UNEP

REGIONAL SEAS

Potential impacts of expected climate change on coastal and near-shore environment

UNEP Regional Seas Reports and Studies No. 140

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PREFACE

In line with Decision 20 of the Fourteenth Session of the UNEP Governing Council on "Global Climate Change", the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of UNEP launched and supported a number of activities, on regional and global bases, designed to assess the potential impact of climate changes and to assist the Governments in the identification and implementation of suitable response measures which may mitigate the negative consequences of the impact. This has been effected through the establishment of Regional Task Teams for the regional seas areas covered by UNEP's Regional Seas Programme, and two Global Task Teams on coral reefs and mangroves. UNEP (OCA/PAC) supported site-specific case studies which comprise a more or less representative samples of various categories of coastal environments and societal conditions.

A joint meeting of the Co-ordinators of the regional Task Teams on Implications of Climate Change was convened in Singapore (12-16 November 1990), with the main objectives being to assess the main findings of the Task Teams and to prepare a joint statement about it; to review the Task Team's experience in bringing their findings to the attention of the relevant national authorities and international bodies; and to discuss the future work which may be undertaken by the Task.

This issue of UNEP's Regional Seas Reports and Studies was prepared by Messrs. M. Gerges[1] and M. El-Sayed[2] essentially on the basis of the report of Singapore meeting[3] to summarize the main finding of the Regional Task Teams on implications of climate change on the marine environment and coastal areas as well as on the socio-economic activities and structures which may be affected by climate change and sea-level rise in their respective regions.

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1. INTRODUCTION

The problems caused by or associated with the potential impact of expected climate changes may prove to be among the major environmental problems facing marine and adjacent coastal areas in the near future. Therefore, the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP), in co-operation with several intergovernmental and non-governmental organizations, launched, co-ordinated and financially supported a number of activities designed to contribute to an assessment of the potential impact of climate changes and to the identification of suitable policy options and response measures which may mitigate the negative consequences of the expected impacts.

Since 1987 todate, ten Task Teams on Implications of Climate Changes were established for ten regions covered by the UNEP Regional Seas Programme (Mediterranean, Wider Caribbean, South Pacific, East Asian Seas, South Asian Seas, South-East Pacific, West and Central African, Eastern African, Kuwait Action Plan and the Red Sea and Gulf of Aden Regions) with the initial objective of preparing regional overviews and case studies on the possible impact of expected climate changes on the coastal and marine ecological systems, as well as on the socio-economic structures and activities of their respective regions. The establishment of a Task Team for the Black Sea is under way.

The Task Teams are established and work under the overall co-ordination and guidance of the Oceans and Coastal Areas Programme Activity Centre of UNEP. Some of the Task Teams are jointly co-sponsored by the Intergovernmental Oceanographic Commission (IOC) of Unesco.

In selection of the Task Teams, the need for equitable geographic representation and for expertise relevant to the work of the Task Team is taken into account. UNEP's financial support to the Task Teams is provided through OCA/PAC.

The long-term objectives of the Task Teams are:

- to assess the potential impacts of climate change on the coastal and marine environment as well as on socio-economic activities and structures; and
- to assist governments in the identification and implementation of suitable policy options and response measures which may mitigate the negative consequences of the expected impacts.

The short-term objectives of the Task Teams are:

- to analyze the possible impacts of expected climate change on the coastal and marine ecological systems, as well as on the socio-economic activities and structures;
- to prepare overviews and selected case studies relevant to specific regions.

The subjects intended to be analyzed and described in the regional overviews include:

- the possible effects of the projected sea level rise on the coastal ecosystems (deltas, estuaries, wetlands, coastal plains, coral reefs, mangroves, lagoons, etc);
- the possible effects of temperature elevations on the terrestrial and aquatic ecosystems, including the possible effects on economically important species;
- the possible effects of climatic, physiographic and ecological changes on the socio-economic activities and structures; and
- areas or systems which appear to be most vulnerable to the expected impact.

The overviews are expected to be based on:

- the best available existing knowledge and insight into the problems relevant to the subject of the overview;

- assumptions accepted at the UNEP/ICSU/WMO International Conference in Villach, 9-15 October 1985, i.e. increased temperature of 1.5-4.5°C and sea level rise of 20-140 cm before the end of the 21st century (for the purpose of these overviews temperature elevation of 1.5°C and sea level rise of 20 cm by the year 2025 were accepted, with the understanding that these estimates may have to be revised on the basis of new scientific evidences). These assumptions have been adopted by all regional Task Teams in order to allow for a global coherence and to facilitate comparison of the results expected from the Task Teams.

- several detailed site-specific or subject-specific case studies based on the substantial findings of the overviews.

The overviews are intended to cover the marine environment and adjacent coastal areas influenced by or influencing the marine environment of the regions covered by the UNEP Regional Seas Programme.

The regional overviews and case studies are being presented to the intergovernmental meetings convened in the framework of the relevant Regional Seas Action Plans in order to draw the countries' attention to the problems associated with expected climate change and to prompt their involvement in the development of policy options and response measures suitable for their region and countries. The site-specific case studies are planned to be presented to national seminars in the interested countries. The national authorities likely to implement the case studies will be invited to the national seminars to review and discuss these case studies and to recommend adequate policy options.

To co-ordinate the overall activities of regional Task Teams, a joint meeting of the Mediterranean Task Team and the Co-ordinators of the Task Teams for the Caribbean, South-East Pacific, South Pacific, East Asian Seas and South Asian Seas was held in Split, Yugoslavia, 3-8 October 1988, to review the progress in the work of the Task Teams and to exchange experience gained through their activities (UNEP(OCA)/WG.2/23).

In view of the considerable work accompanied by the Task Teams since meeting in Split, a joint meeting of the Co-ordinators of the then established nine regional Task Teams was convened in Singapore, 12-16 November 1990, in order to present and assess the main findings of the Task Teams and to prepare a joint statement concerning them; to review the Task Teams' experience in bringing their findings to the attention of the relevant national authorities and international bodies; and to discuss the future work which may be undertaken by the Task Teams taking into account their achievements and experience, as well as the past, on-going and planned activities of other programmes and bodies.

The meeting in Singapore was attended by Task Team co-ordinators and several members of each Task Team. This publication contains the substantive parts of the meeting's report (UNEP(OCA)/WG.8/2) which reflect the main findings of individual Task Teams in the pursuing sections.

2. MAIN FINDINGS OF INDIVIDUAL TASK TEAMS

2.1 The Mediterranean Region

The Mediterranean Sea is a semi-enclosed sea surrounded by 18 coastal states. It covers an area of about 2.5 million km^2 and the length of its coastline is about 46,000 km. The Mediterranean Sea lies in a trapped basin within a collision zone between the African and Eurasian continents. Climatically, the

Mediterranean is transitional and characterized by its winter-dominated rainfall, dry summers and profusion of microclimates due to the alternating mountains and inland seas.

