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Coastal issues for oceanic islands: implications for human futures

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Abstract

Compared to continental areas, most islands have exceptionally long coastlines relative to their total land area. For this reason, islands are uncommonly vulnerable to problems associated with coasts. The future of the human inhabitants of many island states depends intrinsically on the sustainable management of their coasts, a challenge which grows more pressing as island populations increase and the associated demands on island coastlines change and grow. These issues are presented and discussed in this article. The mechanics of the sustainable management of island coasts is itself an important issue. At the national or local level, management is plagued by problems of insufficient and/or imprecise data and understanding that may lead to inappropriate solutions that even exacerbate the problems they are intended to solve. At an inter-governmental or international level, problems associated with the understanding of island environments need to be resolved before optimal management strategies can be developed. This article presents a brief explanation of the nature of coastal vulnerability on oceanic islands, followed by a discussion of several key problems associated with their sustainable development and the role of human and non-human factors in recent environmental change. It discusses the future of oceanic island coasts in the face of both internal and external threats to their sustainable management. It concludes with a blueprint for their survival. © *1999 Published by Elsevier Science Ltd. All rights reserved.*

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1. Introduction

While the vital role of healthy oceans in global ecosystem management may have been realised only in the last few decades, the inhabitants of islands in the middle of oceans, distant from continental shores, have been aware of the importance of ocean health to their existence for far longer. The reasons are obvious. Where continental dwellers have become accustomed to living along the coast and exploiting marine resources, they were always able to move elsewhere when those resources became depleted. In the early history of human settlement along the Pacific coast of South America, for example, periodic El Niño events impacted nearshore and marine resources so severely that people even sought out the harsh environments of the Chilean desert rather than remain along a barren coastline (Grosjean et al., 1997). Such responses would not have been available to islanders, particularly those living in remote, isolated locations.

People living on such islands understandably developed a different relationship with the coast, derived perhaps from the collectively remembered consequences of the overexploitation of its resources (Clarke, 1995), in which conservation measures intended to sustain what was perceived as the required level of resource availability, became part of traditional culture. Yet even such measures could not prevent the impacts of rapid climate changes from devastating island societies. An example is provided by the transition period, lasting perhaps only 100 years, between the Little Climatic Optimum and the Little Ice Age about AD 1300 in much of the tropical Pacific. This period was characterised by rapid cooling, rapid sea-level decline and perhaps a massive if short-lived increase in precipitation. The combination of these factors largely destroyed food resource bases on many islands, resulting in intertribal conflict in many island groups, the effects of which persisted for hundreds of years (Nunn, 1994a; 1999a). Terrestrial food resources may have been ruined by uncommonly high levels of precipitation, associated perhaps with an increased frequency, intensity and geographical range of tropical cyclones (hurricanes). Moreover, the nearshore reef-related resources on which many people depended during the Little Climatic Optimum were devastated by a sea-level fall, perhaps approaching 1 m in places (Nunn, 1998). The result would have been comparable to the situation following prolonged exposure of reefs during recent El Niño events (Yamaguchi, 1975).

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There are thus similarities between the modern condition of coastal and nearshore waters around oceanic islands and those of at least the last millennium which bear closer scrutiny. In both instances, humans contributed to degradation of these areas but, as will be argued below, there are non-human factors that have both driven and exacerbated the situation at certain times. Just as the successful understanding of past changes requires an appreciation of both human and non-human factors, so successful management of the modern resource base requires an understanding of both sets of factors.

2. Background to understanding oceanic island environments

Oceanic islands—those which occur in the middle of oceans (Nunn, 1994b)—are manifestly different places from continents. These islands, however, have for decades been managed largely by people trained in continental areas in ways that commonly fail to acknowledge important differences between the two environments. The outcomes of this fallacy are recognised, perhaps most tortuously in the fields of biogeography (Roots, 1976), but it is important also to understand its effects in the field of ocean and coastal management.

Of particular importance is the idea which many colonial administrators brought to their insular charges that the ocean was a boundless resource and that it mattered little were it used as a refuse dump, were it polluted or were coastal ecosystems radically altered to accommodate human demands. In more recent times, since most island nations achieved independence, such attitudes have been propagated in places both by in-country planners and through the pathway of development aid. Many planners are aware of the environmental consequences of ill-conceived coastal and nearshore management, but as they have few options, they bend to the will of their political leaders, whose principal objective may be to achieve development targets at any cost.

Gross generalisations about the nature of island environments give the impression that islands are merely small continents that require scaled-down continental solutions. Yet the sustainable management of island environments "demande en particulier qu'on ne les traite pas comme des milieux continentaux de faible taille; toute catastrophe y a des effets irrevérsibles"[1] (Doumenge, 1987: p. 15).

Perhaps the clearest demonstration of how islands differ from continents, particularly their relationship with the ocean, is to consider the much greater ratio of coastline to total land area on an island. It is no wonder that "coastal impacts" is merely another category of environmental impact to continental dwellers, whereas to islanders it may be everything. Many island nations have found that, in international environmental fora, continental nations appear to be downplaying or even ignoring the concerns of their island counterparts. This may be the result of ignorance concerning both the nature of island environments, and the overwhelming importance of the ocean to island peoples.

