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THE POTENTIAL IMPACTS OF CLIMATIC CHANGE AND SEA LEVEL RISE ON THE SOUTH PACIFIC ISLANDS

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Introduction:

Following the UNEP/WMO/ICSU conference to assess the role of carbon dioxide and other so-called greenhouse gases on climatic change held in 1985 and the subsequent meetings in Villach and Bellagio, held in 1987, world attention has been focused at a number of levels on the issues of climatic change and sea level rise. Although world leaders have stressed the need for developing policy and planning guidelines to address the consequent impacts of predicted changes, the mode by which such guidelines might be developed has yet to be identified.

Several of the larger developed countries have established National agencies or committees, empowered to examine the nature of predicted impacts and assess what alternatives exist for mitigating or preventing them. In contrast, most developing countries have yet to establish such national entities and more importantly few possess the indigenous financial or manpower resources to adequately address such issues. International agencies such as the Intergovernmental Panel on Climate Change (IPCC) have through various working groups commenced evaluation of the likely implications of predicted changes for various natural systems and processes, yet the membership of IPCC and its working groups is almost exclusively confined to the developed countries of the northern hemisphere.

Recognising that certain of the least developed states, which include many of the smaller insular micro-states of the Pacific Basin, Indian Ocean and Caribbean do not have the capability to individually address policy and planning implications, the Oceans and Coastal Areas Programme Activity Centre of UNEP, in collaboration with other agencies such as the Intergovernmental Oceanographic Commission of Unesco, established, from 1986 onwards, a series of regional task teams whose brief was to examine the potential impacts of climatic change and sea level rise on terrestrial and marine ecosystems; on coastal environments and on the socio-economic structures of the countries within each region. Much of the data presented here are drawn from the work of these task teams and in particular from the reports of the Mediterranean and South Pacific Task Teams.

The Geography of the Insular States of the Pacific:

The Pacific Basin, contains a number of independent micro-states, dependencies and territories of major powers such as the United States, France, United Kingdom, Australia and New Zealand. Table 1 provides some basic geographical data for these "political entities" (hereafter referred to as "countries") and it can be seen that for most of the 25 countries on the list the land area is insignificant in global terms, being just over half a million square kilometres of which 85 percent is contained within the boundaries of Papua New Guinea.

In contrast the areas of the exclusive economic zones are considerable and for most Pacific countries land forms less than 0.001% of the area within the exclusive economic zone. An isolated atoll as small as one square kilometre and having no neighbouring islands represents an area of marine resources covering some 125,000 square kilometres. It is hardly surprising therefore that most countries of the region depend upon marine resource exploitation both for subsistence and commercial use. Many countries in Micronesia depend heavily on pelagic fish resources such as tuna, as a major source of income for development.

The islands of the Pacific Basin vary from low lying atolls at or below 4 m above sea level to high volcanic islands with steep profile. Island relief is important in terms of both coastal inundation and rainfall/run-off patterns hence the impacts of climatic change will differ in islands of differing relief.

Island types:

The islands of the Pacific may be divided into several major physical categories having different susceptibilities to changes in sea level resulting from global warming. Based on the review of protected areas in Oceania (Dahl, 1987) a relative ranking index of the physical vulnerability of different countries in relation to their land area, altitude, insularity and various other parameters was developed by Pernetta (1988), who identified four categories of susceptibility to climatic change and sea level rise. Of these categories those at highest risk were identified as countries consisting solely of atoll islands. Since different island types generally have quite different susceptibility to changes in sea level the island types are briefly described below:

Volcanic: Islands of volcanic origin, are some of the highest in the Pacific with a generally steep profile and rapid oceanic drop-off into deeper waters. Within the tropics and sub-tropical zones they are usually surrounded by fringing or barrier coral reef systems of high productivity. In general, orographic rainfall is high, as is surface run-off in the form of streams and rivers. Soils are frequently fertile and the dominant vegetation is closed canopy rainforest in areas of high annual rainfall or more open forest on drier islands.