With an assumed temperature increase of 1.5°C by the year 2025, potential evapo-transpiration will increase throughout the Mediterranean, coupled with a possible decrease in precipitation in the South and an increase in the North. Hot dry summers and exceptional events of drought or rainfall and floods, marine storms, tidal surges and of water stagnation and eutrophication, could increase in frequency.

A 1.5°C increase in temperature would lead to an increase in land degradation, deterioration of water resources, decline in agricultural production and damage to natural, terrestrial and aquatic ecosystems. It could also alter marine circulation both in the Mediterranean and the Atlantic, thus affecting marine productivity and the pattern of pollutant dispersal.

The future impacts on Mediterranean society of non-climatic factors (e.g. population increases, present development plans) may far exceed the direct impacts of climate change. Non-climatic factors will cause continuous increases in society's vulnerability to climatic stress, particularly in the South. Together, these demographic and climate change should increase the probability of catastrophic events and hasten their occurrence.

It is particularly difficult to forecast the effects of climate change on agriculture, beyond concluding that irrigation systems will suffer increasing stress and soil degradation will reduce yields in rain-fed system. Salinization of irrigation water would have negative consequences on sensitive grain yield. Consequently, new varieties of crops have to be introduced, adapted to the new natural settings and yield standards.

A global, eustatic rise in mean sea level of about 20 cm by 2025 would not, in itself, have a significant impact in the Mediterranean, except locally (e.g. lagoons). However, local sea level changes could be up to five times this amount because of natural land subsidence, enhanced by excessive groundwater withdrawal. Negative effects of this impact will be felt in low-lying areas, deltas and coastal cities.

Most of the deltaic lowlands of the Mediterranean Sea are experiencing serious environmental problems because of agricultural, industrial, urban and tourist developments over the last two decades. Problems range from water pollution and salinization to land subsidence, shoreline erosion, and restriction and deterioration of wildlife habitats. These problems will be increased by adverse socio-economic conditions, the effects of which will be superimposed upon those of climate change.

Generally, marine and land weeds are expected to benefit from a warmer, CO_2 richer atmosphere. Flora and fauna of the wetlands will be forced to gradually adapt to changed conditions which might be crucial for species that possess reduced tolerance to high salinities. As bioclimatic zonation will gradually shift northwards, several species will migrate to the north, and insect populations might increase. There will be favourable conditions for an increasing risk from agricultural pests, bacteria and diseases, especially in the swamps.

To develop a strategy for responding to the impacts of climate change, it is essential to identify those parts of the Mediterranean coastal regions where knowledge is still inadequate.

Regarding sea-level change, prospective actions can be either preventive or reactive. For example, entire coasts and lagoon margins can be walled in, or choices must be made between irreplaceable coastal uses (e.g. national and military harbours, towns of historical-artistic value, lagoonal resources, uses; and (b) a different approach to beach recreation (i.e. less urbanized), the replacement of extensive, uneconomical crops in low-lying lands, with lagoons destined for aquaculture and nature reserves. The lagoons would act as a buffer belt, since their inner margins can be more easily protected than the expose coast.

The immediate task should be to identify all "high risk" areas, and to re-examine the present factors of coastal dynamics in the context of increasing air/water temperatures and sea levels. Storm impact maps should help provide a scientific basis for proper coastal zone protection. Engineering solutions, such as dikes and walls, are not likely to represent a realistic long term solution to the problem of rising sea level, except in very special cases. The coastal dynamics of erosion and deposition, the relative life span of most human installations, and the possibility of providing complete protection for small areas of special importance mean that it is most likely that adaptation, evolution and land use change will represent the most appropriate responses to sea-level rise.

Clearly, the first need is to develop a realistic sea-level rise scenario, and secondly, to determine the physical impacts on inshore areas.

Close attention needs to be paid to the conservation of soil, groundwater and wetland resources in the Mediterranean, because they contribute substantially to environmental stability. The adverse effects on downstream human settlements and ecosystems of large dam schemes have not been considered sufficiently in past planning. Future water management plans must be scrutinized more closely in relation to climate change.

Studies of the frequency of extreme events (high temperatures, high and low precipitation events, storms surges, etc.) and how these frequencies relate to mean climatic conditions, are required to help predict probabilities of occurrence.

The implications of climate impacts for some regions and processes are highly complex and therefore systems analysis seems to be the best approach to their study.

It is recommended that organizational and legal instruments be developed to control coastal development, land reclamation and groundwater exploitation. Lowlands could be analyzed and zoned in high, medium and low risk categories.

2.2 The South East Pacific Region

The South East Pacific region covers five Latin American countries, and the coastal zone exhibits representative areas of almost all known marine ecosystem types ranging from the tropical coasts of Panama, Colombia, and Ecuador through the subtropics to antarctic ecosystems in the southern extremity of Chile. The world's highest precipitation is recorded in the Colombia-Choco Pacific area. The region also encompasses one of the most productive marine areas in the world due to the presence of the nutrient rich and cold Humboldt Current. The region is also affected by the sporadic appearance of unusually warm water that produces dramatic alterations in local meteorological, oceanic and biological regimes (The El Niño). This has important impacts on the socio-economic structures of the countries, particularly in coastal areas where more than 70% of the total population is located. El Niño serves as a short-term analogue of anticipated impacts resulting from global changes and an additional concern is that the frequency of El Niño may increase under conditions of enhanced temperature.

On a short term basis, an El Niño event results in impacts which simulate those which may result from gradual increases in the temperature and mean sea-level, as a consequence of global warming

The available paleobiological information suggests that during the Pliocene and Quaternary periods, changes occurred in sea-level, and in temperature, favouring the growth and distribution of corals in the Pacific. An increase of 20 cm in sea-level may have no adverse effect on coral reefs. In contrast an increase in temperature, over 1.5°C produces serious disturbances. During the 1982-83 El Niño event, surface temperature reached about 30°C, and as a result of this increase, bleaching of corals and expulsion of the zooxantellae were observed.

With increases greater than two metres in mean sea level low salinity and sedimentation rates were observed, together with massive mortality of the filter feeding fauna of the mangroves. Other species increased in biomass. During the 1982-83 El Niño event, the catch of various species of penaeid prawns was increased.

Drastic reductions in productivity, together with changes in the composition and distribution of species have been observed during the "El Niño". Reduction in the biomass of some species occurred during these events, while others displayed serious physiological changes, as indicated by body weight loss, due to a reduction in oil content. The almost total, local extinction of common species in commercial fish catches, such as the anchovy, was another observed impact. The disappearance of traditional pelagic species affected guano producing birds, and resulted in the mortality of marine predators.

The warming produced during "El Niño", affected benthic species reducing their number as a consequence of the migration of species associated with warmer waters. Polychaetes and Nemertines increased their biomass and density to depths of 50 a 100 m. "El Niño" also affected the pattern of distribution and behaviour of demersal species, some of which disappear totally during such events. At the same time Lutjanidae and other tropical fish invaded subtropical waters. Such changes in distribution were seen even at distances of 150 km off-shore.

