IMPLICATIONS OF CLIMATE CHANGE AND SEALEVEL RISE FOR SMALL ISLAND NATIONS OF THE SOUTH PACIFIC: A REGIONAL SYNTHESIS*

John E. Hay
School of Environmental and Marine Sciences
University of Auckland
Auckland
New Zealand

and

Chalapan Kaluwin
and
Neville Koop
South Pacific Environment Programme
Apia
Western Samoa

ABSTRACT

The global warming resulting from human-induced emissions of greenhouse gases is of great concern to Pacific Island nations. It may lead to sealevel rise, changing rainfall patterns, increased incidence of extreme events such as tropical cyclones, extinction of species unable to adapt to habitat and related changes, and disruption of ecosystems. Owing to their physiographic, ecological and socio-cultural characteristics, South Pacific island countries are also particularly vulnerable to the inherent variations in climate (including extreme events) and therefore to human induced climate change. Agriculture, other life-sustaining activities and tourism will be especially affected.

The potential for damage to the physical, economic and social viability of island nations is profound. Limitations of size, the narrow resource base and the high dependency on coastal areas, severely restricts their capacity to adapt to any intensification of natural disasters. The very survival of low-lying atoll nations, under worst case global change scenarios, is in doubt. Sea-level rise and increased storm activity would affect not only coastline stability but would destroy the freshwater-water lenses. Loss of groundwater-dependent subsistence cropping could render these islands uninhabitable.

Concerns over threats and a perception that climate change events are occurring with increasing frequency and intensity has a psychosocial toll even whilst the scientific debate continues as to how climate change may manifest in the region. The vulnerability of small island states is all the more poignant considering they are among those who contribute least to the process and are largely without means to influence it.

* The opions expressed in this paper are those of the authors, and not necessarily those of the organisations for whom they work.

Island societies are increasingly being driven to adopt western technologies and are critically influenced by their effects. However, their requisite knowledge and skills base is very poor. The basic western education level of the population is low and illiteracy is high. Education and training in science and technology has been generally low in priority and poor in quality. Educated individuals often relocate and there is a heavy dependency on expatriate expertise - thus knowledge is continually lost from the region.

The wide-reaching implications of climate change and sealevel rise call for improved regional coordination and integration of national and local concerns, needs and capacities. This implies enhancement of national level capacity and greater local influence over outcomes. Top down coordination and international support should be integrated with more bottom up development of policies and response strategies. Several generic adaptation policies are proposed, with an emphasis on allowing for a balance of international, national and local input to policy development.

INTRODUCTION

The focus of the findings presented here is the tropical and sub-tropical South Pacific i.e. that part of the South Pacific to the north of the area dominated by the mid-latitude westerlies. Despite the current lack of information and certainty which exists for this scale of analysis, particularly for this part of the globe, the evident vulnerability of Pacific island countries makes such a study imperative.

The intent of this paper is to synthesize the results of a series of studies of the vulnerability of climate change and sealevel rise of individual Pacific island countries, to identify the common issues and finally to suggest some appropriate follow-up actions. Given the large and inseparable interannual variability in climate and sea level that occurs in the South Pacific, vulnerability assessments typically use responses to present day variability as indicators of how systems will cope with future changes in climate. This approach is justified by the belief that a priority for Pacific island countries is to implement policies and plans that address present day variability - they will form many of the most appropriate responses to possible future changes in climate and sea level. Especially in the context of the tropical Pacific, large seasonal and interannual variations dominate both the atmospheric and marine climate signals, making it both difficult to recognize systematic changes and somewhat redundant to plan for them specifically given the significant consequences of the more immediate and possibly more substantial variations.

Assessments such as those undertaken by the Intergovernmental Panel on Climate Change (IPCC 1995a, 1995b) suggest that, for lower latitude areas of the South Pacific, systematic increases in local temperatures may not be the most important consequence of an enhanced greenhouse effect. Rather, it is also necessary to consider other climate elements, such as rainfall and wind, and extreme events such as tropical cyclones. But the naturally large interannual variability in these latter elements, and their poor regional let alone local characterization by climate models, again severely restrict the ability to make reliable estimates of changes in such variables as a result of global warming.

Pittock et al. (this issue) highlight the uncertainty in characterizing the present day climate in oceanic regions, let alone making predictions about changes as a consequence of

global warming. There are significant differences in the responses of model simulations for basic variables such as air and sea surface temperatures and for significant features such as tropical cyclones. On the other hand there is encouraging consistency in model simulations of heavy rainfall intensity. A general increase is indicated (Fowler and Hennessy, 1995). Results indicate that heavy rainfall events with a return period of at least a year will occur 2-4 times more often. In the UKMO and CSIRO9 GCMs there is an approximate 50% increase in the frequency of rainfall exceeding the $1xCO_2$ 90th percentile in the southwest Pacific (Pittock et al., this issue). The IPCC (1995a) assessment is that a general warming is expected to lead to an increase in the occurrence of extremely hot days and a decrease in the occurrence of extremely cold days. Warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places.

Knowledge is currently insufficient to say whether there will be any changes in the occurrence or geographical distribution of severe storms, e.g., tropical cyclones (IPCC, 1995a). The formation of tropical cyclones depends not only on sea surface temperatures, but also on a number of atmospheric factors including the vertical lapse rate of temperature and vertical wind shear.

The IPCC has recently confirmed that, for oceans, the most pervasive impacts of mean atmospheric temperature increases will be on water circulation, water levels, wave climate and, possibly, extreme events. Global sea level has risen by about 18 cm over the past 100 years, with a range of uncertainty of between 10 and 25 cm. As geodynamic models, measurements of vertical land movements and the length of observational record improve, this uncertainty will lessen. The "best estimate" of the IPCC is an increase in global sea level of about 50 cm from the present to 2100. But regional changes in oceanic conditions may differ from the anticipated global changes. For local and regional changes is sea level this is due, in particular, to vertical land movement and ocean current changes. Pittock et al. (this issue) presented an illustration of the differential magnitude of sealevel rise for the southwest Pacific and adjacent oceans. The values take into account thermal expansion only, and hence do not include the dynamic effects of the atmosphere, the melting of land-based glaciers or changes in the mass balance of the Greenland and Antarctic ice sheets. Vertical land movement is also ignored as are the effects of global warming prior to 1973, the start date for the model run. The results show that regional variations in sealevel rise for a doubling of CO_2 can be of order + or - 50%.