Mixed: This class of island includes those with a volcanic core and raised sedimentary facies, usually reef limestone, together with larger islands of more complex geology such as New Caledonia and New Guinea. Altitude and profile vary both within and between islands as do soils and surface water bodies. Forest associations of differing composition dominate the natural vegetation of these islands.

Raised Coral: Such islands are composed of raised limestone of coral reef origin, soils are generally much poorer than those of the preceding types and surface freshwater is generally absent. Freshwater for drinking and agriculture is obtained from the subterranean freshwater lens. The vegetation although of forest type is more restricted in diversity and with a less complex layering of the canopy.

Atolls: Atolls are coral reefs growing on submerged volcanic cones (Guyots). When present, atoll islands are piles of bioclastic sand heaped onto the surface of the reef flat. Called cays or motu, such islands are generally no more than 4 meters above present sea level and are formed in long narrow strips either entirely enclosing a central lagoon or forming a series of small islets around its periphery. Such islands are dynamic and highly susceptible to total destruction through hurricanes; they are biotically impoverished and freshwater is confined to a small underground lens. Many such islands are currently uninhabited and they presently represent a marginal habitat for human existence.

Human Populations:

Population levels, in terms of density are high for most of the smaller states of the Pacific Basin; up to 386 people per square kilometre in Nauru (Maldives has approximately 268 people/km2, Pernetta & Sestini, 1988). The absolute numbers of people are small in global terms with some of the smallest micro-states in the world both in terms of land area and population being found in the Pacific Basin

Most island states have high population growth rates by world standards and the rate of emigration is high in the case of Pacific countries. The largest polynesian city in the world is the city of Auckland, New Zealand, whilst more Tokelauans now live in New Zealand than live in Tokelau.

Not only is the rate of out-migration high but internal migration rates are also high with the remaining populations tending to aggregate around centres of services such as Tarawa in Kiribati, Majuro in the Marshall Islands and Male in the Maldives (Connell & Roy, 1989). Eauripik Island in the Federated States of Micronesia had a population density of 950/km2 in 1980, Majuro in the Marshall islands has a density of 2,188/km2 whilst Male in the Maldives is considerably in excess of that, with 56,000 people inhabiting an island 1,700 metres in length and 700 m wide. Male has an annual population growth rate of 7 % due to births and migration compared with the countries average growth of 3.1% per annum (Pernetta & Sestini, 1989).

Out migration forms an important source of revenue through remittances and indeed many insular communities have become dependent upon the export of labour in order to maintain the local standard of living (Connell & Roy, 1989). In part high birth rates in some insular states are a social response to the perceived need for children both to support their parents at home in their old age and to emigrate overseas to remit money for subsistence (Schultz & Tenten, 1979;

Chambers, 1986 cited in Connell & Roy, 1989)

Social and economic considerations:

In cultural terms the island states of the world contain a disproportionate section of the worlds cultural and linguistic diversity. Over a third of the worlds languages are spoken in Melanesia and each island group is home to distinctive human cultures, having their own social and cultural mores, dance, dress, traditional knowledge and technologies. To preserve such ethnic diversity following migration to a larger, developed and more culturally uniform society would be difficult if not impossible. In part the cultures reflect the ecological and environmental characteristics of the island home and movement away from that environment would automatically weaken those elements of traditional culture dependent upon the native environment.

Most island societies therefore view emigration as a temporary solution to transient problems and the reaction to forced migration in response to a degrading environment and climatic change is difficult to predict. Social problems in Pacific societies resulting from forced migration albeit to other islands rather than to neighbouring developed rim countries, have been reviewed by O'Collins (1988; 1989). Emigration is likely therefore, to place severe strains on the migrant community, its host community and the resident sector of the community which resists emigration until the ultimate point of non-sustainable continuance of their community on its traditional land.

Economically most of the micro-states are viewed by western economists as non-viable at the present time, being heavily dependent upon remittances, aid and development monies for their present survival. As suggested by Connell (1989) this dependence on outside sources of financial assistance is a consequences of the western-style economic structures which developed pre-independence, and have continued into the post-independence era due to a lack of available alternative modes of development rather than through active choice and decision on the part of the Governments concerned.