Penetration of saline wedges occurred in estuarine areas with effects on natural succession especially in the composition of mangroves. The increased sea level resulted in inundation of the littoral zones with changes in the patterns of sedimentation, and in severe cases a massive mortality of the estuarine fauna. In general a regression of the coast line associated with increased erosion will be produced.

The increase in temperature is reflected in a decreased fish catch. In the region these oscillate between 6-8 million tons/year and for the case of "El Niño" 1982-83, they were reduced to 1.5 ton/year. The economic loss with this downtown has been estimated at US$100 million.

Generally, climate change will alter the availability of fish catch by changing its composition and fishing efforts; traditional species will disappear and other rare or scarce species will increase in biomass.

The climate change associated with the 1982-83 El Niño affected basic infrastructure; with damage to health, levels of rotation, and increasing mortality. Malaria reached epidemic proportions. Coastal roads and structures were destroyed or seriously damaged. The economic losses reported by the Economic Commission for Latin America (ECLA) were about US$2.667 million losses in the productive sector, with 18% (US$634 million) of damage to physical infrastructure, and the remaining 5% (US$179 million) in the social sector.

Global warming is expected to increase the intensity and frequency of El Niño events.

2.3 The South Pacific Region

The Pacific region comprises more than 3000 small isolated island, grouped into 24 political entities. Many of these islands are low coral based motus which are highly susceptible to the impacts of sea level rise. The ratio of coastal length to area is high; off-shore water is deep; thus engineering response strategies to climatic change are not feasible. Migration of human populations form impacted zones and islands may be necessary. Although the population is relatively small in absolute terms, numbering approximately 5 million people, the cultural diversity is enormous (one-third of the world's languages are spoken in Melanesia). The social, political, and economic integrity and physical and biological environments of more than 800 separate human cultures will be threatened by projected climate changes.

Isolated small island states are economically vulnerable, and environmental changes which place increased stress on their subsistence or commercial economic bases are commonly extremely damaging. In addition, islands and island nations which are entirely low, coral-based motu are threatened with damage to coastlines and groundwater sources by rising sea levels, or even with total destruction should sea-level rise by more than 1 metre, or wave climates become more stormy.

The Task Team for the South Pacific region found that 14 Pacific island states would be severely or profoundly impacted by even low to medium projected levels of global change.

As a result of greenhouse induced climate change, by the year 2050 all equatorial and sub-equatorial locations in the Pacific, will suffer year-round conditions of severe discomfort and thermal stress. Such decreases in thermal comfort, with associated increases in heat stress while working outdoors, especially around midday, will mean that the patterns of work, especially for outdoor workers will need to change. Increasing thermal discomfort will require an increasing need for atmospheric management in urban areas. Changes could be made in commercial or office building design to encourage air circulation and avoid the need for energy-consuming air-conditioning. There will be an increase in storm surges and higher energy waves generated by intensified cyclonic activity in latitudes North and South of about 10°.

There will be changes in the pattern of temporary high sea level stands as the ENSO pattern changes. Reduction in El Niño events would decrease temporary higher sea level stands in the western and central Pacific and partially offset the impacts of world-wide rise in sea level.

A direct change in local ocean water temperatures of 1 to 2°C may cause coral die-back, which has other implications, notably an expected increase in the energy of coastal wave climates.

The agricultural potential for many food crops will change, with consequent changes in the crop varieties which may be able to be grown, under warmer conditions. Replacement of food crops may not be available.

Impacts of sea-level rise in the South Pacific will be most profound on: low islands; small high islands and raised coral islands (in terms of proportional land loss); deltaic floodplains/mangrove flats/sandspits and lagoons; infrastructure (roads, sewerage, water supply etc); soils, coastlines, water resources, coral reefs; agriculture and forestry; and, health.

Enforced human migration and other social/economic disequilibria are indicated. The region contains a very large number of cultures and traditions which face extinction if sea-level rise forces migration. Cultural identity, an extremely important concern in the Pacific islands, is difficult to maintain in migrant communities.

Pacific island ecosystems are generally very fragile. The islands have high coastline to landmass ratios, are often low-lying and are thus highly vulnerable to the impacts of climate change.

Both institutions and individuals in the Pacific islands are concerned about climate change and sea-level-rise. Media and NGO activity have contributed to this anxiety.

Lobbying at an international level is unlikely to yield satisfactory results. There is a need for interim measures to be taken to maintain an acceptable quality of life in the next 30-50 years before response strategies to rising sea level become imperative.

It has become apparent that there are major gaps in our knowledge, especially of the ocean-atmosphere system. Careful monitoring and continued research are therefore essential if workable strategies are to be found. If remedial strategies are to be successful, Pacific Islanders must be involved in the monitoring and in the strategies themselves. Reliance on outside experts is not seen as a viable option.

Coral reefs are an integral part of the coastal environment and form the basis of many nation states. They appear to be vulnerable to ocean surface temperature rise and therefore careful monitoring of reef systems is necessary. Other species living near their upper limits of thermal or salinity tolerance may be unable to survive rises in temperature or salinity.

Rapid population growth combined with the possibility of eroding land is a disastrous combination. If climate change does lead to additional land being brought into production it is likely to be agriculturally marginal and subject to rapid degradation or erosion.

Physical responses in terms of coastal defence structures are not a practical option for most Pacific islands. Other options (e.g. massive reafforestation or ultimately out-migration) must be considered and their implications and consequences need to be examined carefully.

2.4 The East Asian Seas Region

The East Asian Seas region consists of 5 countries (which include) both coastal and archipelagic states. The region is characterised by numerous islands and extensive coastline lengths. It is also recognised as an area which supports high species and habitat diversity. Most of the economies are agriculturally based. The rapid population growth, concentrated along the coast, has caused degradation of living resources and their over-exploitation. The region has a heavy dependency on the seas, and fish forms the major dietary protein source. Climate changes are anticipated to have major impacts within the region particularly on low-lying coastal centres of population.

With the expected rise in air temperature by the year 2025, rainfall is expected to increase. Present sea surface temperatures are expected to increase, and slightly. Enhanced evaporation and increased precipitation will affect salinity. Vertical stability of the already stable surface waters of the tropics will increase further, thus inhibiting vertical mixing which has implications for the biological productivity of the marine environment.

The expected increase in atmospheric temperature is speculated to be greater in the high latitudes (4 - 6°C) than in the tropics (0 - 2°C). As a result, the warming of the tropical oceans will be less than in the higher latitudes resulting in the North-South temperature gradient in the oceans, which in turn, will diminish the magnitude of the thermohaline circulation.

Sea-level rise may provide the necessary environmental conditions for coral reefs to optimise structure and orientation. A sea-level rise will reduce the frequency of aerial exposure of reef flats and may promote growth in this zone. Depressed salinity will be detrimental to species unable to tolerate large salinity fluctuations. A sudden increase in water temperature may also cause corals to bleach, resulting in mass mortality.

Seagrass and macroalgae can be expected to shift their distribution landward in response to sea level rise provided that the newly submerged shore areas are suitable for settlement of propagules.