The lack of understanding of the variability of island environments is widespread, particularly at the level of global planning for climate change and sea-level rise, largely because of the unthinking marginalisation of discussion of island environments in geographical textbooks in the last hundred years or so (Nunn, 1994b). Part of the problem is also that no oceanic islands are sufficiently large to register on the grid of current General Circulation Models; estimates of what might happen in the future are therefore imprecise and sometimes contradictory. It has to be said that the problem is also significantly compounded by the use of pejorative adjectives such as 'small' in reference to many islands and island nations. This diminishes both the seriousness with which environmental issues on oceanic islands are regarded in international fora, and, therefore, the external assistance provided to island states.

3. Approaches to understanding the vulnerability of oceanic island coasts

Most oceanic islands are located in low latitudes. Many of their coasts are fringed with coral reefs enclosing shallow lagoons, often (once) lined with mangrove forests. On most such islands the nature of the coastal landforms is controlled largely by modern and historical wave regimes, including the recurrence of storm surges or tsunami. Most such islands experience little intra-annual temperature variation, allowing geomorphological equilibrium to be achieved more rapidly than elsewhere.

The first major cause of variability (and thus of vulnerability) among low-latitude oceanic islands is linked to their size and physiography. Large, high islands frequently generate enough terrestrial sediment for this to be the dominant control of shoreline and nearshore sedimentation. Smaller, low islands may consist entirely of marine sediments and are especially sensitive to changes in their supply or to wave regime variations.

A second major cause of variability relates to island history: what might be called the antecedent state of the environment when considering vulnerability to future climate change and sea-level rise. Most island coasts have experienced submergence over the last hundred years. This is primarily a result of sea-level rise, but it is also in certain places exacerbated by subsidence. A few island coasts are rising, some rising faster than the sea level, leading to a situation where they have emerged relative to the ocean surface over this time period (Nunn, 1997).

Some island coasts are subject to major non-human

[1] "...requires particularly that one does not treat them simply as continental environments on a small scale; a disaster here may have irreversible consequences".

Fig. 1. On high volcanic Tutuila Island, American Samoa, the narrow coastal plain is the only place for communication lines and for most buildings to be located [Photo: P. Nunn].

causes of stress. Those coasts that are regularly affected by storm surges associated with tropical cyclones (hurricanes or typhoons), for instance, are almost certainly at the present time less stable than island coasts which are not so affected. This is particularly the case in the Pacific on account of the recent increase in the frequency of tropical cyclones (Nunn, 1994b). Owing to their locations, certain island coasts may have been impacted more profoundly than others during El Niño events, when sea-surface temperatures generally rise higher than normal and when the ocean surface may be alternately higher and lower than normal for prolonged periods.

Yet the main cause of the variability in the vulnerability of oceanic islands results from the variable degree to which humans have both modified and come to depend on their coastal environments. Since the major portion of island populations live along the coasts, most island economies depend almost exclusively on activities in or close to coastal areas. The interior parts of large, high islands are neither suitable to sustain the majority of their inhabitants nor—for a variety of reasons including land ownership—are they readily accessible to groups of inhabitants who might be displaced from coastal areas.

Owing to the comparatively high economic value attached to island coasts, most infrastructural development is located there. Thus vulnerability can be considered under the headings of both potential vulnerability to future climate change and sea-level rise and the vulnerability of investments in infrastructure and other developments. Two examples are helpful. Firstly, the physiography of many islands renders the coastline the only place to construct roads, so any impacts on such coasts directly threaten communications; this is an issue for an entire island not just its coast (see Fig. 1). Secondly, many islands are increasingly earning foreign exchange through tourism, and it is the coastline that is the major drawing card for most tourists. Threats to the coastline may thus impinge directly on the development of the tourism sector in many countries and, if they materialise, may have an overall negative effect on established tourist industries.

When we consider future vulnerability of oceanic island coasts, it is important to consider not only the human impacts but also the cultural value attached to particular parts of coasts by humans. This underscores the point that vulnerability is not easily quantified in monetary terms, especially in cultures where the cash economy is not as dominant as it is in many other countries. People value particular stretches of the coast because of their historical associations, or because they have rights over them, and such values must be incorporated into schemes for the assessment of vulnerability in such places (Yamada et al., 1995).

4. Problems of sustainable development along oceanic island coasts

The greatest challenge facing land managers on oceanic islands today is trying to accommodate the increasing and changing demands of growing populations for a pool of resources which, on many islands, is already under stress.

4.1. Changing demands on island coasts

On most oceanic islands, even the most distant or highest point of land is close to the sea, and activities anywhere generally have significant effects on their coastal environments; "the condition of coastal areas indicates the environmental health of an island; generally, if coastal management is deficient, the entire island is environmentally poor" (Thistlethwait and Votaw, 1992: p. 181).

