sea level will rise. The best estimate is that sea level will rise roughly 15-30cm by the year 2030, with the possibility (albeit remote) of over 40cm, or as little as 5cm. In many regions, the impacts of such changes are likely to be "felt" through changes in the frequency of the climatic extremes - floods, droughts, storm surges, etc.

1.2 "An Overview of Causes and Effects of Sea Level Rise"  
(With emphasis on the Maldives).....Dr. James Titus.

The stable sea level of the last several thousand years has permitted people and other species to develop coastal areas much more extensively than would have been possible with a more rapidly rising sea. In river deltas, coral atolls, estuarine ecosystems, barrier islands, and many of the world's major cities, life is in a sensitive balance with the level of the seas.

An accelerated rise in sea level would upset this balance: lowlands and wetlands would be inundated, beaches would erode, flooding would increase, and coastal water supplies would become saltier. Fortunately, measures are available to mitigate these impacts. Although many of these measures need not be implemented for several decades, there are a number of low cost options that will be effective only if implemented soon.

Perhaps most importantly, it may take a few decades for nations to decide how they intend to respond. Therefore, small states should begin today to identify implications and response strategies. The most important first step would be to survey elevations for representative transects, so that nations will know how much land they are likely to lose. Next, a number of possible responses should be specified. Finally, for each of the possible responses small states should examine the cost, equity, legality, and ability to perform under uncertainty for each of the options.

It is clearly in the interest of small island states to curtail global warming and sea level rise. The nations represented here have small populations and land areas; but they have already had and will continue to have a major impact on the process by which society comes to terms with global warming and rising seas. To ensure that their perspective is fully considered, the small states should send representatives to all IPCC meetings on sea level rise.

1.3 "Measuring Sea Level Changes"...Dr. David T. Pugh.

Sea levels are variable in both space and time. The undisturbed global sea level surface, the geoid, varies from a geometric ellipsoid by  $\pm 100\text{m}$ ; oceanographic effects, including winds and currents, cause the actual mean surface to vary from the geoid by  $\pm 1.0\text{m}$ . Monthly and annual sea levels vary from the longterm mean by  $\pm$

0.05m due to oceanographic variability and there are also change over periods of several years. Estimates of longterm sea level trends from 5-10 years of data are notoriously misleading. Measurements of sea level trends are also affected by local vertical land movements. Present measurements at each site determine only the relative movement of land and sea. The World Ocean Circulation Experiment (1990-1995) will help to understand and remove the monthly and annual variability from sea level records. New geodetic technique will allow land movement to be determined to within 0.02m. As a result, local sea level series may in future be adjusted for these two effects: the remaining series will give clearer and earlier indication of global sea level rise. The Global Sea Level Observing System of the IOC has to serve many purposes including the detection of longterm trends. Some forty five countries have already agreed to participate. Characteristics of the network must include permanence, high vertical precision and stability. Financial support is necessary for key activities to proceed, but without these measurements, planning for the impacts of sea level rise will be speculative and potentially misdirected.

#### DISCUSSION

1. Both speakers gave realistic pictures and not alarming ones. A study has just been released by the Marshall Institute of United States which is almost identical to the review presented.
2. The problem of relative sea level changes basically revolves around four factors:
  1. Land tectonic movement
  2. Sunspot frequency
  3. Meteorological land factors.
  4. Greenhouse effectHas anybody correlated these four factors to determine the relative contribution of each?  
(Question raised by UNICEF Representative)
3. Each of these has been studied separately. In terms of sea level changes over a period of hundreds of years the geoid is not a relevant factor.  
(Answer given by Dr. David T. Pugh)
4. There has been a lot of attention focused on possible correlation between sunspot activity and climate change in the past. Up to now there is no verified relationship between sunspot activity and

sea level changes.

(Answer given by Dr. Richard A. Warrick)

5. The current activities of Australia in the field of sea level and tidal monitoring were reviewed and the extent of Australia's involvement in the establishment of a network of tide gauging stations including 23 stations in the ASEAN region and a further 11 throughout the Pacific. The programmes in the Asia-pacific region include a significant training component. Through its involvements FIAMS Australia is actively engaged in monitoring inter-annual signals and ENSO event prediction. Australia, due to its geological stability has a useful role to play within the region providing a sea level signal that is not conferred by the tectonic and local land movements characteristic of small islands.

(Prof. Geoffrey Lennon)

## 2. Vulnerability of Small States to Sea Level Rise

- 2.1 "Sea Defence, Adjustment and Disaster Preparedness: Requirements for Holistic and International Strategies".....Dr. James Lewis.

Uncertainty prevails regarding climate change and its implications, but within small-island states with wide ranging characteristics, physical, social and economic exposure to impact of tropical cyclones is likely to increase. It will not be a normally benign sea that rises.