Mangroves can theoretically migrate landwards in response to sea-level rise as long as freshwater supply remains adequate. The change in salinity patterns through increased rainfall will affect the non-tolerant species and determine the survival or death of affected zones. Mangrove species are also expected to be stressed by elevated temperatures.

Direct as well as indirect influences on marine productivity can be expected from climate change. The increased level of nutrients washed out to sea can have the positive effect of encouraging growth of primary producers as well as a negative effect where enhanced algal blooms may be detrimental to other marine organisms and mariculture operations. Large amounts of sediments washed out to sea will reduce light penetration which is damaging to coastal reefs and marine plants.

Coastal erosion, through the alteration of coast topography, may cause large changes in nearshore current patterns. This, coupled with salt water intrusion into the estuarine areas, can have adverse effects on the breeding and nursery grounds and migratory patterns of some economically important species.

Fisheries production will be affected through the change in distribution patterns caused by changes in nearshore currents. Mariculture techniques now in operation along coastlines may change. The East Asian Seas is a very productive areas. Sea-level rise may bring about some changes in species composition in highly productive area, including among economically important species, and techniques for fishing would also change.

The effect of climatic change on tropical forests will be severe, adding stress to already existing situations like nutrient-poor soil and the alarming rate of deforestation in the region. The agricultural sector will stand to benefit from climate change through CO_2 fertilization, which may increase yields by 10-50%, providing that moisture is adequate.

Suggestions for increasing available moisture include bunding and strategic irrigation, both of which would be suitable for providing water at critical periods, and allow farmers to enjoy the benefits of CO_2 fertilization.

It is noted that certain beneficial measures could result from climate change, such as use of better irrigation systems to offset the loss of water while taking advantage of the higher CO_2 which increases plant growth rates. Past records show that agricultural practice in this region is very adaptable to extreme climate events such as droughts and floods, and that it is possible to plan for mitigation measures in advance.

It is concluded that impacts on agriculture and forestry from sea level-rise will result more from salinity intrusions inland rather than the actual loss of land.

The impact of sea level-rise on coastal geomorphology is considered to be more direct than elevated temperature. Coupled with changes in nearshore current patterns, coastal erosion and deposition rates will increase and result in changes to coastal geomorphology. This will be further aggravated by the loss of natural ecosystems which, if unable to tolerate the changed conditions, will result in the loss of their coastal protection capability.

Coastal erosion will apply more to soft coasts. Thus, sandy beaches, deltas and cliffs formed from soft materials are more susceptible to erosion from a rise in sea level. For sandy shores, the resulting retreat from a rising sea-level can be predicted to some extent. Coral reefs, mangroves and sandy beaches are identified as being most vulnerable to sea-level rise.

Coastal dikes and other man-made protection devices will have to be raised or modified to prevent increased wave overtopping.

The impacts of a 20 cm sea level rise by the year 2025 are likely to be insignificant compared with anthropogenic factors operating in the coastal environment. It can be reasonably concluded that sea-level rise will aggravate existing erosion and initiate new erosion. The role of extreme events, specifically typhoons, under conditions of global warming is as yet unclear, though it was suggested that increased occurrences of typhoon activity may result.

A general assessment in the case of Malaysia indicates that the situation may worsen due to the present trend towards the use of impounding reservoirs since the more easily developed surface water sources have already been tapped. This however, may not reflect the situation in the other countries. It can be concluded that the projected sea-level rise will aggravate existing problem of saline contamination wherever it happens. Saline intrusions further inland primarily through the rivers, will have implications on low altitude forestry and agriculture. Saltwater intrusion into coastal aquifers will also result and a general raising of water tables can be expected.

Climatic risk factors associated with the greenhouse effect and the consequent sea-level rise have not been considered in national development plans of the East Asian Seas countries. Policy makers in the region are not truly convinced of the projected climatic change in the next century, and of the need to incorporate such factors into national development plans, because of the lack of concrete evidence.

The projected climate change and sea-level rise will probably exacerbate socio-economic problems that already exist in these areas. The incorporation of climatic risk factors in currently formulated coastal zone management plans should enable responses to be taken against the impacts of climate change and sea-level rise.

2.5 The South Asian Seas Region

The South Asian Seas region includes five countries, two of which (the Maldives and Bangladesh) are considered by experts to be amongst the countries most vulnerable to climate change. Three countries are coastal, one a large island and one an archipelago. The rise in sea level threatens to erode the 1,200 islands of the Maldives and over one third of Bangladesh will be destroyed by intensive flooding, severe erosion, devastating cyclones and storm surges. The countries are all densely populated and the coastal areas are heavily utilised for fish and agricultural production and as centres of industry. Changes in oceanic and atmospheric circulation will have adverse impacts on marine food resources; change the frequency, intensify and paths of tropical storms and storm surges; alter precipitation patterns and increase coastal flooding.

It is noted by the Task Team of the South Asian Seas (SAS) Region that sea-level rise due to global warming may lead to major coastal environmental problems for a number of States of the region. Based on available figures for Karachi and Bombay, sea level has risen 0.1 to 0.15 metres over the last century.

The estuarine environment, particularly the mangrove swamps, serves as a breeding ground for fish. The survival of these deltas is threatened by world-wide and local causes. The world-wide threat is the rise in sea level. The local causes include continued construction of dams and river diversion, resulting in a decrease in sediment flux to the sea and enhanced relative rise in sea level.

Sri Lanka and Maldives are Island nations in the SAS Region. The maximum elevation of Male (capital island of Maldives) above sea level is no more than 2 or 3 meters. Given the high porosity of coral and coral sand, the construction of dikes may not be sufficient to solve the problem of a rise in sea level since the underground continuous flow of water would require an immense amount of energy for drainage.

The principal impact of the rise in sea level in Sri Lanka is erosion of the coastal areas. The tourist industry of the country linked to the beautiful beaches will be adversely affected. Both the mangroves and coral reefs will be damaged due to the rise in the sea level.

The Sub-Continent comprising Pakistan, India and Bangladesh has many common features although there are differences in the impact of the global warming and sea level rise in different countries of the Sub-Continent. Any change in the rainfall pattern due to global warming will disturb the complex balance between agriculture, disastrous floods, droughts, etc. and global warming will change the air-sea interaction due to reversal of monsoon effect on the oceanic circulation which in turn is related to fisheries production.

The outstanding feature of the South Asian Seas region in terms of the impacts of climate change and rise in sea level is its high population of over one billion. About 10 per cent of the people of the region lives on the coast. According to demographic experts, the population will probably double by the turn of the century and definitely reach two billion by the year 2025.

The coastal zones are already under great pressure due to accelerating population growth, pollution and flooding problems. Changes induced by global warming will most severely affect these through their reduced courses onto the deltas, the coastal seas and the oceans acting in accordance with alteration that humans have imposed and continue to impose at an accelerating rate.

