

# The end of the Pacific? Effects of sea level rise on Pacific Island livelihoods

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*Editor's Note:* The following is the tenth in the *Singapore Journal of Tropical Geography* Lecture Series. It is based on the plenary presentation of 16 August at the AOGS–AGU (WPGM) Joint Assembly held in Singapore in 2012.

As in the past, most Pacific Island people live today along island coasts and subsist largely on foods available both onshore and offshore. On at least two occasions in the 3500 years that Pacific Islands have been settled, sea level changes affected coastal bioproductivity to the extent that island societies were transformed in consequence. Over the past 200 years, sea level has been rising along most Pacific Island coasts causing loss of productive land through direct inundation (flooding), shoreline erosion and groundwater salinization. Responses have been largely uninformed, many unsuccessful. By the year 2100, sea level may be 1.2 m higher than today. Together with other climate-linked changes and unsustainable human pressures on coastal zones, this will pose huge challenges for livelihoods. There is an urgent need for effective and sustainable adaptation of livelihoods to prepare for future sea level rise in the Pacific Islands region. There are also lessons to be learned from past failures, including the need for adaptive solutions that are environmentally and culturally appropriate, and those which appropriate decision makers are empowered to design and implement. Around the middle of the twenty-first century, traditional coastal livelihoods are likely to be difficult to sustain, so people in the region will need alternative food production systems. Within the next 20–30 years, it is likely that many coastal settlements will need to be relocated, partly or wholly. There are advantages in anticipating these needs and planning for them sooner rather than later. In many ways, the historical and modern Pacific will end within the next few decades. There will be fundamental irreversible changes in island geography, settlement patterns, subsistence systems, societies and economic development, forced by sea level rise and other factors.

**Keywords:** climate change, coasts, Pacific, sea level, society, livelihoods

## Introduction

The land area of the Pacific Islands is around 0.4 per cent of the area of the largest ocean basin on Earth.<sup>1</sup> Home to around 2.1 million persons, Pacific islands are organized in geographical groups (Melanesia, Micronesia, Polynesia) and encompass a diversity of island types and cultural traditions (Figure 1). Most people living on Pacific islands today depend, more or less, on foods produced in the island group they inhabit, particularly those from nearshore coastal areas that consist mostly of reef-bounded lagoons. For the 3500 years since people first settled on the Pacific islands, nearshore marine foods of this kind have been their principal source of routine sustenance which, along with ease of access to trade networks, explains why most such people in the region have favoured island coasts for settlement, a situation that continues today.

Owing to their high dependence on coastal subsistence, the history of Pacific Island peoples has been marked by societal changes that were driven in some cases by (rapid) sea level changes, which periodically caused enduring food crises for coastal dwellers (Nunn, 2007a; Nunn *et al.*, 2007; Carson, 2008). A comparable situation has arisen