For the reasons of high interannual variability in the present climate, the uncertainty in characterizing future climate and the strong interdependence between the environment and a suite of climate variables, Basher et al. (1990) argued against considering individual climate elements. They proposed and pursued a more holistic approach based on systematic and coherent changes in circulation features and phenomena, such as El Nino-Southern Oscillation (ENSO) events, and in the frequency and intensity of extreme events, such as tropical cyclones and storm surges. The complex interactions between these features and natural and managed systems similarly requires an integrated approach. Moreover, the current dominance and anticipated significant impacts of these features also justifies an high level of attention being paid to them, now as well as into the future.

In recent years the South Pacific Regional Environment Programme (SPREP), with financial support from the United Nations Environment Programme and assistance from regional experts, has undertaken a studies of the potential impact of expected climate

change on the national environment and socio-economic structure and activities for 10 countries in the region. The first study to be undertaken and completed was that for the Republic of Kiribati (Sullivan and Gibson, 1991). This served as something of a model for the subsequent investigations, by recognizing that changes in climate and sea level are only two, and in many cases not the most urgent, of a number of environmental problems facing small island nations in the Pacific. Thus the approach adopted in the Kiribati study, and followed to a large extent in subsequent assessments, was to focus on existing and anticipated environmental problems which are likely to be exacerbated by a change in climate or an increase in sea level, or both.

The subsequent studies, listed in order of publication, were for Tuvalu (Aalbersberg and Hay, 1992), Cook Islands (Sem and Underhill, 1992), Marshall Islands (Connell and Maata, 1992), Tonga (Nunn and Wadell, 1992), Western Samoa (Chase and Veitayaki, 1992), Tokelau (McLean and d'Aubert, 1993), Federated States of Micronesia (Hay and McGregor, 1993), Palau (Sem and Underhill, 1993) and Guam (Prasad and Manner, 1994).

In addition, several other country studies have been carried out under the auspices of SPREP and other organizations. These include assessments for Kiribati (McLean, 1989), Tonga (Fifita et al., 1993), Majuro Atoll in the Marshall Islands (Holthus et al., 1992), Fiji (Nunn et al., 1993; Nunn et al., 1994a; Porter, 1994) and for Western Samoa (Kay et al., 1993; Nunn et al., 1994b). Details of the methods used and the boundary conditions assumed in the above studies may be found in the individual reports referenced above. In general, the studies for Fiji by Nunn et al. and those for Western Samoa have followed the vulnerability and resilience assessment methodology described by Kay and Hay (1993) and elaborated by Yamada et al. (1995). Fifita et al. and Holthus et al. based their studies on the Common Methodology (IPCC, 1991).

The following section synthesizes the regionally relevant findings of the preceding country studies with respect to the environmental, cultural and socio-economic problems which will be caused or exacerbated by changes in climate and/or increases in sea level. The conclusion includes broader considerations that will influence strategies and priorities for response options.

COMMON FINDINGS IN THE COUNTRY STUDIES

While each country in the South Pacific faces its own specific mix of environmental problems which will be caused or exacerbated by changes in climate or sea level, or both, it is possible to identify features that are held in common. Despite their diversity, the island nations of the South Pacific do have many common environmental concerns, as was demonstrated so forcefully at the U.N. Conference on Environment and Development (SPREP, 1992; Asian Development Bank, 1992).

Based on the findings of the country studies listed above, the following are the common themes, issues and findings relating to variations in, and changes to climate and/or sea level.

Physical Changes to the Environment

The relevant factors leading to physical changes to the coastal environment include

not only sealevel rise, but also significant variations in the characteristics of storm surges, wind velocity, nearshore currents and wave energy. Possible consequences depend on a range of factors - island size, elevation and shape; exposure to wind and waves; length of shoreline and its composition; vegetation cover and the nature of any adjacent reef and lagoon features.

Calculations of shoreline retreat for an assumed rise in sea level, while straightforward, are dependent upon coastal lowlands being mapped with an appropriate contour interval. Holthus et al. (1992) estimated shoreline retreat for 4 study areas at Majuro Atoll (Marshall Islands). Even for a 25 cm increase in sea level, the shoreline would retreat by as much as 5 m. For the four sites combined nearly 10% of the dry land area would be lost as a consequence of such a higher sea level. Additional flooding will result from wave runup and overtopping of berms, reefs or artificial protective structures as a consequence of the effects of tropical cyclones, storm surges and strong winds being superimposed on a higher sea level. Overtopping means that larger waves than present will be able to cross reefs, resulting in increased scour and sediment movement in lagoons and along shorelines. The case study for Majuro found that flooding would impact a further 30% of the land area. At one site, with a 25 cm increase in sea level, flooding frequencies would increase from the present 1 year in five to 10 times per year.

Similar studies for other Pacific island countries typically lack relevance due to assumptions of sealevel rise (e.g. 1.5 m) that were excessive given the timeframe of the assessment due or to the large contour interval on existing topographic maps forcing assessments to be unreasonably crude. For example, calculations had to be based on contour intervals of 100 ft for Viti Levu in Fiji (Nunn et al., 1994a) and 10 m and 50 ft for Upolu and Savai'i in Western Samoa (Nunn et al., 1994b).

Tropical cyclones can either add to island size by depositing lagoon sediment or ocean rubble onto land, or decrease it by eroding coastal landforms. For example, in 1972 Hurricane Bebe deposited a 19 km long bank of boulders up to 4 m high on the ocean side of Funafuti Atoll, Tuvalu. This increased the island size by about 20% (Baines and McLean, 1976). Had a second hurricane occurred before sediment was replenished offshore it is likely that the large waves would have been erosive as there would be little additional material to deposit and wave energy would not be dissipated by such sediment transport. Thus the frequency of tropical cyclones, a variable that might change with global warming, can determine whether such an extreme event will add to, or reduce, an island's land mass.

Many Pacific islands have long coastlines per unit area of land, making even small changes in the coastline of considerable significance. This is particularly so given the cultural importance of land to most island societies. The shorelines of the true atoll motu (sand islands) are especially dynamic, even in the absence of climate change. For example, since 1945 the west and northwest coasts of Betio, the western islet of South Tarawa, Kiribati, has undergone a maximum of 75-100 m of accretion while the southwest corner has receded by 40-50 m (Howorth and Radke, 1991). Should global warming bring about systematic changes in atmospheric and nearshore circulation patterns it is highly likely that atoll shorelines would become even more dynamic.