Rapidly growing urban populations along island coasts are responsible for much of the degradation of coastal resources, particularly mangroves and beach areas, pollution of lagoons and harbours and fouling of coastal areas, especially seagrass beds and coral reefs. Many of these problems result from increased sediment input to coastal areas from construction, changes to land use, coastal development activities, and the careless disposal of sewage and other domestic and industrial wastes.

Rapid population growth is of particular concern on islands that lack the carrying capacity to support it (Thistlethwait and Votaw, 1992). The amount of available arable land per person is commonly small and many islanders are coming to depend on imported foodstuffs. Population growth in urban areas is high because of in-migration, high birth rates and low death rates; good examples are provided by Tarawa and Majuro in the Micronesian islands (Bryant, 1993).

In some island cities, population increase is so rapid that the associated demand for urban facilities and services cannot be met. Furthermore, on many islands, informal and unplanned peri-urban development is also becoming increasingly evident, further increasing the pressure on coasts. For example, squatter settlements near Honiara in Solomon Islands have overrun the country's only national park, negating its intended conservation goals. In Nuku'alofa, the capital of Tonga, and in Suva, the capital of Fiji, squatter settlements have developed in cleared mangrove forests along the coasts (Bryant, 1993; Nunn and Waddell, 1992). Unsanitary conditions and health problems related to overcrowding and improper disposal of water and excessive use of coastal areas contribute to the degradation of reefs and lagoons in these places and elsewhere (Bryant, 1993).

Other problems specifically related to pollution of freshwater resources and tourism, are dealt with by other authors in this issue: Falkland on freshwater resources and Pantin on tourism. In addition, mining has had a further negative impact on island coastal areas. In New Caledonia, for example, the extensive erosion and sediment transport in watersheds affected by opencast nickel mines and associated infrastructural works has been well documented. Specifically "the effect on coastal systems has been the input of large amounts of often coarse grained materials, changing the extent and composition of the shoreline. Deltas and mangrove forests have been extended and low-lying muddy areas replaced by gravel beaches" (Brodie, 1990: p. 18).

Often because of population and development pressure on oceanic islands, shorefront reclamation is required. This encroaches on the dynamic coastal area that was part of an active beach system. Therefore erosion is often still experienced after reclamation. Erosion is also prevalent in areas where causeways are constructed between islands: "...causeways cross and often close-off the channels which extend from ocean reef to lagoon areas and block the natural current and sediment transport through the channel" (Sherwood and Howorth, 1996: p. 18). For example in Tarawa, Kiribati, there has been both erosion and changes to the shoreline as a result of causeway construction (Byrne, 1991).

4.2. The state of inshore fisheries

Within the last 30 years, increasing population pressures and consequent pollution of sensitive coastal environments, increases in tourism and coastal developments, the utilisation of new technology, greater pressures on the traditional fishery of reef and lagoons, and dwindling resources have led to an unprecedented expansion of all aspects of the inshore fishery on many oceanic islands. In spite of the emphasis on sustainable development in the policies of most of these islands, the management of inshore fishery resources is constrained by several factors. These factors are dealt with extensively by Anne Platt McGinn in her review on fisheries in the *Natural Resources Forum*'s Special Issue on Oceans (May, 1999).

5. Human versus non-human impacts

One of the major issues which continues to hinder understanding of many island environments is a lack of knowledge concerning the relative contributions of human and non-human impact to observed environmental change. The history of the study of many oceanic island environments, particularly the nature of environmental change, has been adversely affected both by the inappropriate backgrounds of most investigators and by the ignorance (compared to many continental areas) surrounding the way in which such environments are constituted and how they respond to extraneous causes of change (Lasaqa, 1973; Cox and Elmqvist, 1997; Nunn, 1999b). Much 20th century writing about island environments has emphasised human impacts to the almost total exclusion of non-human impacts, leading to a situation where most island planners and most consultants employed to advise them, highlight the former. A popular view, without any empirical support, is that island environments would return to a steady-state were all deleterious human impacts either stopped or reversed. Given that premise, it is no surprise that many such people perceive the looming threat of climate change and sea-level rise as something novel when in fact it is of a kind which has been faced by people on many occasions since they first inhabited most oceanic island groups (Nunn, 1994a; 1997; 1999a).

5.1. Non-human impacts

The first, most widespread group of recent non-human impacts to be considered is that associated with temperature rise over at least the past hundred years. The evidence for this on oceanic islands is not widespread, owing to a paucity of long-term continuously monitored records, yet sufficient

to demonstrate that it is similar to the more numerous records from continental areas. The statistically significant rise of 0.5°C at the Government House in Suva, Fiji between 1887 and 1986 is representative of records from low-latitude oceanic islands (Nunn, 1990).

It is probable that this temperature rise has been one of the main causes of the increase in frequency of tropical cyclones experienced, at least in the Pacific, over the last 50 years or so (Holland et al., 1988). The effect of this increased frequency of tropical cyclones in growing landscape instability has been profound and often mistaken for a purely human impact (Nunn, 1990; 1997).