Climatic change due to global warming is expected to increase the intensity of the monsoon circulation. The atmospheric low pressure (generally known as Heat Low) that develops over the sub-continent during summer is likely to intensify and drive the monsoon winds strongly. At the same time, a warm ocean can supply more moisture to these winds. The present interannual variability of the monsoon system will probably smooth out, giving place to almost steady wet monsoons each year and as such the periodic occurrence of droughts can be expected to wane gradually.

The variation in the wind system due to the increase in temperature is likely to affect oceanic circulation. The wind stress pattern is likely to change, resulting in shifting of gyres, rings and eddies, mixing of waters from rivers will increase, nutrients in the sea will be redistributed and so will primary productivity and fish stock. The new thermal field of the sea is liable to trigger large fish migration. Undoubtedly, the temperature increases would also have an influence on evaporation and precipitation patterns, species composition, and occurrence of plankton blooms. Upwelling will be intensified off Somalia and Arabian Peninsula.

Sea-level rise is considered to be the single most important source of change in coastal zone processes and activities such as: beach erosion; farm land loss; wet land loss (including mangroves and coral reefs); frequency and severity of flooding; infrastructure improvement and disturbance to hydrologic systems.

These impacts are severe indeed, affecting the lives of many millions of people living in the deltas and low-lying areas. They can threaten unique ecosystems, and have enormous negative economic impacts.

Various phenomena in the South Asian Seas region are likely to be intensified by climate change including: variability in southwest monsoon and associated precipitation pattern; intensification of cyclones, their frequency and path; intensification of storm surges with the rise in sea level; changes in the air-sea interaction causing changes in circulation and in marine productivity.

The main concern is the increase in intensity of tropical cyclones. As the sea surface temperature rises from 26° to 30° C, the saturation vapour pressure increases by 26%. Therefore considerably more water vapour and latent heat will be available for conversion to kinetic energy.

As far as frequency of the occurrence of the tropical cyclones is concerned, they have been found to occur even during SW monsoon months which are not the usual months for cyclones. To some extent this indicates an extension of the period of occurrence, suggesting future increases in the frequency of cyclones. Thus green house warming is likely to increase the frequency, intensity and path of cyclones which together with associated storm surges will create an increase in coastal hazards.

2.6 The Wider Caribbean Region

The Wider Caribbean region is characterised by a varied tectonic history and by diverse physical landscapes and habitats. There are low-lying coral islands, volcanic uplands, coastal plains, deltas, coral reefs and wetlands. These characteristics, combined with the region's racial and cultural diversity make many countries important recreation and tourist centres. If climate change and sea level rise of the magnitude predicted were to actually occur, then there would be significant dislocation of the economic structures of many of these countries.

The major deltas of the Wider Caribbean especially the Mississippi (USA), Magdalena (Colombia) and Rio Grande (Mexico/USA) would be likely to experience shoreline retreat involving thousands of hectares of land. Benthic systems in these deltas would be most vulnerable to such regression.

Estuaries must be assessed on a case-by-case basis because of the variation in tectonic movements across the region. Minimal impact would be expected in areas where there is crustal emergence (e.g. North coast of Jamaica, Southeast coast of Cuba, Barbados, Southwest Gulf of Mexico). Areas experiencing downwarping and/or subsidence would be among the worst impacted (e.g. Maracaibo region of Venezuela, northern Gulf of Mexico from Texas to Florida, western Gulf of Honduras). Coastal lagoons, estuaries and salinas could experience saline intrusion.

Based on the record of the last 5000 years BP, many wetlands in the region have kept pace with rising sea levels, but in subsiding regions they would be in danger of becoming inundated. There could be significant loss of wetland economic activities (such as shellfish industries) with a 20 cm rise in relative sea level (RSL).

For coastal plains, no single rule applies, given tectonic variation, offshore topography, beach structure etc. The primary impact is likely to be flooding. Migration of shorelines will vary spatially, but sandy beaches will suffer more than rocky coasts. Heavily populated, subsiding zones (e.g. Port au Prince, Texas-Louisiana coast near Galveston) are the most vulnerable.

If reefs continue to grow at currently estimated rates of 1-20 cm/year, they could keep pace with a sea level rise of 20 cm by the year 2025. However, not all species develop at the same rate; and those affected by other kinds of environmental stress (e.g. storms, sedimentation, pollution, turbidity, etc) would be unable to cope with a sea-level rise of the magnitude predicted.

While the response of mangroves will vary by species, these are generally expected to cope favourably with predicted rise in sea level (RSL), provided other stress factors do not become critical.

Seagrass beds are important for stabilising bottom sediments and are critical habitats for juveniles of many fish species. A RSL rise of 20 cm is not expected to have a widely detrimental impact, provided that factors such as wave energy, light penetration, substrate conditions and the influence of herbivores, do not change significantly.

The greatest impact of sea-level rise on fisheries would be expected where there is a simultaneous increase in turbidity. Estuarine-dependent species could be badly impacted if there is a change in salinity conditions. The most vulnerable areas would include the Mississippi, Everglades, Guyana and the Orinoco Delta region.

It is expected that most migratory organisms would cope with a 1.5°C rise by 2025. Some corals would be negatively impacted (e.g. by bleaching events), but other stresses might be more critical. Mangroves are highly adaptable and most species should be able to withstand the predicted temperature increase, unless the increased heat affects their reproductive cycle. Likewise, only the seagrass beds already in thermally stressed environments (shallow lagoons, or near power plants) would be really vulnerable.

The loss of agricultural land through saline water intrusion would vary with the character of the coast, but continental margins are not likely to be widely affected. The expected impact on forestry should be negligible for most of the region.

Tourism is the single most important industry in the Wider Caribbean. In islands like Bahamas, Barbados and Antigua, this is the number one foreign exchange earner and employs large numbers of people. The most significant impact of climate change on tourism would be beach erosion. While shoreline migration may lead to the creation of new beaches, the protection and stabilisation of exiting ones could be burdensome on national economies. When the effects of climate change are coupled with other stress factors (e.g. sand mining, mortality of reefs, etc), the region's beaches would be highly vulnerable.

Where seawalls, bridges, revetments and other engineering structures become necessary, severe stress could be placed on the economies of many states. Municipal water supplies, sewerage systems and drainage will have to be modified substantially in vulnerable, low-lying areas where large populations would be at risk. Again this will have certain financial implications for the region.

It is expected, as elsewhere in the tropics, that both a temperature rise and sea-level rise will affect human health. Certain disease carrying organisms and pathogens could find more favourable habitats thereby creating additional health problems.

2.7 The Eastern African Region

The Eastern African region covers four continental, coastal countries along the East African Coast, one large island state, three smaller archipelagic states and the Eastern African territories of France in the S.W. Indian Ocean. The region is characterised by vulnerable economies, large populations estimated at 62 million people with a high rate of population growth, and areas subject to environmental stress. The region is dependent to a significant extent on coastal resources. The regional Task Team which was established in June 1989, has recently completed a draft overview of the implications of climate change. No case studies have yet been implemented, but the overview concludes that low-lying coastal areas and marine ecosystems, water resources, terrestrial ecosystems and human settlements and coastal infrastructure are subject to risk as a consequence of climatic change impacts.