Islands with more resistant shoreline materials and higher elevations are less vulnerable to sea level rise and storm waves. As in the case of some islands in Tonga and

Vanuatu, vulnerability to sealevel rise may be lessened still further or even totally offset by tectonic uplift. Nunn (1990) used surrogate data to study sealevel changes over recent decades in coastal settlements from the Solomon to the Cook Islands. He found that many islands in Vanuatu, and Niuatopatapu in Tonga, are rising so fast - uplift rates up to 5 mm/year have been determined by Taylor et al. (1980) - that the effect of the regionally rising sea level (Wyrtki (1990) gives a figure of 1 mm/year) is being reversed. Kirch (1978) reports that Niuatopatapu has increased in area by 60% since initial settlement some 3000 years BP. Shorelines have emerged by some 12 m since the 1930s, while for the tectonically stable islands of Tonga lateral shoreline inundation has been at the rate of around 10 cm/year (Nunn, 1990), similar to that occurring in 48 tectonically-stable coastal settlements from the Solomon Islands to the Cook Islands.

Flooding of land, or at least excessive levels of soil water or salt, may result from a rising water table which is in turn a natural consequence of higher sea levels. In lowland areas, groundwater can also lead to increased surface flooding or land can become swampy and springs more prevalent should rain storms be heavier or of longer duration. On steep uplands excessive soil loss can be expected with such changes, or with modification of surface land cover and use as a consequence of changes in the climate. The resulting sediment will likely have detrimental effects on lagoon and nearshore ecosystems (Holthus, 1991). Soil can be also be degraded through a loss of moisture due to decreased precipitation or enhanced evaporation, changes that are anticipated for some other areas of the Pacific.

Under storm conditions, strong winds are capable of carrying sea salt inland for considerable distance, with detrimental impacts on natural vegetation and crops, physical infrastructure and potable water supplies.

The effect of sea level on groundwater conditions can be increased further by dredging and quarry operations increasing the coupling of the ocean and groundwater. Similarly, projects such as channel development or causeway construction may modify lagoon circulation characteristics, and hence the factors controlling water level differences between lagoon and ocean (Buddemeier, 1991).

A major issue is how coral reefs will respond to the projected rises in sea level. Their response may well be conditioned, in part, by higher ocean temperatures since above a certain temperature corals typically eject their symbiotic algae (zooxanthellae). This results in "bleaching" and possible widespread death of corals. As this response is also associated with other excessive stresses on the ecosystem, a healthy reef ecosystem is more resilient to rising sea-surface temperatures. In the past healthy reef systems have survived 1000 years or longer periods were sea level has risen by 20 mm y^{-1}. At the other extreme a reef system suffering 50% mortality resulting from high ocean temperatures was found to be eroding vertically at 6 mm y^{-1}. A "best guess" of maximum vertical coral accretion is 10 mm y^{-1}, but modal rates for shallow lagoonal reefs is 0.6 mm y^{-1}, for coral reef flats 3 mm y^{-1} and for coral thickets 7 mm y^{-1}. On the other hand a "best guess" for sealevel rise is around 4 mm y^{-1}. Thus healthy reefs may be able to adapt to sealevel rise, the response being helped by fewer exposures at low tide and by enhanced water circulation. But such responses will be severely hampered by coral bleaching, sedimentation effects, physical reef damage, feshwater inputs and human exploitation of the reefs.

Nunn and Wadell (1992) note that when Pacific reefs reached close to present sea

level some 3000-4000 years ago, they became dominated by species involved in lateral reef extension. These replaced the species which dominated during the preceding sealevel rise when reefs were growing vertically. Should sea levels rise again due to global warming, any consequential change to a species composition favouring vertical growth would likely be hampered for reef ecosystems under additional stress due to increased water temperatures.

Where reef fronts do not keep pace with sealevel rise there will be greater opportunity for storms and cyclones to damage exposed and degraded parts of lagoons, such as by burying corals and other animals in sediments and eroding shorelines. Particularly in the case of nursery areas for vertebrate and invertebrate species, destruction of these habitats could have a serious impact on the nearshore environment and resources, and hence on the lifestyles of the people who depend on them.

Creation of a storm rampart on the outer reef platform can also restrict circulation between the ocean and the lagoon. But in the absence of such extreme events, the enhanced movement of water across the reef flat may help rehabilitate lagoons by decreasing the effects of pollution, runoff and siltation.

Physical Resources

Here we emphasise the potential of climate change to impact adversely on water resources and materials availability. Considerable concern exists with respect to issues of water quality, quantity and security of supply.

Climatic factors are extremely important in determining the nature of small island surface- and ground-water supplies. The amount, frequency and intensity of rainfall, the evaporative regime and the permeability of surface and subsurface materials modify the water resources. The quantity and quality of the groundwater is further influenced by sea level and related factors. While one of the initial effects of sealevel rise may be a slight increase in groundwater resources - a consequence of the increased capacity of upper water-bearing units - in the longer term serious losses will likely occur. Two main causes are identified (Buddemeier, 1991). Catastrophic flooding due to high storm tides may not have a permanent effect, but through saltwater intrusion may well make the groundwater resource unusable at a time when other water supplies are also disrupted. The second, and more insidious effect is a consequence of island area loss, either by frequent tidal inundation of low-lying areas or by erosional loss of shoreline. Holthus et al. (1992) estimated that for a 25 cm rise in sea level the cross-sectional area of the fresh water lens on Laura (Marshall Islands) would decrease by some 10%.

The groundwater resource is already under extreme pressure in many islands. For example, on Fongafale in Tuvalu the compacting of land by road and airfield construction and increased land coverage by construction has reduced rainfall infiltration into a freshwater lens already fragile due to the narrowness of the land mass and the demands of a relative large and growing population. As a result, there is no longer significant fresh groundwater on the islet. Throughout the South Pacific rain-fed supplies of potable water are dependent on reliable precipitation, a situation that cannot be guaranteed under present conditions, let alone if climate changes. A similar situation exists for water supplies for the limited irrigation that occurs in Pacific island countries. Since interannual variability in rainfall is strongly linked to the El Nino-Southern Oscillation (ENSO) phenomenon (Hay et

al., 1993), uncertainties regarding the response of ENSO to global warming (IPCC, 1995a) give little basis for planning.

Demand for natural materials arises from four major activities - new construction, reclamation, protection and upgrading of infrastructure. Material can be removed from the lagoon, other land areas or from offshore. In all cases there are significant adverse effects on the environment, though impacts vary somewhat between source areas (Aalbersberg and Hay, 1992). In the absence of other readily accessible sources, on many atoll and reef islands material is taken from coastal sand deposits or rubble banks created by cyclonic storms. Since these formations are integral to the continuing existence of the island system their removal increases vulnerability to many of the likely manifestations of climate change.

Dredging of lagoon sediments may also prove to be unsustainable under present conditions and increase vulnerability to future changes in climate and sea level by removing sediment from the natural system. For example, dredging represents the biggest threat to benthic marine communities around the main Palauan islands of Koror and Babeldaob. In addition it threatens such historical or cultural resources as burial sites sacred platforms, fishing grounds and underwater war relics. Adverse environmental effects are not mitigated by the use of sediment screens or siltation curtains (Birkeland et al., 1990).