The most talked-about result of 20th-century temperature rise for oceanic islands has been sea-level rise. It is estimated that sea levels have been rising in most low- and mid-latitude parts of the oceans (independently of tectonic changes) at an average of around 1–1.5 mm/year for the last 100 years (Wyrtki, 1990; Nunn, 1997). The effects of this have been experienced along many oceanic island coasts as inundation, shoreline erosion, and groundwater salinization among other things. Many of these effects have been misinterpreted and ascribed to local human impact.

5.2. *Human impacts*

Human impacts on island coasts have generally been more diverse than non-human impacts. Particularly within the past few decades on many islands (and elsewhere), the increasing diversity of human impacts has led to situations where the exact source(s) of an undesirable effect, such as inshore pollution, is identified only in the most dire circumstances (Carpenter and Maragos, 1989). Human impacts are not only diverse, but also more variable in both space and time than non-human impacts; many island coasts are highly 'developed'; others hardly at all.

Given both the greater diversity and greater variability of human impacts, it is more difficult to generalise about their effects on island coasts. It is convenient to classify human impacts as those derived from the land (terrestrial), those derived from the sea (oceanic) and those derived from within (in situ).

The principal terrestrial human impacts on island coasts result from human-induced changes to island interiors. One of these is reduction in land cover, particularly resulting from forest clearance for agriculture on steep lands, which increases water and sediment transport into coastal areas; agriculture may also introduce pollutants such as pesticides and fertilisers. This group of impacts also includes mining, the consequences of which have been dire for many oceanic island coasts (see Brown, 1974; Dupon, 1986).

One of the most widespread human-caused oceanic impacts derives from the dumping of pollutants offshore, including mining wastes—particularly those associated with offshore mining—and effluents from ocean-going vessels. Fears have been raised that radioactive spillage from waste-carrying vessels could enter the oceans and impact island coasts.

Perhaps the most diverse and variable human impacts on island coasts are those that occur in situ. These include land-cover changes, commonly around tropical islands, such as removal of fringing mangrove forests and the conversion of shoreline vegetation to types less suitable to withstand environmental stress. Also of note are physical changes to the shoreline, including beach removal as a result of sand mining or the ill-advised construction of artificial structures, the creation of boat channels, harbours and marinas. Other changes include land reclamation, and construction of barriers to the movement of water and sediment, an impact particularly well illustrated by the construction of causeways linking islands on atolls (Carpenter and Maragos, 1989; Byrne, 1991). Impacts on reefs by human activities are also included in this category. The overexploitation of reef food resources may also result in physical damage to reefs, a process exacerbated by tourism, reef-rock mining, dynamiting to maximise fish catches, and many other factors.

6. Future threats

Much of present practice of human interaction with oceanic island coasts is unsustainable in the long term. Unless appropriate management strategies are enforced, it is likely that the potential value of coastal resources to human society will fall significantly, and that this will threaten the survival of the inhabitants on some islands. This section attempts to predict the nature of the main types of threat that will arise in the next hundred years or so.

In the Pacific Islands, the national reports prepared for the United Nations Conference on Environment and Development provide a summary of environmental issues that pose the greatest threats to the islands. All oceanic islands expressed concern over the loss of biodiversity, pollution of reefs, lagoons and coastal areas, management of solid wastes in urban areas, and disposal of sewage in urban and industrial areas (Thistlethwait and Votaw, 1992). All of these concerns relate directly to the growing concentration of population and activities in urban and coastal areas. A state of the environment report prepared in 1982 (10 years prior to UNCED) for the Conference on Human Development in the South Pacific held in Rarotonga also indicated the major concerns as population pressure and urbanisation. Increased population pressure has also led to the increase in coastal reclamation activities including destruction of mangrove ecosystems. The Regional UNCED report states, "The concern among Pacific Islanders for pollution of reefs and lagoons remains high despite 10 years of exhortation by many people on the need to protect these vital resources" (Thistlethwait and Votaw, 1992: p. 205).

Following the Earth Summit in 1992 and the Conference on Small Island States in Barbados in 1994, many oceanic

island nations are writing and/or implementing national action plans for the development and management of environments including coastal areas.

To meet the increasing needs and changing aspirations of the growing population on many islands, employment opportunities must be created. Economic development focuses increasingly on the direct and indirect exploitation of natural resources such as fisheries, coral reefs and mangrove areas, beaches and some upland activities such as agriculture, forestry and mining. The oceanic islands are also part of the global economy and thus subject to external pressures such as fluctuating demand and increased competition. In many of the smaller islands, local capital is not easily forthcoming. Many commercial activities are foreign owned.

While a need for sustainable coastal management is recognised on many islands, trends indicate continued degradation of the environment. The need for the necessary capacity in terms of expertise and technical skills, financial resources, and an institutional and legal framework is important. Possibilities for such capacity building exist through local, regional and international cooperation.

Inshore fisheries are discussed below as an example of continued unsustainable human development on island coasts. The principal non-human effects to be considered in the future are climate change and sea-level rise, each of which is discussed separately below.