Some 14% of the mainland population reside on the coast, while on the islands, coastal settlement is much more common. A critical factor in the region is the rapid rate of population growth, resulting in high pressure on resources. Rapid urbanisation has led to inadequate water supply, overcrowding and unsatisfactory waste disposal which is discharged directly to rivers and to the sea. The present infrastructure network is not to very high specifications and is not well developed.

The economies of the countries are dominated by agriculture. Fishing is an important source of food and contributes to the economy of the majority of the countries. Tourism is an important activity. The level of industrialisation of mainland countries is relatively low and among the islands, only Mauritius has a genuine industrial base. Wastes are not presently being handled in an environmentally sound manner.

Greenhouse warming of the planet will lead to a general increase in regional temperature and sea- level rise. Changes in the global temperature will also lead to changes in precipitation pattern over the region through changes in regional circulation patterns. Such changes will in turn affect surface and groundwater flow and river discharge; surface and groundwater availability; the incidence of floods and sedimentation; the movement of marine water masses (waves, tides and currents); the intensity and tracks of tropical cyclones; natural ecosystems; as well as human activities, especially in the coastal zone, including changes to agriculture, fishing, industry, tourism and the quality of life.

Climate change will alter marine and atmospheric parameters, such as pressure systems, rainfall, glacial melt, salinity, coastal weathering patterns, oxygen, evaporation and density gradients. The spatial and temporal distribution of rainfall and cyclones will change and cyclone intensity may be increased.

There will be impacts on the coastal zone, in natural habitats such as coral reefs, lagoons, and mangroves. The reefs will be vulnerable to wave action and sea-level rise as well as sedimentation. As reefs form part of the natural defence systems, this may encourage further coastal erosion.

Through changes to components such as the distribution and amount of rainfall, evapo-transpiration, surface runoff, river discharge, recharge, and aquifer volumes, hydrology and water resources, will be affected. Such changes will affect the quality and quantify of water available from the three dominant regional sources (rainfall, rivers and ground water) as well as the future regional distribution of water resources. Increased flooding risks, rising sea-level and recurrence of storm conditions would also lead to a decrease in water quality. Increased dry conditions would place an inordinate pressure on water resources.

Climate change will impact ecosystems, leading to latitudinal and altitudinal shifts in plant and animal species and disruption to the present ecological balance. On islands, the problem of water limitation will occur and biodiversity will be reduced. Increase in aridity along the dry coastal areas would, in the long run, affect the current ecological balance while extreme events can be destructive to coastal forests and to mangroves.

There will be agricultural impacts, with positive and negative effects on different crops. A global increase of CO_2 would have some positive effects on coastal agriculture, whilst moisture deficits would lower crop yields and require additional irrigation resources. Sea-level rise would increase the intrusion of saline water up river mouths and also decrease the area available for cultivation on low-lying coastal areas and river estuaries.

Fisheries will be affected by changes to the breeding and migratory habits of most fish, hence, year to year variability of stocks could increase leading to a planning and management problems.

Socio-economic activities, and infrastructure such as port facilities, waste disposal, roads, are already under stress. Climate change would create additional stress hence reducing economic performance and growth. The area is already characterised by excessive growth.

The many differences in topography and other regional characteristics will lead to extreme variability in the impacts of precipitation. The need for a regional climate scenario, for a doubling of carbon dioxide, is critical for accurate forecasting of the impact of temperature increases and sea-level rise. Such a scenario should take into consideration the existing wide regional variation.

The impacts of sea-level rise appear much easier to forecast, but no clear indication of the more serious consequences of expected regional sea-level rise has been evolved. The effects would be more serious if subsidence occurs which would mean higher relative sea-level rise.

At the national level, all work being carried out is disseminated on account of compartmentalized thinking and there are difficulties of horizontal consultation and exchange. There is a general shortage of local experts.

The countries of the region should review all their major development plans and decisions, taking sustainable development, cost effectiveness and climate change into consideration.

In the field of energy, fuel efficiency should be encouraged at all levels. Priority should be given to the use of clean, renewable, local resources (hydro, solar, tidal, thermal, biogases) in preference to expensive imported fossil fuels which, not only increase the carbon emissions, but also use up valuable foreign exchange in the process.

In view of increasing urbanisation and greater extremes of precipitation and dry periods, as a consequence of spatial and temporal changes to rainfall, there would be greater need for water storage, for domestic and irrigation purposes. The encouragement of further hydro-electric schemes would increase multiple demand for water. Here, hydrogeological research should be encouraged into the exploitability of the massive underground aquifers which would normally be less expensive to build than surface water projects. Recycling of water should also be encouraged.

Conservation of forests should be enhanced so that, in addition to their natural functions of ecological balance, they can also contribute to reducing carbon dioxide in the atmosphere. National forestry services should be given the resources to carry out their tasks. Agro-forestry projects providing woody biomass adequate for domestic purposes should be encouraged in the vicinity of settlements.

Encouragement should be given to national strategies which would reduce fuel consumption, encourage efficiency as well as achieve other socio-economic goals (minimise journey to work, encourage use of bicycles, favour efficient mass transit system with low energy use).

Governments should favour the adoption of an integrated planning approach to the development of coastal areas, lack of planning in the past has contributed to haphazard location, and creating greater vulnerability to sea-level rise. Governments also should adopt a Coastal Management Strategy which will identify all vulnerable areas; ban, where necessary, new developments; and start protection measures for heavily built up areas. Governments should be encouraged to review all major investment decisions, not yet implemented, involving coastlines or coral islands under their control, such decisions being confirmed only after a review of sea-level rise issues. Major investments include port and airport development; industrial, tourist; and infrastructure investments. All coastal development should be screened from a climate change viewpoint, in addition to the conventional issues contained within the planning process. Permitted development should incorporate siting parameters which include both a distance from the High Water Mark as well as a height above sea-level component.

There are considerable gaps in research and an inventory of such gaps needs to be made to quantify impacts and facilitate the evolution of response strategies. Response strategies must be based on climate change scenarios, expected impacts and future plans for the coastal areas of the region, but scenarios for the region may take some one or two decades before being developed.

As national awareness of climate change occurs, the need to collaborate more closely on these issues will be felt at the regional level. A co-ordination programme between the various national climate change units should be encouraged at regional level.

2.8 The West and Central African Region

The West and Central African region comprises 21 coastal countries from Mauritania in the North to Angola in the South. Weather and climate variations are of considerable importance to the economies of these countries. An increase in frequency, intensity, duration and/or changes in the spatial distribution of extreme events, if they occurred in association with predicted climatic changes would have severe consequences for these countries. The rapidly increasing coastal populations, which increase pressure on the natural resources; the location of high capital value infrastructure in large low-lying urban centres; the diverse marine and coastal ecosystems; the extensive coastal renewable and non-renewable resources which are currently subject to degradation; and the importance of coastal areas to all countries of the region, require special attention in any assessment of the impacts of predicted climate change in this region.