Developments in health care and social services have greatly reduced the mortality rate and at the same time led to the explosive growth in populations which accentuates the current environmental problems. The Maldives for example had a population which fluctuated around 60-70,000 people from the early 1900's and possibly even earlier. Malaria control (next year will see the WHO announcement of the eradication of Malaria in the Maldives, provided no new cases are detected) and improved health care particularly in the treatment of childhood dysentery and diarrhoea lead to an explosive growth in population from the late sixties to a population of 200,000 just twenty years later.

Regrettably whilst health care has greatly improved in many island nations over the last two decades the consequent high survival of children has resulted in pressure on other social services such as education, which have been unable to cope with the exponential increase in school aged children. The consequence of this is a dramatic shortage of skilled manpower in all fields and at all levels in most island communities (For a review of scientific and technical manpower production in the Pacific, see Pernetta, 1984).

Current environmental problems:

As a consequence of past development strategies, population growth, inter-island migration and the breakdown of traditional social and cultural values, many insular societies demonstrate extremes of environmental degradation. Problems resulting from inadequate sewage disposal range from contamination of drinking water supplies, eutrophication of enclosed lagoons, and human health problems. Solid waste disposal is a problem for many islands, in particular small atolls where land for dumping is unavailable. Municipal wastes from capital cities particularly in the atoll states have caused smothering of corals in neighbouring reef areas. Solid wastes vary in size from items of plastic packaging to cars and ships, with the cars often being disposed of in the coastal marine environment simply because of the absence of alternative means of disposal. Toxic chemicals including pesticides form an environmental hazard of great importance in small islands (Mowbray, 1986) particularly when disposal is required.

Virtually all sources of land based pollution in the Pacific Island nations are imported since few states, with the exception of Papua New Guinea, Fiji, Guam and one or two others, have any internal industrial capability. Most industrial development is confined to larger, high island states and includes mining and ore processing, large scale agriculture and processing of products such as sugar and palm oil. For most small atoll based states some fish processing and drying of copra may be undertaken but by and large secondary processing with its attendant environmental problems occurs outside the countries producing the primary product.

Perhaps more significant at the present time, and of greater importance in the context of climatic changes are the environmental problems resulting from physical manipulation of fragile atoll environments, particularly in terms of stabilisation of the shorelines, and the construction of harbours, wharves, jetties, piers, groynes and other structures which modify the local current and sediment transport regimes, resulting in erosion at other points in the atoll system. In some instances major biological changes have occurred in atoll lagoons as a consequence of joining, by means of solid structures previously isolated motu to form single long islands. The gaps between the motu in atolls function as channels for interchange of lagoon and open ocean water and closing off of such channels has resulted in major environmental problems in Tarawa lagoon in Kiribati for example.

In many states increased populations have resulted in increased demand for construction materials leading to mining of lagoon sediments for construction sand, or in some instances mining the coral substrate on which the entire nation depends Although not a commmon practice in the Pacific this is widespread in the South East Asian and Indian Ocean regions. Not only do such activities cause direct environmental damage but increased turbidity may affect neighbouring coral communities and the area of impact may be quite extensive, beyond the confines of the dredging or mining area.

Many of the current pressing environmental problems of the small island states will be accentuated both by climatic change and sea level rise; and by the unrestricted growth in human populations. It is apparent that a failure to adequately manage current environmental problems will leave such island nations highly vulnerable to the predicted climatic changes and hence, any policy assistance designed to assist such states in planning for climatic change and sea level rise must take an holistic view which includes the management of current problems.

Impacts of climatic change:

Of major importance to the small island states will be any changes in regional circulation patterns which can be expected to change local climates quite dramatically. The absence of adequate regional and sub-regional climatic models which enable prediction of changes in rainfall patterns poses distinct difficulties in predicting impacts.