6.1. The future of inshore fisheries

Inshore fisheries are amongst the most productive and, as the closest and most accessible to island coasts, the most threatened by pollution and overexploitation. Intensive fishing efforts associated with population increase, and increasingly efficacious fishing techniques are inevitably going to lead to the depletion of fishery resources in these areas. Yet most island coastal communities have still to be convinced of the need to protect the capacity of the ecosystem to cleanse and repair itself while simultaneously supporting varying fishing activities. This task will be difficult because of national emphasis on fisheries development, which encourages people to invest in equipment, allowing them to maximise short-term profits without regard to long-term sustainability.

Fishery development projects are part of the economic development initiatives being undertaken in many oceanic island countries. Often externally funded, these projects need to be better formulated and implemented to benefit the people involved while protecting the resources and the integrity of the environment. Concerted efforts should be made to address the problems associated with the failure of such projects in the past. The main problems continue to be: (1) lack of consultation with the project beneficiaries; (2) poor project planning and implementation; (3) lack of environmental protection; (4) inadequate human resource development and institution-building components; (5) lack of integration with other development activities; (6) inappropriate technology; (7) lack of capital; (8) poor information; and (8) undue political interference (Lawson, 1980; Carleton, 1983; Johannes, 1989; Liew, 1990; Dolman, 1990; Munro and Fakahau, 1993a,b; Kane et al., 1996). Further, rather than being regarded as generic entities, fishery projects should be carefully tailored to the specific conditions of each particular location.

The need for reliable scientific information cannot be overemphasised. Although scientific information today is better than it ever was, it is still barely adequate to allow people on many oceanic islands to manage their fisheries. In the South Pacific, scarcely anything is known about biodiversity of the reefs and other inshore ecosystems, so we are in a sense rushing to preserve the unknown (South, 1993; Veitayaki and South, 1997). The need for scientific information is complicated by the changing nature of scientific investigations. Coastal environments around many oceanic islands are changing rapidly as a result of socio-economic development, which places greater stress than ever before on their ecosystems. It is common for scientific advisers to fail to recognise sufficiently the limits of their approaches, to underestimate the impact of uncertainty, to underuse social and economic sciences, and to implement solutions which are routinely overtaken by technological developments (Garcia et al., 1997).

It is also important that traditional systems of successful resource management available in particular places should be put to good use wherever feasible. Resource management is about people and how they relate to their resources, and it should therefore employ methods that are acceptable to people, even where they have no demonstrated scientific basis. In societies where good environmental practices cannot be effectively enforced by outsiders, the critical thing to remember is that environmental management must be acceptable to local inhabitants. Unfortunately there has been only slight acknowledgement of such systems in terms of practical and appropriate resource management models for island coasts (Veitayaki, 1998).

The FAO Code of Conduct for Responsible Fishing (Food and Agriculture Organisation, 1997) should be adopted by all coastal communities, allowing for local adaptation to improve efficiency. The Code should be widely promoted in schools and communities, and local fishing groups should be encouraged to work with the government on the formulation, implementation and enforcement of associated management practices. It is vital that an integrated and participatory approach be undertaken to ensure the successful implementation of appropriate management initiatives (Garcia et al., 1997). This approach should alleviate the great expense and frustration associated with fisheries management in many inshore areas of oceanic islands, and should address the overriding issue of sustainable resource management and development.

6.2. Climate change

Since this paper focuses on coasts, sea-level rise is the major non-human future threat to consider. Yet, were we considering island environments as a whole, it would be clear that other aspects of future climate change would merit similar attention. Certain of these other aspects need brief mention at this point. It is likely that changes in temperature on many oceanic islands over the next hundred years will see changes in land use occurring independently of human actions as a result of increased stress on existing ecosystems. Also future changes in precipitation patterns could have potentially very profound effects which, like land-use changes, may result in changing stream loads and sediment supply to island coasts.

It is unclear how tropical-cyclone frequency may change in response to an even warmer world in the future. It seems unlikely that it could increase much above its present level in the cyclone belt in the western Pacific. Yet it is possible that tropical cyclones of increased intensity may develop (Emanuel, 1987), and also that tropical cyclones will develop increasingly outside what is generally regarded as the 'cyclone season' in many island groups. The impact of such changes will be to increase the instability of many island coasts, thereby reducing their capacity to respond appropriately to future sea-level rise.

6.3. Sea-level rise

It is unfortunate that 'sea-level rise' has come to be regarded by many people, ranging from decision-makers in international environmental agencies to educated people in many countries, as *the* problem for oceanic island nations. There are many other problems associated with future climate change which island governments ignore at their peril.

Yet, because their coastlines are so long compared to their total land area, oceanic island (particularly archipelagic) nations are clearly at greatest threat from problems like sea level rise that will affect coastlines more than any other areas. The main effects of sea-level rise will be reef overtopping, increased shoreline erosion (especially along sandy shores), inundation of low-lying coastal areas, and increased salinization of groundwater.