Living Natural Resources

Historically, living natural resources have been generally abundant throughout the South Pacific. But this is changing rapidly as population increases and as modern and non-selective methods of exploitation replace traditional ones. The modern cash economy is also a major contributing factor to diminishing resources, as is the shift of focus from community welfare to individual benefit. Thus organisms already under stress risk are likely to be further pressured by the consequences of climate change. For higher islands, living marine resources would be adversely affected by substantial increases in freshwater runoff and sediment input to lagoon and reef ecosystems. These would change salinity and light levels, as well as impair the physiology of many species. Some 90% of all indigenous and plantation trees on the Samoan island of Savai'i were defoliated during the Cyclone Val, while 40% of the indigenous and 47% of planation trees were snapped in half or uprooted.

With the high degree of endemism in terrestrial species in the South Pacific native plants, animals and birds could be further threatened by land loss, inundation, flooding, drought and salinization.

Extreme Events

Natural hazards already have a disproportionate effect on the environment, resources and population of the Pacific islands. This is especially due to there being little excess natural or human capacity to absorb the additional stresses. Therefore island nations of the Pacific are particularly vulnerable to extreme events such as tropical cyclones, earthquakes, tsunami (seismic sea waves), storm surges and volcanic activity. None of these events is predictable within a planning time frame. The IPCC (1995a) warns against overly simplistic conclusions that, since sea surface temperatures are likely to increase, so too will the occurrence of tropical cyclones. Although some models now

represent tropical storms with some realism for present day climate (e.g. Walsh and McGregor, 1995), the IPCC has concluded that the state of the science does not allow reliable predictions of future changes.

Neither do extreme events occur uniformly in time or in space. For example, the length of time between each of the last five major cyclones to affect Tokelau has decreased, viz. 1914 - 1966 - 1987 - 1990 - 1991, taking the experience beyond that of traditional knowledge and practices (McLean and d'Aubert, 1993). Tonga has experienced earthquakes of magnitude 7.5 or greater on 9 occasions this century while on the island of Niuafo'ou ten volcanic eruptions have occurred since 1853 (Nunn and Wadell, 1992).

The current inability to predict any of these extreme events which have substantial influence on human safety and wellbeing and on environmental sustainability, provides a special challenge to planning and management, as the concluding section will highlight.

Agriculture, Forestry and Food Security

The productivity of some plants is expected to increase as a result of increased carbon dioxide concentration in the atmosphere (Jacobs, 1990), but this advantage may well be offset by increased heat and water stress, factors which are already prevalent in many countries by the end of the dry season. Prolonged droughts raise the likelihood of fires which destroy protective vegetation and agricultural crops, thus increasing the incidence of soil erosion and, in turn, reducing land productivity. On the other hand, excessive rainfall can threaten the viability of certain crops.

Salt water intrusion into pulaka and taro pits has traditionally been a problem, especially during droughts, and hence could be exacerbated by global warming since higher sea levels and waves are likely to cause more salt mixing in the freshwater lens. Storm wave overwash and salt spray would also damage crops, while increases in the groundwater level and the associated increased flooding of low-lying areas would reduce other opportunities for agriculture.

The observations of Chase and Veitayaki (1992) provide some compensation to the above mentioned concerns. They describe how in Western Samoa after Cyclone Ofa (February, 1990) staple food crops were scare and vegetables were not seen in normal quantities for ten months. By way of contrast, vegetables were soon available after Cyclone Val (December, 1991). In addition, the increased availability of taro and other "storm resistant" crops show that farmers responded quickly to the first cyclone. Farmers have also changed their planting schedules to avoid cyclone damage to crops.

Chase and Veitayaki (1992) also describe how the adaptation of temperate forestry concepts to the higher temperature tropics has required the use of new tree planting and husbandry methods in order to protect seedlings and workers from the sun and from storm damage. These experiences will assist in identifying and responding to the additional changes required should global warming occur.

Very little has been done to model the complex oceanic circulation patterns in the Pacific at large, and locally. Fish is a major source of protein for many Pacific islanders. Fish take is closely related to ocean currents, zones of upwelling and the tidal patterns. For many countries storm conditions bring fishing activities to a halt, or severely reduce

catches. This again compromises food security given fish is often a major food source and cannot be stored for long time periods. Should the frequency of such weather conditions increase as a consequence of global warming this will place added burden on populations already facing protein deficiency and other food shortages. Access to imported foods can similarly be restricted by severe weather conditions limiting boat and aircraft operations.

Human Health

The vulnerability of Pacific island people to health problems is a concern as is the inadequacy of facilities for treatment. While increases in thermal discomfort and heat stress may not be as great as those based on earlier estimates of global warming, higher watertables in some circumstances are likely to cause deterioration in human health. For example, longer periods of standing water could lead to an increase in mosquitoes which in the South Pacific are vectors for dengue fever, malaria and elephantitis. The degree of contamination of surface, ground and lagoon water by human and domestic waste will also increase as the water table rises.

Aalbersberg and Hay (1992) provide further elaboration of the possible implications for human health with changed environmental conditions and the availability of food and fresh water. Higher temperatures would influence the ability to store food and medication while climate change in general has implications for healing of injuries and skin and other infections. The demand for mental health services may also be affected due to increased psychological stress resulting from anxiety and other factors. They go on to question whether the reported appearance of melanoma in the indigenous population of Tuvalu is related to improved diagnostic and reporting procedures, to environmental factors such as ozone depletion or to other as yet unrecognised causes.

Many of the dispensaries and related health care facilities in the more remote areas of the Pacific are housed in buildings which are highly vulnerable to hurricane force winds. This, and possible damage to other structures such as radio transmission equipment, would greatly impair the ability to arrange for, and provide, emergency care during adverse weather conditions. There is also the possibility that underground reticulated systems (power, telephones) will be adversely affected by rising and salt-contaminated ground water.

Commerce, Transport and Communications

In most countries there is a scarcity of raw materials and even the existing tenuous methods of supply are highly vulnerable to disruption by natural events. Many island nations have sea and air services run by single operators with limited or no reserve capacity. In-country interisland communications often make use of vulnerable high-frequency radio. Several countries are now totally reliant on satellite-based systems for international telecommunications. But to reduce the risk of damage to the antenna the usual procedure is to take it out of service and protect it when tropical cyclone or other potentially damaging conditions are forecast. This may well be the time when there is the greatest need to send messages overseas. The maintenance of transportation and communication systems is critical for human welfare.