Based on assumptions of expected climate change in the humid areas there would be increases in both precipitation and temperature. This increase in rainfall may be accompanied by increases in intensity and greater frequency of violent storms particularly hurricanes. Increase in temperature would also increase evaporation and potential evapo-transpiration. In contrast to the humid tropical regions, the savanna and semi-arid areas would have a tendency towards decreased precipitation. This, coupled with temperature increase would reduce soil moisture availability and lead to greater drought stress. With the additional effects of man, the characteristic problems of the various socio-economic activities, would be increased.

Erosion and flooding of coastal areas are currently twin scourges along the West and Central African coasts. The rates of retreat of the shoreline and the frequency of inundation of land by sea water are too rapid, putting lives and property at risk. The effects of these environmental hazards would be increased with climate change and sea-level rise. Many barrier islands would be vulnerable to flooding while many industries and oil handling facilities would also be affected. Sea-level rise would also result in flooding and disruption of natural ecosystems.

In general, both the atmospheric and oceanic circulation would be affected as the wind patterns would be modified and higher sea surface temperature and increased wind force may lead to further increases in thunderstorms.

There would be greater tendency for droughts and desertification in some parts of the region. Climate change would affect the water supply systems and lead to greater water stress and economic losses particularly in the savanna and semi-arid areas. Climate change would also lead to problem of water shortages for maintaining reservoirs (e.g. lakes) and consequently have socio-economic implications resulting in hunger, famine and death. It would also lead to increase in depth of water table.

Climate change would lead to greater stress on forests for fuel particularly as there would be decrease in areal extent of forests. Hydro-electricity would also be adversely affected as there would be shortage of energy supply. This, in turn, would affect water demand.

Most of the current coastal and low-lying flood plain vegetation and ecosystems would be lost due to flooding and inundation.

Fisheries would be affected as there would be changes in the characteristics of the coastal ecosystems. There would be greater salinity stress with ingress of sea water.

Climate change would affect the extent of the potential growing season, crop yield and variabilities in the yields, yield quality and sensitivity of crops. In general, there would be a change in the agro-ecological zones.

Other socio-economic activities which would be affected include transportation, commerce, industry, tourism and recreation. For example, there would be chaos in movement of goods as many of the modes of transportation services would be inundated. The inundation of the coastal areas would also have adverse consequences on commerce and industry and would lead to closure of many industrial and commercial institutions. Examples are the oil producing wells. Climate change and sea-level rise may also lead to crippling of tourism and recreational facilities.

Climate change would dislocates the population patterns and distribution. It would lead to social discomfort and disruption of norms and values. It would also affect health as the population would suffer from heat and water-related diseases.

Strategies for averting or reducing climate change induced by CO_2 and other greenhouse gases were identified and include (a) those for reducing the demand for fossil fuels especially by conserving and using alternative energy sources; (b) those which adopt technical solutions to collect and control CO_2 emissions and (c) those which involve increasing biomass production (e.g. re-afforestation of denuded areas).

It was concluded that it is necessary: to evolve and implement measures both regionally and locally; to stop the haphazard urbanisation processes; to preserve the ecological characteristics of the coastal areas and, to promote sustainable development of the coastal zone.

2.9 The Kuwait Action Plan Region (The ROPME Area)

The Kuwait Action Plan region includes a major area of enclosed shallow sea with the highest salinities, temperatures and rates of evaporation of any body of water having free contact with the wider ocean. Another part of the area is influenced by the annual reversal of wind direction with attendant consequences for current directions and upwelling.

The Regional Organization for the Protection of the Marine Environment (ROPME) can be naturally divided into three sub-regions: the southernmost area, South of Oman and Iran outside the Gulf of Oman is part of the northern Indian Ocean known as the Arabian Sea (Area I); the Gulf of Oman, a major, deep arm of the Indian Ocean (Area II); and an inner, semi-enclosed, shallow, sill-less gulf connected to Area II by the narrow strait of Hormuz, fed by freshwater from the Shatt Al Arab River and other intermittent streams from the Zagros mountains of Iran (Area III). In general these sea areas have not been adequately described, but historical data exist in national archives.

Area I lies in the monsoon belt with strong warm SW winds blowing regularly from April to October. These winds bring rain and cause upwelling. Summer air temperature is high, but the water surface temperatures are lowered by the process of upwelling. Winter air and sea surface temperatures are seasonal. The coast of Area I comprises a wide range of physio-geographic features ranging from well-developed sandy shore with a large continental shelf to rocky highlands with a narrow continental shelf.

Area II displays transitional characteristics between I and III. The depth of the water decreases from deeper than 1000m at the mouth to 100m at the strait of Hormuz. Fresh water reaches the ocean from streams rising in Oman's highland, and Iran's southern-most mountains.

Area III is a most interesting area, it is dry with the highest evaporation rates in the world. In spite of fresh water flowing into it from Shatt Al Arab and the Iranian streams, the salinity of its waters reaches a maximum for any body of water freely in contact with the ocean, higher than the Red Sea and the Mediterranean Sea. Its shallowness makes its response to atmospheric variations swift and large, and helps reduce the residence time of its water (estimated to be between 1.5 to 4.5 years). The bottom topography of Area III is asymetric, having a gentle slope (35cm/km) on the Arabian side and a relatively steep slope (175cm/km) on the Iranian side. Land relief on both sides reflects this difference, with wide flat areas in the south, west and north, and mountains in the east.

On the coasts of the ROPME Sea Area are located some of the most important cities of the ROPME countries and the coastal population is around 10 million. In the 4 most populous countries it represents 20% or less of the total population while in the other 4 it represents 95% or more. It is estimated that 6.7 million barrels of oil are extracted daily from the ROPME Sea Area.

Important fisheries exist in the region, principally where the upwelling occurs and in Area III. Open coasts and mangrove ecosystems occur where conditions are favourable from the latitude of Tarut Bay in Saudi Arabia to the southern-most coast of Oman. North of Tarut Bay, cold winter temperatures limit their growth. Coral reefs are also limited in distribution by water temperatures.

The primary effects of climate change will appear at the surface. Changes affecting water in high southern latitudes will affect bottom and deep water formations which spread slowly northwards.

A rise in the sea surface temperature (SST) of a few degrees, in the region however, will have an immediate response. While a rise in SST from 2°C to 4°C (typical temperatures in high latitudes) raises the water vapour pressure in equilibrium with the water by 1.08mb., a rise in SST from 28°C to 30°C (typical summer temperatures in Area III) raises that pressure by 4.63mb, causing a significant increase in the amount of water that evaporates. As condensing water vapour in the atmosphere is the main source of energy for the wind, storms are expected to be more frequent and more violent, especially in the summer. For Area I, this indicates a stronger upwelling, which would be tempered with the increased stability as rain and coastal runoff top the water column. Quantitative models will have to be developed in order to describe these changes.

Because of its shallowness, a permanent rise in the sea-level will also affect natural periodicity in Area III. At present, it is close to 24 hours (diurnal) and is near resonance with the tidal components. K_1 and O1. If the resonance increases to either component, this would change the tidal regime in Area III significantly and hence affect the magnitude and pattern of water exchange between Area III and Area II.