It seems *unlikely*, despite optimistic predictions to the contrary, that many oceanic island reefs will be able to grow upwards in the next 50–100 years at the same rate as sea level is expected to rise (15–95 cm by 2100). The consequence will be—at least in the short term—that for many tropical islands larger waves will be able to reach the shorelines than at present, an analogous situation to that during the middle Holocene era (Hopley, 1984; Nunn, 1994b). Now, as then, this will exacerbate shoreline erosion, particularly during storm surges.

Another cause of increased shoreline erosion will be the rise in mean sea level which, largely along sandy shorelines, produces erosion (Bruun, 1962). This is believed to be a major cause of recent shoreline erosion around many islands, and is likely to become worse in the future (Mimura and Nunn, 1998). Yet there are many other reasons for shoreline erosion along island coasts, most linked to human impact. Clearance of mangroves has been a major cause of erosion, as has been the mining of beach sand that has proved difficult to regulate effectively on many islands (Tappin and Sallenger, 1991; Mimura and Pelesikoti, 1997).

There have been numerous attempts to quantify both the areas and the economic impacts of various scenarios of future sea-level rise on island coasts. Yet because survey data are generally rather crude, it has been difficult to develop precise predictions, particularly those incorporating changes in wave run-up, and amplitude as a result of reef overtopping. What is manifestly clear is that many coastal communities on oceanic islands are already feeling the effects of inundation associated with recent sea-level rise; examples include the Caribbean islands (Granger, 1997), Mauritius (Ragoonaden, 1997) and a variety of Pacific Islands (Aalbersberg and Hay, 1992; Gillie, 1997; Mimura and Nunn, 1998; Nunn, 1990).

The effects of groundwater salinization are potentially profound but as yet few quantitative data are available in support of widespread observations that salinization associated with sea-level rise is already having an effect on coastal vegetation, particularly commercial crops (Nunn et al., 1996).

7. Future prospects

It is difficult to anticipate the outcome of present initiatives related to coastal zone management around oceanic islands. This section highlights several key areas of uncertainty, and outlines the likely developments in each over the next few decades.

7.1. Political and economic issues

In their present political and economic conditions, many island nations are locked into unsustainable development trends in many areas. While many fine words are spoken about the imperative for environmental conservation, the reality is often quite different, and likely to remain so in the immediate future. The problem is not so much insincerity—many politicians and government decision-makers earnestly seek to implement sustainable environmental practices—nor is the problem necessarily one of inability to formulate appropriate laws and guidelines. The problem is mainly one of the inability of island governments at all levels to enforce these.

The problem of enforcement relates to both personnel and to geography. Most island governments have insufficient numbers of trained people to police environmental practices effectively. For this reason most island governments are now seeking to raise environmental awareness through

education, in the hope that this will eventually obviate the need for enforcement. This is not an exclusively insular difficulty, although geography is. In island nations, particularly those that are truly archipelagic (rather than just one or two main islands), the difficulties involved in monitoring, let alone policing, environmental practices are overwhelming. Transport between islands is commonly irregular and infrequent, and transport within islands, particularly those peripheral to the main centres of development, is customarily on foot. Owing to its great length, the coastal zone in such nations is generally the most difficult to monitor at a nation-wide level, and few governments attempt to do so. It is possible that remote sensing methods of monitoring coastal activities will become more common in the future, although the cost of these methods will be prohibitive for many island countries.

In relying on education to attain sustainable development of island coasts, much emphasis is being placed on ways in which coasts were traditionally managed. Appeals to local people to acknowledge the customs of their ancestors in managing their coasts may have some success, but the overwhelming problem is that demands on coastal areas have changed so much that traditional management alone will not satisfy these demands. What are needed are subtle mixes of traditional and modern practices which go some way towards satisfying typically both subsistence and commercial demands on coasts.

Such suggestions are workable, yet, when viewed within the context of social change in island nations, may prove unrealistic. In many places, traditional conservatory practices succeeded because they emanated from tightly-knit societies whose members all had similar aspirations. Although such societies still exist in many island groups, some have broken down and still more are under threat from external market forces. If the fabric of traditional island societies crumbles, then appeals to traditional practice may be doomed to fail, and the only option for many island nations seeking to manage their coasts sustainably may be increased enforcement of environmental laws, similar to the situation which prevails in larger, less traditional, continental countries.

An excellent example of the new demands being placed on island coasts, and the need to mesh traditional and modern resource-management techniques is provided by tourism, discussed in the following section.

7.2. *Tourism*

Since tourism is a key economic activity on many tropical oceanic islands, strategies for sustainable tourism and protection and enhancement of the coastal environment on which the tourism industry largely depends are vital. Long-term planning of tourism activities and demands on resources could produce effective management. Planning can also minimise inter-sectoral and cross-sectoral conflicts and help toward harmonisation of policies on land use in coastal areas. Plans should incorporate environmental guidelines such as measures for control of effluents and waste disposal, and should exclude development in geologically unstable zones. Plans can also take into account the carrying capacity of the environment by having standards and development controls such as building codes that take into consideration environmental characteristics. For example, the type of buildings, their location, height and density and site characteristics should all be included in the building code.