Underground utility reticulation could be affected as water levels rise, especially if the water is saline. In Western Samoa the telephone company has begun replacing the old

pressurized cables with grease-filled cables which will function under water (including sea water) for decades.

Tourism is considered by most countries to be at least a partial remedy to depressed economies, but both operations and patronage can be impeded by adverse weather and climate conditions.

Waste Management

The disposal of solid waste and wastewater is having a serious detrimental environmental impact in most countries, thereby reducing the resilience of these systems to accommodate change. Land, land-based marine disposal and marine disposal are all implicated. The problem is exacerbated by a lack of planning and inadequate management of waste materials, including enforcement of existing regulations. Changed coastal current patterns could have the undesirable effect of preventing the anticipated dispersal of sewage from ocean outfalls. As water levels increase in-ground waste disposal facilities such as septic tanks and latrines could be affected adversely.

Physical Infrastructure

Sea walls, breakwaters, groynes, wharves, slipways, causeways are all threatened by rising sea level and increased storm waves, as are port infrastructure, coastal tourism facilities, roads and other structures built at or near sea level. Such increasing risk is, for example, one motivation for upgrading a secondary inland road that essentially parallels the main road that encircles Rarotonga in the Cook Islands.

Often infrastructure development in coastal areas involves clearance of mangroves, rendering shorelines more vulnerable to erosion and causing loss of important habitat for many marine organisms. This will in turn increase vulnerability to any further environmental changes.

Aalbersberg and Hay (1992) note that preparation of a national draft building code for Tuvalu was begun in response to the high risk of injury and damage that cyclones pose to the people and facilities of Tuvalu. In the draft no provision was made to meet the diverse impacts (e.g. rising water table and flooding) of climate change and sealevel rise on building design and construction practices. Given that an incentive for preparing the code was to mitigate the damage of cyclones, a design speed at Funafuti of 45 m s^{-1} left little margin beyond the maximum observed gust of 38 m s^{-1}.

Nunn et al. (1994a) report on an assessment of the impact of sea-level rise on port facilities in Fiji. A similar study has been completed for Apia Harbour in Western Samoa (Nunn et al., 1994b). For Suva Harbour, Fiji, the wharves themselves would be overtopped if, for example, the sea level rose by slightly more than 0.5 m and the harbour experienced winds and waves associated with a 50 year return period cyclone (Table 1). But before this there would be flooding of the hinterland and the decreased clearance between the wharf superstructure and water level would increase the uplift force and might lead to critical stress on the structure. At Lautoka Port, Fiji, the wharf would not be overtopped in a similar scenario (Table 1), though use of an adjacent breakwater might be restricted by waves overtopping that structure. The port facilities at Apia have a similar vulnerability to those in Suva (Table 1), including both overtopping and flooding of the

hinterland.

The results of Nunn et al. (1994a, 1994b) may be used to confirm the propensity for infrastructure to be located in areas vulnerable to climate change and sealevel rise. But the studies also highlight the difficulties associated with inadequate information resources to support analyses undertaken using more advanced techniques such as those found in geographic information systems. While a contour interval no greater than 0.5 m is desirable, Upolu Island in Western Samoa is mapped with a contour interval of 10 m, forcing the 0 to 10 m zone to be classed as "coastal lowland". The landuse map for Viti Levu was compiled between 1960 and 1972. Substabtial changes have occurred since then. Map scales for Viti Levu were inadequate for locating individual community buildings.

Nevertheless, some results indicative of infrastructure vulnerability are provided (Table 2). For example, while only 6% of the land area is "coastal lowland" on Upolu Island, some 70% of the churches and 60% of the school are located in this zone. This led Nunn et al. to conclude that between 60 and 70% of household infrastructure may also be located on "lowland". Similar values were found for Savai'i Island (Table 2). A preliminary estimate for Viti Levu suggests that more than 70% of the population lives at less than 100 ft above sea level.

Moves away from traditional forms of housing has increased vulnerability to thermal stress and, in some countries, increased the use of air conditioning. For example, in Pohnpei the dominant form of modern construction is solid, concrete structures, built at ground level. Such buildings are designed to be cooled by air conditioning and often have little provision for natural ventilation. As island nations develop or revise their building codes, they should encourage more climatically suitable forms of commercial, industrial and residential construction, for example by maximizing natural ventilation for cooling. Energy demands could also be reduced by limiting solar heat gain and encouraging the use of solar energy for water heating and, in remote centres, for lighting and domestic appliances.

POSSIBLE POLICY RESPONSES

The current lack of information and understanding as to the potential impacts of climate change on Pacific island countries means that it is premature for any study to be prescriptive regarding policy response options. Rather, broader facilitating and adaptive approaches are required, including those which allow for a balance of international, national and local input to policy development. With respect climate change two main categories of active reponse are recognised: mitigation and adaptation (IPCC, 1990). The remainder of this section will focus on possible adaptation responses to changes in climate. This is not an expedient reaction to the imbalance alluded to by Campbell (1993) or highlighted by Henerson-Sellers (1996). Rather, it is recognition that mitigation responses are being defined and actively promoted in other fora, notably the negotiations taking place under the United Nations Framework Convention on Climate Change.

Priority will also be given here to adaptation responses that constitute sound environmental management, wise resource use and appropriate responses to present-day climate variability, natural hazards, more subtle adverse effects and opportunities. Often such strategies are found in policies and plans for sustainable development. Thus, some adaptation responses will be beneficial even if the climate does not change as anticipated - the so called "no regrets" options (Carter et al., 1994).

A policy of enhanced regional cooperation facilitates collective responses to problems of mutual concern. Such a policy expedites activities which no single state or institution can undertake effectively in an isolated way and helps offset a weak knowledge base, any lack of understanding, poor capacity to access, share and act on information and a limited appreciation of the range of responses available for consideration.

A policy of strengthened regional coordination of activities is necessary if redundancies in effort are to be avoided. But the priority must be implementation rather than coordination and administration. Regional initiatives should not conflict with efforts to strengthen the capacity to implement policies and plans at national and community levels. As a "bottom up" strategy, the latter is more consistent with traditional approaches in the Pacific. These can be integrated with benefits that flow from international and regional initiatives.

To date the consensus view in the Pacific has been to view climate change as a imposition, forced on the region by external sources. This has resulted in an unfortunate distinction being made between responses that address possible future changes in climate and those which are concerned with the detrimental consequences of variations in the current climate. A policy of owning the issue of climate variability and change would consider the gains associated with linking these two perspectives.