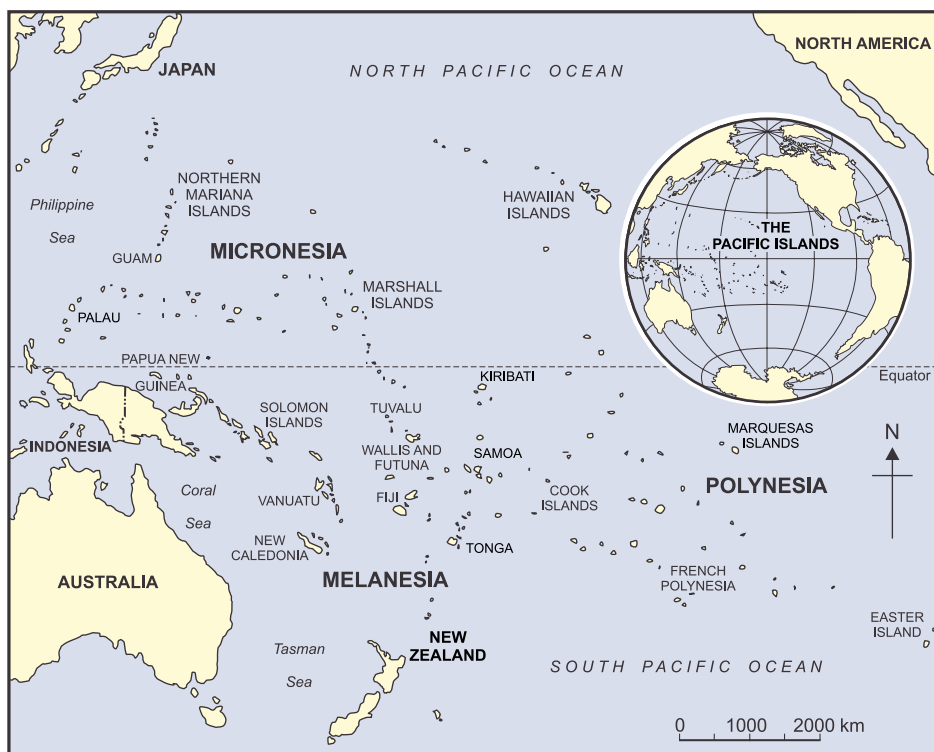


Figure 1. Map of the Pacific Islands region showing its subregions and the principal island nations.

today whereby net sea level rise over the past 200 years, compounded by unsustainable demands on some coastal environments, has reduced nearshore bioproductivity along some coasts that in turn has forced nearby coastal dwellers into alternative (non-traditional) modes of food acquisition (Kinch *et al.*, 2010; Kronen *et al.*, 2010; Turner *et al.*, 2007). Projections of future (twenty-first century) sea level rise, along with other factors, suggest that within perhaps a few decades such situations will become almost ubiquitous along inhabited Pacific Island coasts and that reef-lagoon systems will be unable to contribute significantly to the subsistence economy of Pacific Island peoples, which will have profound consequences for livelihoods (Pratchett *et al.*, 2011; Hoegh-Guldberg, 2011).

This bleak outlook contrasts sharply with most of the discussion about Pacific Island livelihoods within the past two decades, which assumes that traditional livelihoods are sustainable, either once deleterious human impacts on the natural environment are reversed or once livelihoods are adjusted to climate change (Wallace, 2009; Beck & Dorsey, 2009). For example, almost all discussions about food production have ignored or sidelined the probable collapse of nearshore marine food-production systems by the year 2060 as a result of coral bleaching becoming an annual event (Hoegh-Guldberg, 2011; Hoegh-Guldberg *et al.*, 2007; Nunn, 2007a). Another example comes from the failure of many scientists and policymakers to link sea level rise to the increasing lowland flood frequency and impact in Pacific Island coastal areas (Nunn, 2010), the preference being to blame flooding on short-term climate variability and/or increased exposure of terrestrial systems, typically through deforestation (Chandra & Dalton, 2010).

This paper investigates the validity of claims about the potential for continued sustainability of contemporary and recent human-environment interactions in the Pacific Islands. In doing so, it looks first to the past, evaluating emerging ideas about the forcing of fundamental societal change in the region by sea level change. It then focuses on the last 200 years of change along Pacific Island coasts, attempting to tease apart the various contributions to observed livelihood change. The discussion then moves to the next 100 years and outlines the most likely scenarios for livelihood change along island coasts. The final substantive part of the paper identifies the key issues at present that are responsible for shaping the future of Pacific Island coastal livelihoods and what interventions could be made to ensure a more sustainable future for people occupying these fragile environments.

### **Past analogues of livelihood impacts from sea level change in the Pacific Islands**

Some of the major societal changes in the Pacific Islands were initiated as a result of environmental forcing rather than processes of natural societal evolution in isolation. Two examples are given in this section, the first from the earliest settlement period in the western Pacific and the second from the first half of the last millennium. While it is acknowledged that the modern globalized situation in the Pacific Islands region is quite different, these examples nonetheless underline the innate vulnerability of island environments and societies to external climate-driven forcing.

#### *Earliest settlement period in the western Pacific*

When people first sailed east from the western Pacific rim 3500–3250 calBP (1550–1300 BC) to colonize the Marianas Islands in the northwest Pacific (Hung *et al.*, 2011) and Solomon Islands and other groups in the southwest Pacific (Denham *et al.*, 2012), most appear to have subsisted largely from marine foods, settling places along island coasts that were optimally configured for foraging from broad fringing coral reefs (Nunn & Heorake, 2009). The earliest known dates for human settlement in various west Pacific island groups all fall within the period of (late) Holocene sea level fall, which continued throughout the earliest discrete period of settlement (Figure 2).