High proportional socio-economic impact of tropical cyclone disasters makes these of crucial significance to small and small-island states.

Sea-defences do relatively little (and may not be feasible or relevant) to the damages caused by tropical cyclones and some sea-surges. Socio-economic adjustments are required in development to parallel technological measures of sea-defence construction; and disaster preparedness "longstops" must be further developed as a matter of urgency. Seemingly small measures must not be displaced by images of ultimate massive catastrophe.

National governments must adopt holistic island management systems; international and bi-lateral measures may be required to take account of in-country migration and "ecological refugees". National administrative organisation may require modification to

take appropriate account of this most crucial of environmental phenomena.

## 2.2 "A Pacific Perspective"....Prof. Roger Mclean.

The vulnerability of low atoll and reef islands to future sea level rise is in part dependent upon their age and history. In the central Pacific, sea level first reached its present level about 5000 years ago; it then rose above that level and has subsequently fallen to its present position. During the last 24000 years most of the islands in Kiribati and Tuvalu were formed. Thus: (1) The islands are very young; and (2) when sea level rises in the future it will occupy levels where it has previously been. The sea level record from mid - Pacific oceanic islands does not show the global sea level rise over the past 100 years; rather it shows a falling trend from 1932 onwards. Although sea level rise due to global warming may be significant in the long-term, in the mid-Pacific regional sea level fluctuations due to non-greenhouse related climatic and oceanographic events are likely to dominate over the next few decades.

The vulnerability of small islands to sea level rise is dependent, not only on island size and elevation, but also on the length of shoreline, nature of island sediments, exposure, reef and lagoon characteristics etc. It is concluded that extensive erosion and destruction of islands is unlikely and that on some reefs a new phase of island building and extension is envisaged. On reef flats renewed coral growth and increases in reef productivity and sediment movement are likely to contribute to island protection.

### DISCUSSIONS:

1. Mobilization of material that has been loose on the reef, reef flat and/or on the reef slope, as a result of hurricane action on the islands are substantial. If such a hurricane is to take place now, the next event might be an erosional one, if the prior event was a depositional one.
2. One of the problems in looking at sea level variation over the last 100 years is looking at tide gauge records calibrated in terms of possible tectonic movements and possible local effects, taking into consideration regional variations that have been going on in the past, and at the present time.

### 3. Effects of Sea Level Rise on Ecosystems

#### 3.1 "Possible Effects of Sea Level Rise on Corals and Reef Growth".....Dr. Barbara Brown.

Evidence of vertical reef accretion during sea level rise following the last glaciation suggests that reefs can build up at rates of between 1-12  $\text{mmy}^{-1}$ , depending on the type of reef and its setting. For many shallow water reef flats a maximum rate of vertical accretion would be 3-7  $\text{mmy}^{-1}$ , a value which would permit reefs to keep pace with 'best estimates' rates of sea level rise predicted over the next 40y. However, a factor which may be more significant than sea level rise over this time is the increase in surface sea water temperatures expected at tropical latitudes (c 1°C) as a result of global warming. Many corals live very close to their lethal temperature (within 2°C). When stressed they lose their symbiotic algae and/or their photosynthetic pigments - a process described as bleaching because of the loss of colour involved. Worldwide coral bleaching in 1983 and 1987 at locations where temperature anomalies have been recorded suggest that this response may be an early indicator of climate change. Corals can adapt to higher temperatures but the question remains as to the time scale needed for such a response.

#### 3.2 "Possible Effects of Sea Level Rise on Mangrove Ecosystems".....Dr. Joanna Ellison.

In the earlier Holocene, when rates of sea-level rise were rapid, expansive mangrove ecosystems did not exist. Rather, mangroves occurred as disorganised, patchy, individuals with dominant flushing of organic material away from their roots, as seen today on more exposed shorelines. As sea-level stabilized in the mid-Holocene, then the first expansive mangrove ecosystems established in sheltered locations. Today, after a period of stable sea-level or slow sea-level rise, expansive mangrove ecosystems are common, useful in acting as sediment traps to stabilize sedimentary coastlines, protection against hurricanes and storm surges, nurseries for commercially exploited crustacean and fish species, and as a natural resource base for silviculture and a large range of economic products.

Review of the stratigraphic record of mangrove ecosystems during sea-level changes of the Holocene shows that low islands are vulnerable to loss of expansive mangroves during sea-level rises projected for the next 50 years. Mangrove ecosystems in these

locations could keep up with sea-level rise of up to 8 cm/100 years, but at rates of over 12 cm/100 years could not persist. This is due to low rates of sediment accumulation, with limited sources from outside the mangrove area, such as rivers.