A policy of maximizing any benefits of climate change in no way implies that the atmospheric pollution which leads to global warming should be condoned due to the positive consequences. It goes hand in hand with a policy to minimize the costs of climate change, through both mitigation and adaptation. The consensus view globally, and for the Pacific region, is that positive outcomes are few and are more than offset by the costs. But the acknowledged inevitability of climate change, despite uncertainty as to its nature, means that some benefits will likely accrue to regions and nations.

A policy to base plans and actions on factual understanding of climate change recognises that sometimes both views on, and the consequent responses to, climate change, have been influenced by misinformation, either deliberate or inadvertent. Any short term gains achieved in this way will be eroded once the credibility of the information and actions are called into question. Uncertainty should not be manipulated in ways which raise people's fears, cause emotional stress and force reluctant responses.

There is a need to harmonize the policies and activities which impact on environmental quality, economic development, social progress and cultural values. This goal will be achieved most readily through the adoption of sustainable management policies and practices. Under a policy of mainstreaming climate change responses in national planning, one task would be to ensure the economic mainstreaming of climate change response strategies by having them become integral components of such modalities as national development and disaster management plans and national environmental management strategies.

A policy of enhancing capacities to respond to the consequences of anticipated changes in climate reflects the lack of capacity in the Pacific region to achieve the desired goals. Shortcomings may be identified in terms of human resources (e.g. lack of individuals with appropriate training and in relevant employment; absence of well informed politicians and public), institutional structures (e.g. need for improved linkages between the public and private sectors); governance arrangements (e.g. sectoral as opposed to cross-sectoral systems); legislation (e.g. sector and media-based legislation rather than integrated); technologies (e.g. failure to retain, develop or transfer environmentally sound and sustainable technologies); infrastructure (e.g. inability to maintain coastal protection systems); intellectual property (e.g. lack of ability to develop genetic resources); and financial (absence of relevant insurance mechanisms).

Agenda 21 has identified strategies by which such shortcomings might be addressed, as have the follow-up initiatives such as the Global Conference on the Sustainable Development of Small Island Developing States. Within the overall policy, a priority must be that of developing an endogenous and sustainable capacity. Only then can the other policies be implemented in ways that are appropriate to the immediate and long term needs of the region.

Finally, a policy of enhancing regional security would recognise that national or regional security is no longer measured in terms of military strength. Other factors, including vulnerability to natural disasters, are now carrying equal if not greater weight. Water shortages, soil degradation, food shortages, air pollution and habitat destruction are all capable of fomenting social, economic and political unrest. It is not a great step to include climate change amongst these factors, either as a direct or contributing cause. Efforts to limit climate change, and or to adapt to its adverse consequences with minimum disruption, can make desirable contributions to national and well as regional security.

The policies outlined above are mutually supportive rather than conflicting or competing. As such they could well be accorded equal and high priority with respect to implementation. However, securing the capacity to implement these other policies could be accorded some overall priority. This would help ensure that the remaining policies are implemented in a favourable milieu and in a sustainable manner.

CONCLUSIONS

Vulnerability assessments have highlighted the need for more than the simplistic notion that only the low islands of the Pacific are susceptible to the adverse effects of sea level rise. The concentration of human population, economic activity and infrastructural development in the coastal areas of high islands, and the few effective opportunities for retreat in face of inundation consequent upon rising sea levels or increased frequency and magnitude of storm waves and surges, mean that vulnerabilities are very high in such cases. But few land masses in the Pacific are tectonically stable - systematic changes in sea level may be significantly offset or exacerbated by local uplift or subsidence of the land.

Climate change and accelerated sealevel rise are two of the numerous environmental concerns for island nations of the South Pacific. These issues are accorded high government priority in all countries and regionally, for it is widely recognised that they would exacerbate most other environmental problems and many social and economic issues currently facing these countries.

The fact that climate change is caused by industrialised countries soemtimes leads to the belief that the consequences will only be felt outside the region, or are being imposed locally on "innocent victims". This is compounded by feelings of powerlessness - of being inhabitants of "poor", "small", "remote", and "dependent" nations. The spatial and temporal scales of climate change and sealevel rise, and the processes involved, tend to be unfamiliar to all but a minority of well-educated Pacific islanders. For the individual, global environmental change is something caused by others and hence their responsibility. Some inhabitants link climate change and nuclear testing.

There is also the "competition" with more immediate problems - changes occurring over decades or perhaps centuries can be worried about in the future. The complex processes linking changes in the chemical composition of the atmosphere with increased temperatures and higher sea levels offer ample chance for confusion - most often between ozone depletion and global warming. Totally foreign language, concepts and analogies (a "greenhouse" being the prime example!) compound the problem. So too does the widely acknowledged scientific uncertainty associated with global warming and sea level rise, especially when this is exploited by those who seek to modify opinions and hence gain support for their own political and other agendas.

Change is also of less concern to those living in a naturally highly dynamic (variable) environment, leading to a feeling of powerlessness to modify nature. In addition, there is a prevalent attitude that the ability to cope with the devastating effects of tropical cyclones and other natural hazards is evidence of an aptitude to handle any future environmental threats. While this might have been the case in the past, many of today's natural systems have been degraded by human activity and are therefore more vulnerable to stress, be it natural or human-induced. Moreover, changes in construction materials, methods and styles have all reduced the ability to make rapid and locally sourced repairs to homes and other buildings.

Pacific islanders generally share a religious based fatalism or optimism - of either being protected by God or being punished by Him. Many adherents show no concern about sea level rise, drawing comfort from the promise that there will never be another Great Flood. McLean and d'Aubert (1993) report the eloquent comment of a village elder in Tokelau - "When there are no more rainbows I will prepare for sea level rise". Other Pacific islanders

see the direct and indirect consequences of environmental degradation of the environment as "God's will" - a punishment for improper and excessive behaviour.

Over and above these personal attitudes is the perception that global warming and rising sea levels may bring tangible benefits to the South Pacific. For this reason, the changes should not be impeded - rather, the approach should be one of adapting to the detrimental consequences and maximizing any benefits. The latter include the increased productivity of tropical food crops being grown in areas where the climate is distinctively sub-tropical and improved navigation due to increased water depth over hazards to shipping.

Attitudes to the Pacific have also resulted in a "scientific neocolonialism" - scientific and other information is collected in Pacific island countries and adjacent ocean areas, but is seldom controlled by or interpreted by local people (Hay, 1993). In addition, with the increasing moves to privatize government services and to impose user pay charges, information is becoming less accessible, just at a time when there is an expanding need and demand. However, there are some encouraging signs that the situation is improving: growing numbers of Pacific islanders are acquiring the expertise to act as specialist consultants; SPREP has a growing role as a clearing house for much needed information and as a coordinator in order to reduce duplication; and local acquisition and interpretation of data are being made integral parts of research and other international programmes.