This earliest settlement period in each of the island groups shown was characterized by the dominance of marine foraging, usually less at the end than the start of the period, and an increasing contribution of non-marine foods to subsistence economies throughout the period. In many cases, these periods are easy to define by material culture; for example, in Fiji the earliest settlement period was marked by the production of finely decorated (Lapita) earthenware that was replaced abruptly by more crudely made plainware around 2500 calBP (550 BC) (Clark & Anderson, 2009). In addition, many settlements established during the earliest period were relocated following its end, something that has been interpreted as signalling the end of marine foraging as the dominant method of food acquisition and its replacement by horticulture/agriculture for which, in most island groups, other areas of the coastline were better configured (Nunn, 2009a; Carson, 2008).

While other explanations for these changes are possible, the fact that end points of the earliest settlement period on west Pacific island groups cluster around 2500 calBP (550 BC), as in Figure 2, suggests that a regional rather than a local driver of change was responsible for the associated cultural transformation. It is therefore plausible to suppose it was the continuing late Holocene sea level fall that, by slowly exposing or shoaling offshore reef-lagoon systems, led to a progressive reduction in their useful

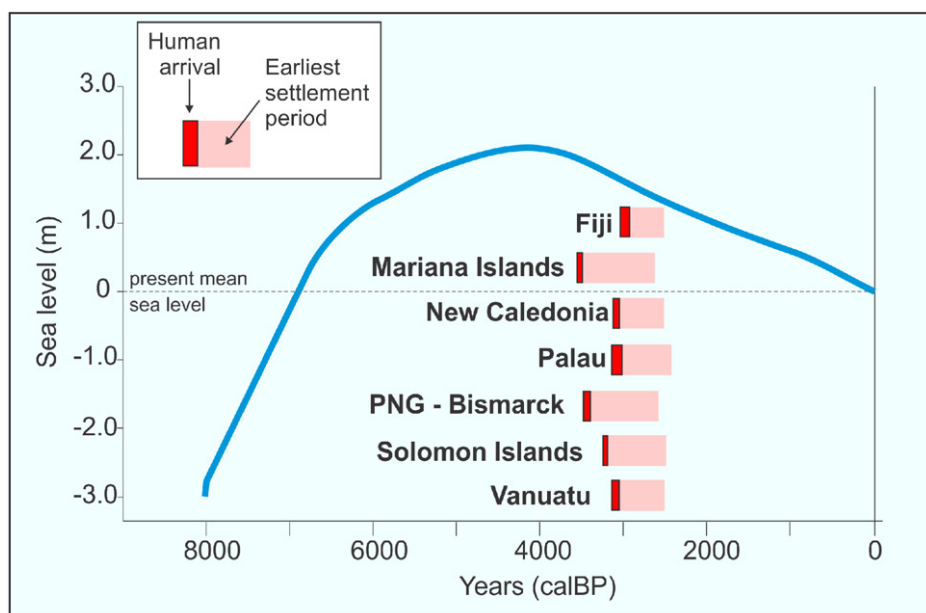


Figure 2. Sea level change during the Holocene in the Pacific (after Nunn and Peltier, 2001) showing the earliest-known settlement dates and the extent of the earliest discrete settlement period in selected island groups (from various sources).

bioproductivity that rendered them unable to supply the subsistence needs of (growing?) coastal populations; for example, sea level fall was favoured as the main reason for the extirpation of the giant clam *Hippopus hippopus* in Fiji around 2700 calBP (750 BC) (Seeto *et al.*, 2012). The replacement of labour-light food acquisition strategies (marine foraging on broad, readily-accessed reefs) – which allowed time to be spent on producing often-elaborate pursuits like tattooing, word carving and pottery decoration (Green, 2003) – with more labour-intensive ones (horticulture and agriculture) explains the often profound changes in material culture marking the end of the earliest settlement period; after abandoning marine foraging as the principal means of food acquisition, far less time for available for tasks unrelated to this. In Fiji for example, the production of decorated pottery, which required more time to produce than plain pottery, ceased.