McGregor (1988) predicts changes in rainfall amounts in different areas of the Pacific depending upon the predominance of Southeast or Northwest season rainfall, and changes in seasonal duration. A northwards shift of the tropical convergence zone may result in changes to the surface wind patterns, oceanic currents and zones of upwelling. Changed wind patterns will impact via waves on depositional beach plan forms, resulting in increased shore-line retreat and erosion in some areas. Changes in the distribution of zones of upwelling may affect both subsistence and commercial fisheries production within the exclusive economic zones of Island States.

Frequency of cyclonic storms may increase in some areas currently just outside the hurricane belt such as the Milne Bay Province of Papua New Guinea, in Vanuatu and the Solomons for example Although there is some debate as to whether the frequency of cyclonic storms will actually increase it seems to be generally agreed that the intensity of such storms will increase under conditions of global warming.

Changes to both rainfall patterns and temperature may be expected to impact terrestrial biological and human communities through changes in evapo-transpiration rates, humidity, run-off and groundwater supplies. Although impacts will vary, increased temperature will generally increase evapo-transpiration rates thus increasing drought stress in areas of current water limitation. In areas where wilting of agricultural crops is currently a serious problem an increase in the number of wilting days per annum may be expected.

Direct impacts of climatic change on vegetation include vegetational responses to carbon dioxide directly (with potentially enhanced growth of some species); to temperature and to water balance. The latter two sources of impact can be expected to have the greatest effects on natural and anthropogenic vegetation although the impacts will vary greatly on a geographic basis dependent upon local changes in circulation patterns and rainfall.

Altitudinally delimited vegetation zones in the Pacific will rise by around 333m under scenarios of a doubled carbon dioxide level and consequent warming. The time lag for the vegetation response following temperature rise is unknown. Alpine grassland habitats will be decreased in Papua New Guinea by more than 50% and will be confined to no more than 10 isolated areas. Such habitats are not found elsewhere in the region but corresponding decreases in the vegetation formations at higher altitudes on smaller islands will occur. Lower and mid-montane rainforest from 1400-2300m altitude will experience increased human impacts due to the improved agricultural productivity which will occur in this zone.

The savannah/lowland rainforest boundary in areas of low rainfall will change towards savannah. Marginal ecotones and relict habitats will be decreased or disappear, the likely extent of this problem in the Pacific region has not yet been evaluated.

Within the Pacific region a decrease in the extent of coastal wetlands may be expected since most will be subject to sea-level rise coupled with changes in freshwater inputs. Exceptions in Papua New Guinea are the Fly, Sepik-Ramu, Vanapa and Musa basins which can be expected to become wetter hence increasing the area of inland wetlands (McGregor, 1988). This vegetational change will be a dynamic interaction between changed climate, changed erosional and geomorphological processes and sea level rise causing inundation of low altitude coastal wetlands.

All of the above effects can be expected to have major tertiary implications in terms of species loss; conservation; and changes in species composition with r-adapted species being at least initially favoured in comparison with k-adapted species.

Under warmer and drier conditions which will occur in some areas increased capillarity in limestone island soils may change the sodium calcium balance in the soil hence reducing soil fertility. In contrast under conditions of increased rainfall increased erosion might be expected in areas where land use practices are not designed to reduce soil loss.

Vertical shifts of the position of mean annual isotherms will extend the altitudinal limit of important subsistence crops. This will occur through an increase in the length of the growing season at higher altitudes; reduction in the number of days of frost; increased yield and reduced time to harvest (Hughes & Sullivan, 1988). Since the present limits to agriculture correspond to climatic limits reflecting land pressure in the highlands PNG, subsistence farmers can be expected to extend their agricultural activity to higher altitudes.

Such changes in land use may have profound impacts on human demographic patterns in the highlands of New Guinea but will have lesser impacts in other Pacific Island States where the areas of land outside the current altitudinal limits of agriculture are absent or greatly restricted in extent. Increased subsistence activity will result in reduction of the extent of upper montane forests which cannot be expected to respond with a corresponding upwards altitudinal shift as rapidly as human activity patterns.