In many instances there is a heavy reliance, even by politicians, government officials and other senior level decision makers, on media reports for basic information related to climate change and sea level rise. Furthermore, in the absence of reliable regional and national scale information, uncritical and imprudent use is commonly made of generalised scientific appraisals, impact assessments and response options that are applicable only at the global scale.

The country studies revealed that in most instances many resource materials on environmental and related themes were not readily accessible, either to the consultants or to politicians, government officials and community leaders. Bibliographic services, cataloguing, consolidation of holdings and storage of materials were often less than adequate. These findings are consistent with those of Stewart (1993), who identified several impediments to the official dissemination and use of information on climate and sea level variability that was provided to Pacific island countries by regional and international organizations.

The "neocolonialism" is also being manifest in other ways, not the least undesirable being the unwarranted duplication of effort by donor countries and agencies. For example, in the last few years five different countries have installed tide gauges in Tonga in response to the concern about rising sea levels. There is no coordination between the researchers, the data are analyzed overseas and the Tongan government has limited access to the results (Nunn and Wadell, 1992). Additionally, the work plans of many regional and national environmental programmes are influenced unduly by the priorities of external funding bodies. But these shortcomings have also been addressed, with increasing vigour, over the past few years. As noted previously, SPREP and other regional organisations are making increasing effort to reduce duplication, enhance cooperation and ensure that national priorities are reflected in bilateral, regional and international initiatives.

A fourth attribute of this "neocolonialism" is the involvement of government officials

and other Pacific islanders in international meetings concerned with global change issues. In such fora these participants typically play a reactive role, if they have an active role at all - they work to a predetermined agenda developed with little consultation with, or appreciation of, the real concerns of those from the small island nations of the Pacific. It is encouraging to note a reversal of the preceding situation as a result of the efforts of such organisations as the Alliance of Small Island States (AOSIS) and of the Governments of Vanuatu and Western Samoa working in the Bureau for the UN Framework Convention for Climate Change. They have all been effective in influencing outcomes prior to plenary sessions.

But even in fora designed to address the regional and more local issues facing small island nations, and where the voices of the inhabitants should be heard, the larger metropolitan countries often have an undue influence on the agenda and on the outcomes. In the South Pacific attitudes as to what is acceptable or unacceptable also vary, and must be understood when deciding regional policies and developing education, awareness and other programmes.

In summary, identifying and responding to the implications of climate change and sealevel rise requires improved regional coordination and integration of national and local concerns, needs and capacities. This implies enhancement of national level capacity and greater local influence over outcomes. Top down coordination and international support should be integrated with strengthened bottom up development of policies and response strategies. Local people must be mobilized to regard climate change and its consequences as their problem, placing them in charge of the remedies. This approach requires participation of nongovernmental organizations, especially religious and village organizations. There is also a need for improved awareness at political level, and at the upper levels of the religious and social hierarchies.

REFERENCES

Aalbersberg, B. and J.E. Hay, 1992: Implications of Climate Change and Sea Level Rise for Tuvalu. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 54, Apia, Western Samoa, 80pp.

Asian Development Bank, 1992: Environment and Development: A Pacific Island Perspective. Asian Development Bank, Manila, The Philippines, 334pp.

Baines, G.B.K. and R.F. McLean, 1976: Sequential studies of hurricane deposit evolution at Funafuti Atoll. Marine Geology, 21, 1-8.

Basher, R., Collen, B., Fitzharris, B., Hay. J. Mullan B. and J. Salinger, 1990. Basic Studies for South Pacific Climate Change. New Zealand Meteorological Service, 70p.

Birkeland, C.H., Richmond, H.R., Matson, E.A., Holthus, P. and N.S. Convard, 1990: Palau Coastal Resources Survey, Phase 1: Babelthaup and Koror - Selected Sites. South Pacific Regional Environment Programme, Noumea; New Caledonia.

Buddemeier, R.W., 1991: Climate and groundwater resource interactions on atolls and small islands. South Pacific Environments: Interactions with Weather and Climate, Environmental Science Occasional Paper No. 6, University of Auckland, New Zealand, 57-63.

Campbell, J., 1993: Policy development for climate change impacts. In Climate Change and Sea Level Rise in the South Pacific Region: Proceedings of the Second SPREP Meeting, J.E. Hay and C. Kaluwin (eds). South Pacific Regional Environment Programme, Apia, Western Samoa, 161-168.

Carter, T.R., Parry, M.L., Harasawa, H. and S. Nishioka, 1994: IPCC technical Guidelines for Assessing Climate Change Impacts and Adaptations. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland, 59pp.

Chase, R. and J. Veitayaki, 1992: Implications of Climate Change and Sea Level Rise for Western Samoa. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 59, Apia, Western Samoa, 44pp.

Connell, J. and M. Maata, 1992: Environmental Planning, Climate Change and Potential Sea Level Rise: Report on a Mission to the Republic of the Marshall Islands. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 55, Apia, Western Samoa, 94pp.

Fifita, N., Mimura, N. and K. Suzuki, 1993: Assessment of the vulnerability to sea level rise for the Kingdom of Tonga: Summary of the Tongan case study. Climate Change and Sea Level Rise in the South Pacific Region: Proceedings of the Second SPREP Meeting. South Pacific Regional Environment Programme, Apia, Western Samoa, 186-195.

Fowler, A. and K.J. Hennessey, 1995: Potential impacts of global warming on the frequency and magnitude of heavy precipitation. Natural Hazards 11(3), 283-303.

Hay, J.E., 1993: Climate change science: A view from the South Pacific. Climate Change and Sea Level Rise in the South Pacific Region: Proceedings of the Second SPREP Meeting. South Pacific Regional Environment Programme, Apia, Western Samoa, 17-22.

Hay, J.E. and K. McGregor, 1993: Climate Change and Sea Level Rise Issues in the Federated States of Micronesia. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 77, Apia, Western Samoa, 48pp.

Hay, J.E., J. Salinger, B. Fitzharris and R. Basher, 1993: Climatological seesaws in the Southwest Pacific. Weather and Climate, 13, 9-21.

Henderson-Sellers, A, 1996: Adaptation to climatic change: Its future role in Oceania. In Greenhouse 94 (In Press).

Holthus, P., 1991: Effects of increased sedimentation on coral reef ecosystems. Workshop on Coastal Processes in the South Pacific Island Nations, SOPAC Technical Bulletin 7, 145-154.

Holthus, P. Crawford, M., Makroro, C. and S. Sullivan, 1992: Vulnerability Assessment for Accelerated Sea Level Rise. Case Study: Majuro Atoll, Republic of the Marshall Islands. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 60, Apia, Western Samoa, 107pp.