Stratigraphy from high islands, that have more sediment coming off the land into intertidal areas, shows that mangrove ecosystems will be better able to keep pace with the rise, possibly up to 25 cm/100 years.

The ability of mangroves to persist during sea-level rise can be helped by enhancing sedimentation, the process by which mangroves raise their substrate.

Removal of trees should be controlled, as these provide organic sediment, and more active management strategies should be considered.

#### DISCUSSIONS:

1. Retention of sediment and leaf litter on the swamp surface is critical in providing biodegradable friction matting or low offset barriers in the context of sea level rise.
2. Those mangrove species having longer aerial roots have the ability to cope with the expected sea level rise.
3. As the sea level rises the mangroves in the inland areas will significantly be affected. An accelerated replanting program may be a more practical approach than something that may be more intensive as matting.
4. Mangroves and coral reefs are natural protections during sea level rise and therefore it is of importance to conserve these natural habitats.
5. Coral bleaching may also be induced by damaging ultra violet radiation. Increased temperature and high irradiances may act synergistically to produce damaging effects in corals. Corals which survive bleaching show reduced growth and impaired reproductive ability.

#### 4. Effects of Sea Level Rise on Resources.

- 4.1 "Salt Water Intrusion into Ground Water: An Assessment of Effects on Small Island States due to Rising Sea Level".....Dr. Colin Woodroffe.

There are a number of different island types within the tropical oceans. The threat of sea-level rise, and impacts on ground water resources, will be felt most on the low-lying reef-top islands and the reef islands of coral atolls. The freshwater lens on small island is generally estimated using the Ghyben-Herzberg principle. This is a useful first order approximation but it has been shown to require refinement. Permeability and porosity of reefal sediments vary considerably, and the hydrogeology of individual islands is a function of reef structure and the pattern of the late Quarternary development of reefs and islands. Predicting change associated with sea-level rise is difficult because of uncertainty about individual island history, and as to how the process of reef island formation will adjust to the various anticipated rates of sea-level rise that are predicted. If sea-level rise results in extensive erosion and retreat of the shoreline, a substantial reduction in the freshwater lens is likely as island size decreases. On the other hand, the continued production and transport of biogenic carbonate sediment, may, at least in the early stages of a slow rise in sea-level, result in continued island accumulation. If sea-level rises the water table will rise, and the central depression which is frequently a feature of both reef-top islands and atoll reef islands will be more prone to flooding, and will also become an area from which freshwater is lost more rapidly by evaporation and evapotranspiration. This high water table, in some cases will increase salinity resulting from overwash, may require land use changes. Changes in the rainfall received or in the storminess of tropical seas, both of which have been predicted in some greenhouse scenarios, will also affect the groundwater resources of islands. However, despite uncertainties about the pattern of global change in our climate and hydrogeological characteristics of islands, the greatest threat to the freshwater lens, both now and over the next two or three decades, comes from anthropogenic factors such as over-abstraction and pollution.

4.2 "The Potential Impacts of Climatic Change and Sea Level Rise on the South Pacific Islands"

.....Dr. John C. Pernetta.

Geographically the islands of the Pacific Basin fall into four major types and the range and magnitude of climatic and sea level rise impacts will be different for each type. In general however, several characteristics of small states in the Pacific Basin can be recognised which affect the present environment and future ability to respond to potential impacts resulting from climatic change. These include:

Small total land area, and large exclusive economic zones such that the ratio of land to sea is generally less than 0.001 percent of the total. Atoll islands generally have altitudes lower than four metres, and although populations are small in global terms the density on individual islands is high (up to 386 people/km sq.). Pacific island economies display a strong dependence on marine resources, aid, remittance, and development income.

Potential impacts must therefore be viewed holistically since climate changes will affect rainfall patterns, soil erosion may increase and coastal zones receive greater impacts of sediments affecting reef growth. Sea level rise impacts include inundation, increased flooding saline intrusion into estuaries and ground waters. All potential impacts will have social and economic effects in terms of capital investment in infrastructure, power demand and supply, inter-island and inter-country migration and loss of cultural heritage.

It is suggested that small states should "think globally and act nationally"; that actions should be taken now to insure the future; that the problems faced by global climatic change need to be considered within an holistic framework, since the linkages between resources and environmental management problems cannot be split and the environment successfully managed on a sectoral basis. Finally it is suggested that the principle "the polluter pays" be applied since the small states in general, and archipelagic states in particular may suffer dramatic impacts as a consequence of a problem to which they themselves have not contributed.

**DISCUSSIONS:**

1. The usefulness of satellite imagery for recording natural resources in small island states was

discussed. It was stated that satellite imagery has enormous potential for mapping some resources, in particular, shallow water environments. Several individual projects were mentioned and the prospects of stereoscopic determination of elevations were described.