Legislative and regulatory measures such as zoning of land use and EIA legislation are also critical, together with effective enforcement. Other institutional measures can also be considered, such as better coordination of agencies dealing with the tourism industry, to reduce grey areas of tourism issues. It is critical to provide training in environmental management tools such as EIAs, planning tools such as carrying capacity estimates and economic tools such as natural resource accounting.

It is also important to enhance the understanding of local non-governmental organisations (NGOs) and communities concerning coastal dynamics. Water pollution through sewage, household and industrial wastes and agricultural runoff should be monitored and assessed for runoff to coastal areas, and measures should be taken to remove pollutants through appropriate treatment.

Locations of landfills along island coasts should be selected carefully in view of the risk of water pollution. On small oceanic islands, controlled burning in incinerators is useful where land is scarce. For example in the Maldives, incinerators are used as a means of disposal on resort islands (ESCAP, 1995).

7.3. *Technology transfer*

Problems of sustainable coastal management are not all one-way traffic. While most island governments have opted for bottom–up resource-management strategies, many island communities desperately need advice about solutions to coastal environmental problems. Although many governments (and inter-government bodies) may have access to advice, it is not effectively trickling down to where it is needed.

The best example relates to the construction of artificial shoreline-protection structures, many of which are unsuitable and exacerbate the problems they are intended to solve (Mimura and Nunn, 1998). This problem is less difficult to solve than some of the others raised. What is needed is clear advice, written perhaps in vernacular languages, about the best type of shoreline-protection structures. Designs should be simple yet effective, and the structures should depend wherever possible on readily available, low-cost materials (such as bamboo) rather than on more costly ones (such as bricks and cement).

An integrated approach to coastal protection practices should be within the context of integrated coastal zone

Fig. 2. Mangrove nursery and reclamation scheme at Korotogo, Vitilevu Island, Fiji. Serious erosion and exposure of this settlement to wave erosion, particularly by storm surges and tsunami, began when mangroves were cleared from the front of the village decades ago. Now the villagers realise that replanting mangroves will not only protect their village but also enhance coastal ecosystems [Photo: P. Nunn].

management (ICZM). Also, response or adaptive strategies to coastal erosion problems need to consider more than just coastal engineering solutions and structural options. Based upon the nature of the physical problems and the socio-economic situation, appropriate adaptive responses to coastal erosion can be identified and decided upon.

Coastal revegetation is another area in which both governments and local communities could reduce the problem of shoreline erosion and increased nearshore sediment mobility. Just as mangroves have been a conspicuous casualty of 20th century development along many island coasts, their replanting as a feature of 21st century development could significantly reduce coastal problems and serve the goal of sustainable coastal management (see Fig. 2). Other options such as setback and 'set-up' (see Fig. 3) are also strategies which could be employed more widely to reduce direct human impacts on coasts, particularly when accompanied by revegetation of coastal fringes.

These are simple examples of the problems of coastal technology transfer, currently the subject of a Special Report of the Intergovernmental Panel on Climate Change (IPCC) which should appear in 1999.

Fig. 3. Maloku village on Moala Island, Fiji, was formerly located on a low narrow coastal plain (where some buildings remain). Owing to the effects of cyclones, rising sea level and land subsidence, this lowland site was abandoned by most people in the village, and a new site cut into the hillside above, where most of them now dwell. Such responses are also typical of what might become increasingly common on high oceanic islands in future [Photo: P. Nunn].

7.4. Assessment of threats to coastal zones

The IPCC Common Methodology for Assessing Vulnerability to Sea-Level Rise has been found wanting with reference to many oceanic island coasts, largely because of its emphasis on a monetary basis of vulnerability assessment. It is also considered inflexible in dealing with archipelagic nations, rather than the continental ones for which it was initially designed (Yamada et al., 1995).

The development of more appropriate methodologies for oceanic islands has evolved in the southwest Pacific (Kay and Hay, 1993; Nunn et al., 1996). However, since these have focused on replacing the quantitative basis of the IPCC Common Methodology with a more qualitative one—not an exclusive preoccupation of island nations—this issue is not explored further here.

7.5. International and regional initiatives

Since most oceanic island nations do not have the capacity to either develop or implement their own coastal zone management strategies, such nations are in need of appropriate support from international bodies and other countries to achieve such goals. Such support has been generally forthcoming but it is not clear whether the present level of support, particularly in technical fields, will be maintained if coastal problems multiply in donor countries as a result of accelerated climate change and sea-level rise in the next few decades. Given this possibility, the need for in-country capacity building among oceanic island nations has become a priority.

Most island nations are signatories to the United Nations Framework Convention on Climate Change (UNFCCC) and are trying to realise their commitments to this, and other similar international agreements, in various ways largely through bilateral aid arrangements. It seems likely that the future success of monitoring programmes in particular will require something more than such short-term arrangements, and many island nations will need to tap recurrent sources of funds.

The voices of island nations will have to continue to be heard at the global level, a challenge which may become more difficult if environmental problems associated with future climate change and sea-level rise accelerate, as widely predicted. In global fora, the creation of the Alliance of Small Island States (AOSIS) to represent the shared concerns of island nations has proved an effective way of drawing international attention to their concerns about the problems of their coastal zones. The AOSIS should continue to represent these concerns vigorously, as they did at the Global Conference on the Sustainable Development of Small Island Developing States held in Barbados in 1994.