#### *Rapid livelihood change around AD 1300 on tropical Pacific Islands*

Within the first part of the last millennium, most Pacific Island societies changed profoundly; most experienced widespread and sustained conflict for the first time, marked by the establishment of settlements in fortifiable locations (typically inland and uphill on higher islands) following the abandonment of those in exposed locations, commonly along island coasts (Field & Lape, 2010; Nunn, 2007a).

While several explanations have been proposed for these changes, most explanations fail to acknowledge the point that, as with the previous example, these changes appear approximately coincident on island groups across the tropical Pacific, an observation that demands a region-wide driver rather than a series of local ones. The only available such driver is sea level, which several records show fell perhaps 70–80 cm between AD 1250 and AD 1350, a period named the AD 1300 Event (Nunn, 1999;

2007b; 2012). The near-coincidence of this period of rapid sea level fall with the least ambiguous indicators of societal breakdown strengthens the case for a causal connection (Nunn, 2007a).

It is argued that prior to the AD 1300 Event, coastal dwellers in the Pacific Islands were generally able to negotiate the vagaries of climate (including sea level change) and continue to follow coastal-tethered livelihoods. Yet the rapid sea level fall that characterized the AD 1300 Event had several environmental effects, including the exposure of reef surfaces and associated loss of useful bioproductivity, the shoaling of lagoons and their consequent increased turbidity, and the lowering of water tables on coastal plains, all of which combined to abruptly reduce the amount of food obtainable. The result was a food crisis that endured so long that conflict ensued and coastal dwellers relocated in response (Nunn, 2007a; 2012). Following the AD 1300 Event, sea level remained low for the 450 years of the Little Ice Age and on most tropical Pacific island groups, conflict continued, albeit with often decreasing intensity. Written accounts of Pacific Island societies from the nineteenth century, when sustained European contact began with most, frequently highlight the evidence for such conflict (Nunn, 2007a).

### **The last 200 years of sea level change in the Pacific Islands**

There is evidence that global sea level began rising at the end of the Little Ice Age about 200 years ago (Jevrejeva *et al.*, 2008) and has continued since, something established independently for the Pacific region (Nunn, 2007a). While sea level has not risen monotonically within this period, it is clear that the overall trend has been upward; some long-term tide-gauge records from the Pacific are illustrated in Figure 3. The most reliable data show that global sea level rose 210 mm between 1880 and 2009, an average of 1.6 mm/year, accelerating in recent decades. Within the period 1993–2009, sea level rise averaged  $3.2 \pm 0.4$  mm/year (Church & White, 2011). In some parts of the tropical Pacific, the rise between 1993 and 2009 was much faster – up to 10 mm/year in Solomon Islands and parts of Micronesia; elsewhere, particularly in the eastern low-latitude Pacific, the rate was less than average (Becker *et al.*, 2012).

The effects of sea level rise on Pacific Island livelihoods over the past 200 years are associated mostly with changes to coastal environments that typically reduce useful bioproductivity, principally through shoreline erosion, direct inundation (flooding) and groundwater salinization. There are other climate-linked effects that need to be considered when evaluating changing livelihoods in this region over the past 200 years, principally changes (including sea level changes) associated with interannual variations such as ENSO (El Niño – Southern Oscillation) and PDO (Pacific Decadal Oscillation), regional patterns of wind and wave setup, and changing periodicities of tropical cyclones, which are a major cause of rapid coastal change in the region (Terry, 2007).

The last 200 years have also seen unprecedented societal changes in Pacific Island countries, associated largely with their absorption into an increasingly interdependent global society. Many of these changes, particularly those associated with increased, commonly unsustainable, demands on island coasts, have had effects on livelihoods similar to those of sea level rise and it is sometimes difficult, even controversial, to attribute particular effects to particular drivers of change.