2. Future satellites promise greater spatial and spectral resolution. Present satellites do not always allow the spatial resolution desired for natural resources mapping and need to be supplemented by aerial photography. Remote sensing must be verified by observations on the ground. In this connection, mention was made of the Earth Observation System and the launching of the four satellites by 1995, one with the help of the Soviet Union and one with the help of European Space Community, one by Japan and one by NASA.

## 5. Perspectives for the Future.

- 5.1 "Sea Level Rise - A Coral Atoll Perspective on Marine Resources".....Mr. Maizan Hassan Maniku,

Atoll human cultures provides striking examples of the astounding adaptability of man to environment. However, with the rapid progress of modern technology the ability of man to cope with and control the forces of environment seem to be a matter of finance. The fallacy of this belief is that the planet is in a state of flux to achieve a stable and predictable balance. Attempts to control have had little or no effect on the natural processes and often exacerbate their effects. Global warning on Sea level rise marked the beginning of a major experiment to achieve a revolutionary change in our institutional approach to the management of the global environment. International Collaboration is required at three levels; Political, Scientific Research and Education. The greatest problem facing international initiatives at all three levels is the discrepancies between developed and developing countries. Small States, due to the nature of their existence are the most disadvantaged of all human Communities on this planet.

5.1 "Sea Level Rise - A Coral Atoll Perspective on Terrestrial Environment".....Mr. Mohamed Ali.

In the light of climatic changes, the consequences of sea level rise pose a serious threat to coral atolls like the Maldives. Under the predicted global warming scenarios, the weather and ocean dynamics imply potential destructive effects on the limited resource base of such countries. In addition scenarios, the terrestrial and marine environment in such countries are already stressed by anthropogenic factors. Enhanced wave action on the beaches, coastal infrastructures and other installations can have serious economic implications as well.

Weather modifications such as increased temperatures or changes in rainfall affect groundwater resources, vegetation and the human population on these atolls. The case of Male', the Maldivian capital, clearly exemplifies these changes.

The need to gather data and environmentally sound management planning are some issues to be addressed in the immediate future.

5.2 "Strategies for the Future: The Role of Coastal Management".....Dr. Alasdair Edwards.

Three sea level rise related issues are addressed from a coastal management view point, viz.

- 1) How much time do we have before action needs to be taken?
- 2) The need for careful coastal management now to reduce the economic burdens of the next generation.
- 3) The role of science and education in preparing society and government for the consequences of sea level rise. (Based on Maldives case study).

1. The conclusions are that action must be taken now to develop environmental databases, governmental infrastructure and trained personnel who will be needed in about 10-15 years time to plan and execute governments' responses to rising sea level. If action is taken now and development aid is forthcoming the necessary preparation should be achievable in 10-15 years.

2. It is expensive to defend small island states from the rising sea. The smaller and the more linear

(long and thin) islands are, the less cost-effective is their sea defence, in terms of area defended for a unit amount of expenditure. However, on the positive size for small island states of the tropics is that they tend to be surrounded by coral reefs. These reefs can grow upwards and keep pace with 'best estimate' rates of rising sea level. In so doing they can both maintain their service as free breakwaters and continue to contribute sediment to help islands build up.

Careful coastal management is needed to ensure that coral reefs, and other natural systems, are allowed to continue their protective roles.

3. To prepare for sea level rise science and education must work hard in hand with governments to:

1. train the necessary skilled manpower,
2. educate society as to sea level rise and its consequences,
3. establish environmental database to serve as a basis for planning,
4. establish coastal zone management legislation,
5. develop public awareness of environmental issues which affect the ability of natural system to respond,
6. carry out research to improve local and regional information on critical natural systems

#### DISCUSSIONS:

1. In most cases there is no sound basis for estimating the probabilities associated with the projected sea level rise. Climatic Research Unit and IPCC are presently attempting to do that.
2. Mean sea level is going to increase at about a 5mm per year. Tidal ranges are generally stable, but they may change in the next 25 or 50 years. There is still uncertainty about mean sea level rise and random storm surges.
3. Mangroves can be considered a coastline solution, reefs, an offshore solution and these are both environmentally sensitive and important.
4. Introduction of porous structures on coastlines can reduce run-ups and reduce the overtopping. By extending existing reefs towards the shoreline by

the provision of a stable sub-structure on which they can grow, can reduce the wave energy on the reef.

5. The agencies that could provide financial support wish to see a coherent strategy for coastal zone management for a given area or region.
6. In developing a strategy it is important to have a legislative and an institutional framework with one entity responsible for the management of the coastal zone.

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