Forest plantings of Pinus carabaea in rainshadow areas may be adversely affected by decreased rainfall, as will many commercial and subsistence crops which may require irrigation. Irrigation may be successfully increased as a response to crop wilting only in those areas where surface run-off and/or underground aquifers provide a large enough water resource. It is likely that in most areas affected by increased drought these two sources will prove inadequate for such purposes.

Changed temperature regimes apart from their direct effects on crop plants may be expected to influence agricultural production through changes in other components of the natural/agricultural system. Agricultural crops which are stressed by increased temperature and/or changed rainfall may become more susceptible to diseases particularly pathogenically caused diseases such as bacterial wilt. The generation time of pests may be changed such that more than one generation may affect a single crop generation hence the impacts may be changed. Pollination and seed set may be adversely affected in species which are pollinated by animals through changes to the natural pollinator populations.

The nature of the resource may itself be changed, winged beans for example set tubers only under certain conditions of temperature and water availability. Stock fertility (particularly males) may be adversely affected by increased temperature.

The balance between plantation and small-holder production of important cash crops may be affected, thus causing changes to national economies. Coffee in the highlands of Papua New Guinea is grown by both small and large scale producers, an upward altitudinal shift will favour increased small-holder production on somewhat steeper slopes than larger plantation production which at present is largely located on the lower valley floors. Small holder coffee is of a generally more variable quality than that produced through plantation systems.

In general epidemiological patterns can be expected to change as a consequence of changed climatic patterns. Warmer, drier conditions as predicted to occur in some areas will result in increased wind borne dust, hence an increase in respiratory inflammation/infections. The patterns of incidence of tuberculosis, other respiratory diseases and skin infections can be expected to change with increases occurring in areas of higher rainfall and humidity.

Perhaps the most dramatic change to health patterns is likely to occur through changes in the distribution patterns of vector borne diseases, in particular malaria. Altitudinal shifts in the distribution of the mosquito vector of malaria can be expected to result in chronic malarial rates occurring in the highly populated highlands of Papua New Guinea. These populations are currently at and beyond the altitudinal limit of the mosquito vector. This impact is unlikely to be important elsewhere in the Pacific since malaria is confined to Melanesia and in the Solomons and Vanuata no major centres of population are found outside the altitudinal limit of the vector.

Other regionally important vector borne diseases however, include filiariasis and dengue fever. Areas which experience increased rainfall and extended wet seasons are likely to experience extended breeding seasons for the mosquito vectors and hence increased frequency of outbreaks and cases of these diseases. Areas where such diseases are currently of low frequency are generally rather dry with distinct seasonal rainfall, such areas are unlikely to experience increased incidences of these diseases.

At higher altitudes where wood is used extensively as fuel for heating dwellings, increased temperatures may result in reduced fuel-wood use with consequent flow on effects in terms of reduced forest clearance and reduction in respiratory infections. The reduction in forest clearance if any is likely to be counter-balanced by increased clearing for subsistence agricultural production.

As measured by the relative strain index there will be a generally widespread deterioration of climate from the point of view of human comfort throughout the tropical Pacific. This will be particularly so in areas of current high humidity (McGregor, 1988). Changes to temperature and humidity affect work efficiency and whilst this may be uncontrollable in an external environment, buildings are frequently environmentally controlled. More buildings will require air conditioning and/or fans, hence increased power consumption and economic costs will result. Dramatic changes in architectural design and building materials will also be required. We can expect that workers in the primary sector will have reduced productivity, whilst workers in the service, industrial and commercial sectors will require increased environmental control if current productivity is to be maintained. Some areas within the region are currently close to the limit normally taken as that for human habitation, many of these will exceed this limit under the climatic regimes predicted (McGregor, 1988).

Impacts of sea level rise

Permanent coastal inundation can be expected to occur to a significant effect in areas of high islands where the coastal profile is flat or gently sloping. The extent and nature of land loss is estimated in a number of case studies presented in Pernetta (1988) and Pernetta and Hughes (1989) and inundation will be extremely important economically, since in the Pacific most fertile agricultural areas are at, or close to, present sea level. Loss of coastal agricultural areas will result in increased agricultural activities inland, frequently in areas of increased slope with consequent increases in erosion and soil fertility problems.