The effects of sea level rise are clearest when extreme (wave and precipitation) events are considered, with many Pacific Island coasts experiencing increasingly severe flooding and storm erosion at such times, although in many places this is also a result of increased exposure to such events through increased coastal development and

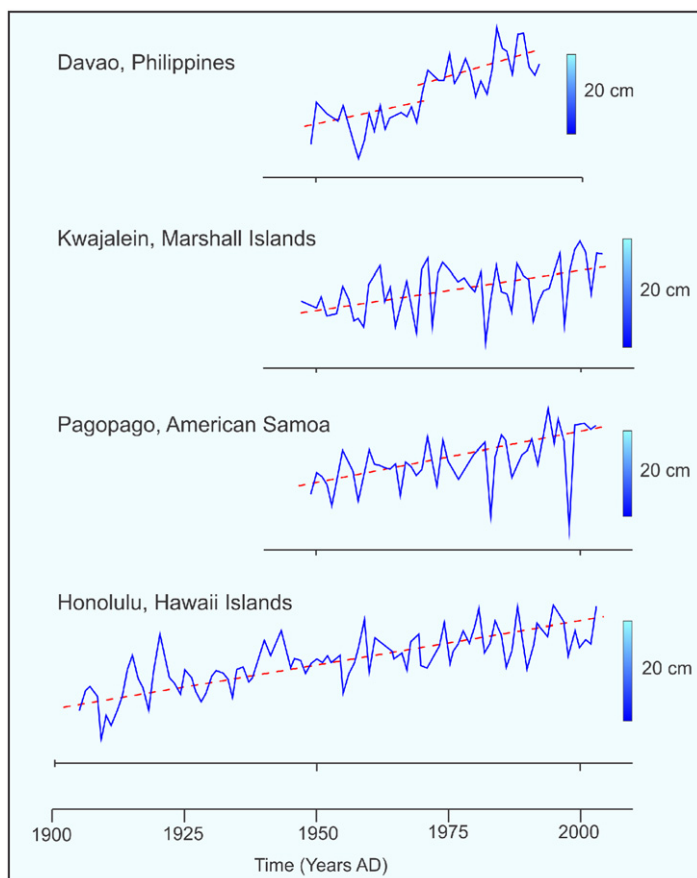


Figure 3. Selected records of sea level change from tide gauges in the Pacific. All data from the Permanent Service for Mean Sea Level ([www.psmsl.org](http://www.psmsl.org)).

population density. The effects of human adaptive responses, both infrastructural and institutional, to livelihood change and sea level rise have often worsened the situation, as have the sometimes unsustainable demands placed on coastal ecosystems, particularly for the production of food surpluses (McGregor *et al.*, 2009).

This section of the paper discusses only the major issues as they relate specifically to livelihoods affected by sea level change within the last 200 years. Detailed discussions of other changes to Pacific island livelihoods within this period can be found elsewhere (Crocombe, 2001; Christensen & Mertz, 2010; McNeill, 1994; Thaman, 2008).

#### *Environmental changes associated with sea level change*

One of the most widespread effects of sea level rise over the past 200 years or so is shoreline retreat, evidence for which has been noted from almost all low-lying Pacific Island coasts (Mimura & Nunn, 1998; Nunn, 2000; Webb & Kench, 2010; Ford, 2011; Collen *et al.*, 2009). Coastal settlements that formerly extended further seawards are often now either crowded into restricted lowland areas or have extended inland or shifted elsewhere; coastal recession in such places is often marked by lines of fallen/falling coconut palms (Figure 4A).





Figure 4. A. Fallen and falling coconut palms is a sign of shoreline erosion along many Pacific Island coasts; this view is from Naigani Island (Fiji).

B. Donor-funded seawalls are common along the shoreline in prestigious locations in the Pacific Islands; this view is of the shoreline at Avarua (Cook Islands).

C. Community-built seawalls are often inappropriately designed and constructed, often collapsing after 12–18 months; this view is of the remains of the seawall at Yadua Village (Nadroga), Viti Levu Island (Fiji).

D. Given that mangroves were intentionally cleared from many Pacific Island coasts in the past, mangrove replanting is a natural solution to shoreline erosion and ocean flooding; this view is of the mangrove nursery at Yadua Village (Nadroga), Viti Levu Island (Fiji).

Examples of shoreline erosion likewise abound in the Pacific Islands, and while comparatively few examples have been formally reported (Leatherman, 1997), there is little doubt of their ubiquity. At Ucuivanua on Viti Levu island (Fiji), 15 m of shoreline retreat between 1937 and 1987 was associated with a loss of 3500 m<sup>3</sup> of material despite the planting of deep-rooting trees tolerant of saline groundwater (Nunn, 1988). Much shoreline erosion takes place during extreme events (Terry, 2010). Commonly associated with shoreline erosion is evidence that coastal flooding from (storm) waves extends far inland, flooding areas that were once considered beyond the reach of such waves. This situation has become especially acute for livelihoods on atoll islands (Terry & Chui, 2012); flooding of these islands can deposit a saltwater layer over the freshwater lens that may impact food productivity for months (White & Falkland, 2009).