Regional bodies, such as the South Pacific Regional Environment Programme (SPREP), have an important role in both helping island nations manage their coastal zones and in conveying these nations' concerns to regional or international bodies. A key role which regional bodies need to take on is the maintenance of assistance, recently expressed as a longer-term low-key, low technology approach rather than short-term assistance accompanied by a high level of technical assistance (Kaluwin and Smith, 1997).

7.6. Traditional uses of the coastal zone

Coastal resources on oceanic islands are interwoven into the fabric of the terrestrial, social and economic lives of their inhabitants. Common to most island coastal areas is a rich marine lore that has been built up and survived for centuries, even millennia, while being modified to suit changing customs, traditions and the socio-economic aspirations of people.

In addition to providing for a basic subsistence livelihood, the coastal zone remains a focal point for trading, exchange and transportation. This is well illustrated by the Sepik-Ramu coastal area of New Guinea where coastal extension within the last few thousand years allowed the area to become a major centre for contact between highland and lowland dwellers, perhaps stimulating the remarkable material culture for which the area is renowned (Swadling and Hope, 1992; Nunn, 1999a). In Fiji and elsewhere, traditional exchange of food items and handicrafts was practised between islands and also between coastal peoples and those living inland. This involved the barter of marine products with root crops and artefacts, particularly products made from the native hardwoods found only in high island interiors. Fijians routinely ventured at least as far as Tonga and Samoa as a part of the traditional trading network (Hau'ofa, 1993).

The settlement and development of coastal areas are not usually matters of choice for oceanic peoples but occur as a result of a lack of economic alternatives. Limited economic and political bargaining power results in these small island states bearing the ecological footprints of larger industrialised nations. Cities and major urban areas were recently aptly described as 'parasites' because they had their ecological base elsewhere and had ecological footprints far larger than their total area, often extending to island coastlines (Swan, 1998).

With pressing needs for resource conservation, especially within the coastal zone, a successful approach to integrated coastal management has been the concept of community-based management. Community participation in management initiatives is not a new concept in the majority of oceanic states where the fundamental basis for social and cultural functions is the community. These functions are regulated by unwritten but respected rules of conduct which ensure the appropriate use and distribution of resources. In Fiji for example, these regulatory systems involve having allocated communal working days, specified functional roles of people within the community, and designated traditional fishing areas. Underpinning these is

people's intimate knowledge of their coastal environment. Seasonal occurrences of marine species, coastal migrations of certain fish species, effects of the moon, tides, and storms on abundance of species and people's knowledge of the diverse species and habitats within the coastal zone bear testimony to this (Johannes, 1982; Veitayaki, 1998; Baines, 1995; Vunisea, 1996). Scientists are often reluctant to accept traditional environmental knowledge as valid because of its spiritual base. What they may fail to recognise is that spiritual explanations often conceal functional ecological concerns and sound conservation strategies derived from relevant environmental practice for generations (Johnson, 1992).

Currently communities are beginning to participate actively in the planning and implementation of coastal management ventures. In Samoa, the government together with non-government sectors and local communities, has successfully implemented community-based coastal fishery management plans in more than 70 villages (King et al., 1998). In Fiji, the government is working closely with other sectors in the application of community-based management initiatives (South et al., 1997). Non-indigenous communities, translocated to places such as the Caribbean have over the years developed community-based fishery management systems with a strong social element, and a body of accumulated knowledge (Baines, 1995).

8. Conclusions: Will islands survive?

The most sensationalised aspect of the issue of the impacts of future climate change and sea-level rise on oceanic islands is the possibility that whole inhabited islands may 'disappear' in the next hundred years or so. While a probable scenario for certain atoll islands, the sensationalism surrounding what is just one aspect of a multifaceted problem is unfortunate. There is now a popular perception among many people in the Pacific Islands, for example, that atolls are the *only* island types substantially threatened by future climate change and sea-level rise.

People, including many government decision-makers, living on higher oceanic islands have often used this perception to justify not allocating funds to projects intended to mitigate the effects of future climate change and sea-level rise. Worse than this is the current assertion among many people concerned with global initiatives that sea-level rise is the *only* noteworthy problem that oceanic islands face in this context.

The dangers of these fallacies are many, and it is hoped that oceanic island states succeed in both realising and convincing other people that all islands are very much threatened by the changes which are predicted as imminent, and that sea-level rise will be only one of the whole gamut of associated problems with which island nations will have to deal.

Survival in a physical sense may prove subordinate to survival in a cultural sense. For many island communities, already threatened with a dilution of cultural integrity, the loss of ancestral coastal lands may prove the final straw, causing widespread societal breakdown.

The future need not be so bleak. Effective forward planning could minimise the worst effects of climate change and sea-level rise on island coastal zones, but it requires priority attention to the problems by island governments, which is not happening widely at present.

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