In addition many roads and most urban centres lie in close proximity to the sea increased frequency of flooding and/or inundation will cause engineering problems in terms of water supply and sewage disposal systems. Harbour and coastal constructions will need to take into account projected changes in sealevel rise and whilst the general pattern for the Pacific suggests an annual rise of between one and two millimeters planners must constantly monitor this situation, since models would suggest that this rate may increase in the near future.

There will be an overall decrease in the extent of low-lying wetlands, with a corresponding decrease in freshwater species diversity and abundance for most catchments in Melanesia. By and large the biggest estuarine/deltaic systems in the region are backed by relatively flat coastal plains. Coastal regression may be extensive in such areas resulting in reduced habitats for some species of conservation concern such as crocodiles and turtles.

Inundation of outlying islands and loss of land above the high tide mark may result in loss of exclusive economic rights over extensive areas of the marine environment.

Episodic flooding of the coastal zone may be expected to increase both in frequency and geographically as a consequence of increased cyclonic activity. Flooding can be expected to have impacts on storm water drainage and control in urban areas; and to detrimentally affect recruitment to populations of saltwater crocodiles and other species where reproductive success is largely determined by flooding of nests. Extension of the periods of inundation may render coastal areas, uninhabitable in the long-term, particularly in areas of beach ridges backed by swamp (Hughes & Bualia, 1988).

A critical question for most tropical states is the issue of coral growth rates and if one assumes that coral growth rates will keep pace with rising sea level one may also assume that existing barrier reefs will continue to provide the same level of protection to the coastline as they do at present. Should this assumption not be correct then increased wave action may result in an increase in wave generated erosion in currently protected shoreline areas.

The impact of global changes to carbon dioxide availability on the growth of symbiotic algae and hence the hermatypic, reef building corals is not known. A rise in temperature will decrease the solubility of carbon dioxide, but increase the solubility of calcium carbonate. The consequences of these two processes for symbiotic algal growth and reproduction and hence skeleton formation in hermatypic (reef-building corals) are not known. What is clear at the present time is that many species of hermatypic corals are currently growing at the upper limit of their thermal tolerance, and that any increase in lagoon water temperatures may well cause increased frequency of coral bleaching and death, with resultant changes to the community structure and growth of the coral community as a whole (Sullivan and Pernetta, 1989).

From the perspective of the atoll states, current models of sand genesis and movement within atoll systems are inadequate to describe and define the processes of motu formation and erosion. Since the bulk of the sand is derived from biological sources any changes to the growth rates of the organisms concerned will dramatically change the sand budgets of atolls and hence influence the rate of motu formation and destruction. Coral atolls and cays may be expected to decrease in size and/or be eroded entirely as a result of accelerated loss of sand to off-shore sinks.

Beach plan forms will be changed by changing wave patterns resulting from modification of regional and sub-regional wind patterns. Such changes will have important consequences for coastal marine communities of sea grasses, coral flats and algal beds and for sand budgets, particularly in the case of areas currently receiving sediment inputs through longshore drift which can be expected to generally decrease as the volume of coastal sinks increases.

In estuarine areas an inland extension of the tidal prism may be expected. In coastal plains saltwater contamination of the groundwater may have profound effects on both the suitability of areas for human occupation and upon the nature of the vegetation. A rise in sea level will cause a rise in water table particularly a vertical rise in freshwater. In the case of sand and limestone aquifers this will result in a decrease in the volume of the aquifer both for human consumption and agricultural use although the magnitude of this impact will be greatly affected by the subsurface geology (Buddemeier and Oberdorfer 1989). Loss or reduction in the volume of freshwater resources may render small atoll and limestone islands uninhabitable long before the loss of material results in land loss.