Examples of permanent inundation abound in the Pacific Islands although few have been formally reported.<sup>2</sup> Among the latter, around the coast of Ovalau and Moturiki islands (Fiji), net average rates of lateral inundation approaching 2 m/year for 65 years were reported (Nunn, 2000). In 1990 at Satalo on Upolu Island (Samoa), around 70 m of lateral inundation was reported as having occurred within the preceding 90 years

(Nunn, 1990b). At Naloto village on the east coast of Viti Levu island (Fiji), 60 per cent of the village and surrounding lowlands that was occupied in the 1940s was underwater in 1987 (Nunn, 1990a).

Much has been made in the mass media of Webb and Kench's (2010) research which found some atoll islands had been growing in area over the past few decades. A headline in *The Times* (London) on 3 June 2010 stated that 'Sinking Pacific Islands are really growing' and one in the *Daily Mail* (London) on 5 June 2010 stated that 'Low-lying Pacific islands growing not sinking as sea levels rise'. Such reports imply that concerns about rising sea level in the Pacific (and elsewhere) are unfounded given that islands are evidently not 'disappearing' but actually 'growing'. This interpretation is incorrect, as indeed Webb and Kench concluded – 'islands will undergo continued geomorphic change . . . results do not suggest that erosion will not occur' (2010: 12). In addition, many of the islands studied by these authors showed net change in shoreline position; both shoreline progradation and erosion are expected to occur on different parts of the coast on such islands, which are often in dynamic equilibrium with sea level (Woodroffe, 2008).

Sea level rise has affected coastal food supplies largely by the drowning or salinization of productive land including coastal wetlands (Jenkins *et al.*, 2011). Examples have been reported from the island groups of Cook Islands, Fiji, Vanuatu and several atoll nations (FAO, 2008; Webb, 2007). On Pukapuka Atoll in the northern Cook Islands, it took 11 months for freshwater lenses to recover and as much as three years for taro plantations inundated by storm surges in 2005 to return to full productivity (Terry & Falkland, 2009). Along many coasts, economically important tree crops like *Casuarina* spp. and coconut palms have died as a result of salinization; sugarcane, an important cash crop in lowland Fiji, has also been impacted by salinization in recent decades (Nunn, 2009b). Some communities in the Rewa Delta (Fiji) have started to build raised gardens with perched water tables to continue growing food crops above increasingly salinized groundwater (Lata & Nunn, 2011). Groundwater salinization of food gardens in some coastal parts of Papua New Guinea and Vanuatu have forced affected communities to relocate (Lal *et al.*, 2009). The effects of sea level rise in causing salinization of drinking water for coastal communities in the Pacific have been reported from several atolls (Terry & Falkland, 2009; White & Falkland, 2009) and may be responsible for increases in health hazards among coastal communities elsewhere (Lal *et al.*, 2009).

#### *Coastal food supply: natural and human impacts*

While reliable data are difficult to obtain, it is likely that today most rural communities (and many urban dwellers) in the Pacific Islands region obtain most of their routine food supply directly from the natural environment, typically fish and other seafood from nearshore (shallow-water) marine ecosystems (especially reef-lagoon) and staples and vegetables from food gardens close to their homes. Surpluses of traditional subsistence foods are often produced/gathered for sale, placing additional strain on these supply systems (Kronen *et al.*, 2010; McGregor *et al.*, 2009).

Particularly in the past 30–50 years, sea level rise has had an increasing effect on coastal food supplies of these kinds, not just through shoreline erosion, inundation and salinization (see above) but also related, typically more localized, effects such as changed pathways of nearshore sediment movement, changed wave regime from overtopping of reef surfaces and changed estuarine dynamics. There have also been direct human impacts, such as increasing coastal population densities (especially in peri-urban coastal areas), water pollution and unsustainable impacts on coastal systems (such as



dynamiting, fish poisoning, reef-rock and beach-sand mining), that have exacerbated the effects of sea level rise, often making these difficult to isolate. The increased incidence of coral bleaching that has been experienced in the Pacific region over the past few decades has also undoubtedly affected nearshore marine food supply, not least because reef ecosystems often take years to recover from bleaching episodes during which nearshore food supply may drop profoundly (Hoegh-Guldberg, 2011).