A rise in the sea-level would increase the area suitable for mangroves ecosystem development, especially on the Arabian side of Area III. If winter minimum temperatures rise, this would extend the northern limit of mangroves beyond Tarot Bay.

Coral reefs represent an important ecosystem in Area III. At one time, pearl diving on the coral reefs supported a significant fraction of the coastal population. At present coral reefs are observed to suffer in many areas of the world possibly due to warmer water temperatures. An increase in the summer temperature would adversely affect the coral reefs in the area, although milder winter conditions might balance that.

The population of the ROPME countries is increasing at a high rate, and the coastal population is increasing at an even higher rate, because of economic, recreational attractions and Government's settlement policies. These changes expose an increasing number of people to the consequences of climate change. Reasonable alternative strategies for coping with expected problems need to be investigated.

3. STATEMENT ON THE MAIN FINDINGS OF THE TASK TEAMS

3.1 Although it is difficult to predict the magnitude, significance and spatial distribution of specific climate change impacts on land-use practices, natural systems, physical processes and socio-economic activities in general it is nevertheless possible to state that there will be profound and sweeping changes.

3.2 It is clear that climate change and sea-level rise will have major effects on all countries and that the areas which are likely to be most profoundly affected are the low-lying islands and coastal zones of the world where more than 70% of the world's population currently lives.

3.3 The work of the 9 regional task teams covers 109 countries and includes contributions by approximately 200 specialists from a wide range of disciples. The results demonstrate the diversity and significance of potential impacts to all sectors of human activity, and in particular for freshwater management, agriculture, fisheries and forestry. The work further documents the impact of climate change on the structure and functioning of natural ecosystems.

3.4 Predicted changes in temperature, precipitation, radiation budgets, as well as in patterns of atmospheric and oceanic circulation will alter the spatial distribution of primary and secondary productivity in both the land and ocean environments. Such changes will result in long-term changes in resource availability and use by different societies.

3.5 The frequency, intensity, and duration of extreme meteorological events, including hurricanes, storm surges, droughts, and rain-storms, if increased as predicted by some experts, will cause additional stress on societies, reducing their food security and ability to achieve sustainable development.

3.6 The rise in sea level will inundate lowland areas, erode beaches, exacerbate flooding and increase the salinity of soils and groundwater, rivers, estuaries, lagoons and aquifers. Some of the most adverse consequences can be diminished or mitigated if society takes timely anticipatory action.

3.7 A global rise in mean sea level of up to 20 cm would not, in itself, have a significant impact except locally; however, relative changes could be as much as five times this value due to factors such as subsidence, groundwater extraction and sediment compaction.

3.8 More severe impacts can be expected if sea level rise exceeds the anticipated increase, or if the rate of the increase exceeds the capability of sensitive coastal ecosystems to respond.

3.9 In many cases the future impacts on society and the environment of non-climate factors may far exceed the direct impacts of climate related changes. In particular, the rate of population growth and human migration patterns are causes for concern. Such factors will increase the vulnerability of societies to climate related stress, and may trigger impacts of catastrophic proportions.

3.10 Environmental problems are already critical in many parts of the world, and the potential impacts of climate change will exacerbate current problems. Without prompt remedial action, such problems will increase, rendering sustainable development an unachievable goal in many countries. In addition, a failure to address these problems now will make future responses to climate change and sea level rise more difficult and in some cases impossible.

4. FUTURE STRATEGIES

Communication and information transfer

4.1 Co-ordination and cooperation between the Task Teams and the Intergovernmental Panel on Climate Change (IPCC) should be improved in order to utilise to the maximum possible extent the findings and resources, in formulating policies and management options.

4.2 Communication at the national, regional and international levels needs to be improved in order to ensure the optimum use of current expertise and information in the formulation and design of policy options to mitigate the potential adverse impacts of predicted changes.

4.3 To achieve improvements in communication, the UN system and other international agencies need to support the continued operation of Task Team activities and to ensure that the findings of their activities are presented in a usable format to all agencies and governments concerned with implementing development decisions.

4.4 The regional Task Teams have generated a considerable body of information concerning potential impacts resulting from climate change. In the immediate future there is a need to "translate" this information into a usable format and ensure its wide dissemination globally, regionally, and nationally.

4.5 The nature of climate change impacts is such that all sectors of society will be affected; it is therefore important that information is made available in an appropriate format to all sectors and levels of society, including industrialists, policy and decision makers and the general public.

Information and research priorities

4.6 Given the current inadequacies of existing data, models, and predictions concerning the potential impacts of climate change, the UN system and its specialized agencies should support continued research activities designed to address present areas of uncertainty in these predictions.

4.7 Our current ability to predict regional and local climate changes with any degree of certainty is inadequate. It is imperative that more accurate predictions of local climate and sea level changes are developed if the uncertainty concerning the magnitudes and rate of potential impacts is to be reduced.

4.8 The inadequacies of current predictions concerning impacts necessitate improved data collection and management systems, for effective national, regional and global exchange of data, and their use in model and scenario verification and environmental planning.

4.9 In order to detect predicted changes it will be necessary to establish long-term monitoring programmes. The Task Teams should identify current gaps In data and information in order that such long-term monitoring systems when established can address such problem areas.

4.10 Studies of the frequency of extreme events (temperature anomalies, high and low precipitation events, storms, storm surges and hurricanes are needed to assist in the prediction of the probability of occurrence and to detect whether or not the frequency and intensity of such events are changing in relation to mean climatic conditions.

4.11 There exists a clear need to determine the priorities for action at local, regional and global levels, based on a sound scientific assessment of vulnerability to climate change impacts and taking into consideration other sources of environmental change and degradation.

Transfer of appropriate technology; limitation strategies; and approaches to long-term environmental planning for sustainable development

4.12 Future objectives for the Task Teams should include evaluation and development of appropriate technological alternatives for mitigating expected impacts, and encouragement of the exchange of appropriate information and technologies among the developed and developing countries.

4.13 The Task Teams recognise the importance of limitation strategies in addressing global climate change issues but feel that this is outside their terms of reference and more properly falls within the purview of bodies such as the IPCC.

4.14 National institutions and agencies should be strengthened and more fully integrated into the work of the Task Teams in order to ensure that the information generated by current operational activities such as those in the fields of fisheries, agriculture and land-use management is incorporated into building models of local climate change impact. Such involvement would ensure that the planning activities of the national institutions and agencies are strengthened through the inclusion of a consideration of climate change in preparing future development plans.

4.15 The sectoral approach of government agencies is counter-productive in the sphere of environmental management since it increases compartmentalisation of skills, knowledge and data and prevents the intergradation of such data in formulating solutions to general problems and overall strategies and policies for addressing climate change impacts. Cross-sectoral communication between line departments, needs strengthening and support, at an operational level. Governments may wish to consider the advisability of setting up a specific climate change unit or committee, for coordination of activities between different line departments.

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