Howorth, R. and B. Radke, 1991: Investigation of historical evidence for shoreline changes: Betio, Tarawa Atoll, Kiribati; and Fongafale, Funafuti Atoll, Tuvalu. Workshop on Coastal Processes in the South Pacific Island Nations, SOPAC Technical Bulletin 7, 91-98.

IPCC, 1990: Climate Change - The IPCC Response Strategies. Report prepared for the Intergovernmental Panel on Climate Change (IPCC) by Working Group III, Island Press, Washington, D.C., 270pp.

IPCC, 1991: Assessment of the Vulnerability of Coastal Areas to Sea Level Rise: A Common Methodology. Response Strategies Working Group, Intergovernmental Panel on Climate Change, Geneva, Switzerland, 56pp.

IPCC, 1995a: Climate Change 1995: The Science of Climate Change. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 55pp.

IPCC, 1995b: Climate Change 1995: The Second Assessment Report. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Jacobs, B.C., 1990: CO_2 climate change and crop physiology in the South Pacific. In Global Warming Related Effects on Agriculture and Human Health and Comfort in the South Pacific. Hughes, P.J. and G.R. McGregor (eds), Association of South Pacific Environmental Institutions, University of Papua New Guinea, Port

Moresby, Papua New Guinea, 1-23.

Kay, R.C. and J.E. Hay, 1993: Possible future directions for integrated coastal zone management in the Eastern Hemisphere: a discussion paper. In Eastern Hemisphere Workshop on the Vulnerability Assessment of Sea Level Rise and Coastal Zone Management, N. Mimura and R. McLean (eds). Intergovernmental Panel on Climate Change Regional Workshop, Tsukuba, Japan, 181-194.

Kay, R.C., Cole, R.G., Elisara-Laulu, F.M. and K. Yamada, 1993: Assessment of Coastal Vulnerability and Resilience to Sea-Level Rise and Climate Change. Case Study: 'Upolu Island, Western Samoa. Phase I: Concepts and Approach. South Pacific Regional Environment Programme, Environment Agency, Government of Japan and Overseas Environmental Cooperation Center, Japan, 101pp.

Kirch, P.V., 1978: The Lapitoid period in west Polynesia: excavations and survey in Niuatoputapu, Tonga. Journal of Field Archaeology, 5, 1-13.

McLean, R.F., 1989: Kiribati and Sea Level Rise. Unpublished Report to the Commonwealth Secretariat and the Government of Kiribati.

McLean, R.F. and A.M. d'Aubert, 1993: Implications of Climate Change and Sea Level Rise for Tokelau. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 61, Apia, Western Samoa, 53pp.

Nunn, P., 1990: Recent coastline changes and their implications for future changes in the Cook Islands, Fiji, Kiribati, the Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa. In Implications of Expected Climate Changes in the South Pacific Region: An Overview. Pernetta, J.C. and P.J. Hughes (eds), UNEP Regional Seas reports and Studies No. 128, United Nations Environment Programme, Nairobi, Kenya, Association of South Pacific Environmental Institutions, University of Papua New Guinea, Port Moresby, Papua New Guinea, 149-160.

Nunn. P. and E. Wadell, 1992: Implications of Climate Change and Sea Level Rise for Tokelau. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 58, Apia, Western Samoa, 39pp.

Nunn, P., Kay, R.C., Ravuvu, A.D. and K. Yamada, 1993: Assessment of Coastal Vulnerability and Resilience to Sea-Level Rise and Climate Change. Case Study: Viti Levu Island, Fiji. Phase I: Concepts and Approach. South Pacific Regional Environment Programme, Environment Agency, Government of Japan and Overseas Environmental Cooperation Center, Japan, 188pp.

Nunn, P., Aalbersberg, W., Ravuvu, A.D., Mimura, N., and K. Yamada, 1994a: Assessment of Coastal Vulnerability and Resilience to Sea-Level Rise and Climate Change. Case Study: Yasawa Islands, Fiji. Phase 2: Development of Methodology. South Pacific Regional Environment Programme, Environment Agency, Government of Japan and Overseas Environmental Cooperation Center, Japan, 118pp.

Nunn, P., Balogh, E., Ravuvu, A.D., Mimura, N., and K. Yamada, 1994b: Assessment

of Coastal Vulnerability and Resilience to Sea-Level Rise and Climate Change. Case Study: Savai'i Island, Western Samoa. Phase 2: Development of Methodology. South Pacific Regional Environment Programme, Environment Agency, Government of Japan and Overseas Environmental Cooperation Center, Japan, 109pp.

Porter, J., 1994: The Vulnerability of Fiji to Current Climate Variability and Future Climate Change. Climatic Impacts Centre, Macquarie University, North Ryde, Australia, 123pp.

Prasad, U and Manner, H., 1994: Climate Change and Sea Level Rise Issues in Guam. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 82, Apia, Western Samoa, 36pp.

Sem, G. and Y. Underhill, 1992: Implications of Climate Change and Sea Level Rise for the Cook Islands. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 57, Apia, Western Samoa, 24pp.

Sem, G. and Y. Underhill, 1993: Implications of Climate Change and Sea Level Rise for the Republic of Palau. South Pacific Regional Environment Programme, SPREP Reports and Studies Series, Apia, Western Samoa. 43pp.

SPREP, 1992: The Pacific Way. South Pacific Regional Environment Programme, Apia, Western Samoa, 52pp.

Stewart, A., 1993: Information Flow: A Pacific Islands Case Study. MSc Thesis, Environmental Science, University of Auckland, Auckland, New Zealand.

Sullivan, M. and L. Gibson, 1991: Environmental planning, climate change and potential sea level rise: report on a mission to Kiribati. South Pacific Regional Environment Programme, SPREP Reports and Studies Series No. 50, Apia, Western Samoa, 55pp.

Taylor, F.W., Isacks, B.L., Jouannic, C., Bloom, A.L. and J. Dubois, 1980: Coseismic and Quaternary vertical tectonic movements, Santo and Malekula Islands, New Hebrides island arc. Journal of Geophysical Research, 85, 5367-5381.

Walsh, K. and J.L. McGregor, 1995: January and July climate simulations over the Australian region using a limited area model. Journal of Climate, 8, 2387-2403.

Wyrtki, K., 1990: Sea level rise: the facts and the future. Pacific Science, 44, 1-16.

Yamada, K., Nunn, P.D., Mimura, N., Machida, S. and M. Yamamoto, 1995: Methodology for the assessment of vulnerability of South Pacific island countries to sea-level rise and climate change. Journal of Global Environmental Engineering, 1, 101-125.