Changes in coastal vegetation following sea level rise and inundation may be dramatic in areas currently having a flat coastal plain (Pernetta & Osborne, 1988). The distribution and zonation of vegetation, in particular mangroves, will be altered in areas where the coast is currently stable. In areas where the coast is accreting and sediments being actively stabilised the rates of accretion may decrease, whilst in areas which are presently retreating the rate will increase unless increased rainfall induced erosion increases the inputs of sediment to the coastal systems. In cases of coastal retreat the zonation of vegetation will be compressed, resulting not only in an overall reduction in the extent of such transitional habitats but extensive reduction in the seaward seres, and consequent reduction in important economic off-shore resources such as prawns which are dependent upon the mangrove as nursery areas. In general both individual species abundance and species richness will decline.

<u>Common problems:</u>

The initial UNEP/ASPEI task team reports reviewing potential imapcts of global change in the Pacific Islands was presented to an Inter-Governmental Meeting in Majuro, Marshall Islands, in July 1989.

Whilst it was recognised that certain common elements or problems face all small states in addressing this issue, the full consequneces of the predicted impacts can only be addressed by site specific studies.

Current and potential problems shared by many small island states in the Pacific and elsewhere include:

1. potentially increased rates of coastal erosion and alteration of beach plan form, with increased impacts from "high waves".

2. changes to aquifer volumes with increased saline intrusion exacerbating already critical supplies for human consumption.

3. increased demand for air conditioning and hence increased energy consumption and adverse impacts of the balance of payments through increased fossil fuel importation.

4. adverse impacts on coral growth resulting from coral deaths under increased sea water temperature regimes.

5. social impacts resulting from inter-island migration resulting from changes to island stability and/or habitability.

6. loss of capital infrastructure on some of the smaller more vulnerable islands".

7. changes in reef growth and local current patterns.

8. increased vulnerability of human settlements due to their aggregation and increasing size.

9. changes to agricultural production particularly traditional atoll, taro pit cultivation.

Present human activities which may be identified as being of major importance in affecting the vulnerability of such countries include:

1. Coral and sand mining;
2. Land reclamation;
3. Construction of harbours piers, wharves, groynes, jetties and breakwaters with no prior examination of local current regimes and sand budgets.
4. Overdraw of aquifer resources.

All of these current problems are exacerbated by:

1. A lack of mechanisms within Government for taking environmental problems into consideration during the planning process;

2. A lack of guidelines and procedures for the evaluation of environmental issues;

3. A lack of an adequate in-country data base covering many physical and biological parameters; and

4. A shortage of trained manpower at all levels.

The initial review in the Pacific targeted atoll islands and states as being potentially the most vulnerable and strongly recommended that a number of unknowns in such systems be addressed as a matter of urgency. It is perhaps opportune that IOC, Unesco recently held a meeting in Bremehaven to discuss with potential funding agencies the manner in which oceanographic and marine science might address itself to the problems of providing assistance and services to developing countries. Such a re-evaluation of accepted modalities of operation is vital if a concerted global effort is to be achieved in addressing this problem.

Whilst it is clear that small islands will suffer many of the effects listed above the nature and extent of individual impacts is difficult to evaluate from a regional review of potential impacts. Site specific characteristics will undoubtedly affect the extent and severity of projected impacts not only when comparing between island nations but also when comparing between sites within such nations. It becomes important therefore for small states to "think globally and act nationally.

Recognising the site specificity of impacts and consequently the need for more geographically focused analysis of potential impacts the Inter-Governmental Meeting of South Pacific Regional Environment Programme, government representatives in July this year decided to initiate 8 major, national studies during the next biennium. These studies are to be modelled on that proposed by UNEP for the Republic of the Maldives as a joint programme of assistance in planning for climatic change and sea level rise.

The Maldive programme was formulated following a preliminary visit by two members of the UNEP task teams on climatic change from the Mediterranean and South Pacific regions, in December 1988 (Pernetta & Sestini, 1989). In October 1989 a National Workshop on environmental Management and Planning was held in Male which reviewed the current environmental problems, policies and constraints to action. The workshop drafted and adopted a National Environment Action Plan and subsequently the National Commission for the Protection of the Environment recommended the implementation of an integrated set of activities in 1990-1991 designed to address both current problems and to establish an environmental planning capability within the Ministry of Planning and Environment which will enable the predicted changes which may result from global climatic change to be incorporated into National Planning.

To achieve the aims of this ambitious programme assistance will be required from the developed countries, both from donor agencies and from the international scientific community. Given the stated concerns of world leaders concerning the possible impacts of climatic change and sealevel rise particularly in the case of small, less developed and archipelagic states it is clearly opportune for the Republic of the Maldives and His Excellenecy President Maumoon ASbdul gayoom to have convened the present meeting.

Conclusions:

In conclusion it might be suggested that the changes in assistance and cooperative programmes which will be necessitated by the need for a rapid development of policies and planning mechanisms for coping with global climatic change and sea level rise by developing country Governments may be as great and as far reaching as the predicted impacts of climatic change itself.

Many of the developing countries, particularly the small island states, are currently ill-equipped to handle their existing environmental problems. Many of the current problems will be exacerbated by the predicted impacts of global climatic change. It is therefore incumbent upon the industrial nations, which are largely responsible for the current global crisis, to assist, both financially and technically those small island states which may well suffer dramatic impacts as a consequence of a problem to which they themselves have not contributed.

Furthermore it is imperative that programmes of assistance should be individually tailored to the countries concerned and that they should be designed to enhance or establish general capabilities in the field of environmental planning and management. A failure to satisfactorily solve present environmental problems will mean that global climatic change will place the goal of sustainable development beyond the reach of small island states. Given the commonality of problems facing small states in general and archipelagic states in particular it would seem opportune for a specialised unit or agency to provide a co-ordinating unit for the provision of such assistance.

In reacting to the possible consequences of climatic change it seems clear that national capabilities in environmental management and planning need to be strengthened if this issue is to be adeqautely addressed. Given the fact that most of the small states are nett importers of carbon dioxide rather than nett exporters, and given further that whilst such states have not contributed significantly to the present crisis they will nevertheless be some of the first countries to suffer impacts and potentially some of the worst affected: it seems clear that the global community has an obligation to support research and other efforts designed to provide planning and policy alternatives for such small states.

Table 1. Various geographic parameters for Pacific Island countries

	Land Area sq Km	Sea area sq Km.	Estimated Population	Land/ Sea	Pop'n/sq Km land	No Isl.	Max. Alt. m.
American Samoa	197	390000	33200	.00000051	169	7	931
Cook Islands	241	1830000	18200	.00000013	76	8	652
Federated States of Micronesia	727	2978000	79500	.00000024	109	17	791
Fiji	18272	1290000	671712	.00001416	37	22	1323
French Polynesia	3265	5030000	166700	.00000065	51	38	2237
Guam	549	218000	107000	.00000252	195	1	393
Kiribati	690	3550000	59900	.00000019	87	14	81
Marshall Islands	171	2131000	31800	.00000008	186	10	4
Nauru	21	320000	8100	.00000007	386	1	71
New Caledonia	19103	1740000	139400	.00001098	7	11	1628
Niue	259	390000	3600	.00000066	14	1	67
Northern Mariannas	475	1823000	17600	.00000026	37	14	965
Palau (Belau)	512	629000	14800	.00000081	29	16	207
Papua New Guinea	466973	3120000	3010727	.00014967	6	22	4694
Pitcairn	45	800000	44	.00000006	1	3	304
Solomon Islands	27556	1340000	235000	.00002056	9	19	2446
Tokelau	10	290000	1600	.00000003	160	3	4
Tonga	699	700000	97400	.00000100	139	29	1125
Tuvalu	26	900000	7600	.00000003	292	2	4
Vanuatu	11880	680000	117500	.00001747	10	9	1979
Wallis & Fortuna	255	300000	12408	.00000085	49	3	762
Western Samoa	2935	120000	156400	.00002446	53	8	1857
Line Islands	10	130000	40	.00000008	4	5	8
Philip, Norfolk, Lord Howe.	53	130000	1849	.00000041	35	13	875
Sunday	29	411870	n/a	.00000007			516
Easter	166	105200	1200	.00000158	7	2	600