*Responses: sustaining livelihoods?*

Over the past few decades, in response to the spread of unsustainable demands on Pacific Island coastal zones and the consequent deterioration in useful bioproductivity observed in many places, there has been considerable effort devoted to ways of sustaining livelihoods of coastal dwellers. Many top-down initiatives, brokered by regional agencies with external donors on behalf of national governments in the region, have been implemented but very few appear to have sustainable outcomes. Most coastal communities, especially in rural parts of the region, have witnessed changes to useful bioproductivity but their responses have been largely uninformed and not especially effective.

Over the past 25 years in the Pacific Islands, despite significant amounts of external assistance (Gani, 2009), much targeted at climate change adaptation, there has been little discernible change in the average person's understanding of climate change and the challenges this poses to livelihoods (Barnett, 2008; Barnett, 2007; Nunn, 2009b; Lata & Nunn, 2011). Much of this is due to the nature of the messages provided. Most messages are filtered through private media, usually newspapers, that have understandably (yet regrettably) focused on more extreme views and situations to which most communities and individuals cannot relate to their individual circumstances; good examples come from atoll nations, for which there is no shortage of bleak prognoses (Farbotko, 2010).

Yet this situation has also arisen because of the way that the external assistance has been used, something that reflects both the requirements of donors as well as the priorities of recipient governments (Nunn, 2009b). Donors will not guarantee funding beyond a certain timeframe, typically 3–5 years, meaning that donors' funds are generally be used only to fund initiatives, often 'pilot' projects. The expectation that recipient governments will then take over the costs of these projects has generally proven unrealistic; projects are usually terminated after external funding ends, and the situations commonly revert to those existing prior to the inception of the projects.<sup>3</sup>

Since the issue of climate change adaptation has become inexorably contextualized in monetary terms, it is unsurprising that Pacific Island nations, most of which are classed as 'developing', have come to regard this issue – and indeed most issues around national environmental sustainability – as one that is properly funded only by external assistance, not by internal revenue (Nunn, 2009b). Yet not only does this approach discourage ownership of climate change adaptation by such nations, it also subordinates it to donor preferences and funding periods. Thus Pacific Island nations have for decades had to accommodate 'adaptive solutions' from other, often quite different environmental contexts, imposed uncritically on Pacific environments and cultures where their efficacy is far less, just because these solutions are those favoured by donors. That such impositions have gone largely unremarked by most Pacific leaders, and particularly by those in the regional agencies charged with advising them on environmental stewardship issues, is testament to the high degree of dependency on external assistance. The fact that all such assistance is time-bounded explains why the history of climate change

adaptation in the Pacific Islands over the past 25 years has been marked by piecemeal assistance in both time and space, rapidly changing foci, sometimes significant waste, and in the end no widespread improvement in awareness and no sustainable solutions.

A good example is provided by seawalls (Nunn, 2009b). Along the coasts of many richer countries in the world, a common response to shoreline erosion and increasing ocean flooding has been to build artificial structures that serve to also protect vulnerable human infrastructure and livelihoods. The most common structures are seawalls, the form and orientation of which are typically decided on the basis of appropriate amounts of empirical data about coastal processes. Those countries (and organizations) that give external assistance to Pacific Island nations for climate change adaptation often believe implicitly in the efficacy of seawalls as shoreline protection. They often fund their construction in the Pacific Islands without considering whether there are sufficient empirical data (on tides, wave heights, extremes, sea level changes) to design optimal structures, or more importantly, whether seawalls are a culturally acceptable solution. In the latter context, it is clear that many beneficiary nations in the Pacific Islands have neither the funds nor the commitment to maintain these seawalls beyond the period of donor interest.

Yet so widespread has the belief in the efficacy of seawalls become that donor-funded seawalls (usually in important or conspicuous locations) have become widely emulated by many rural communities (Figure 4B). Such seawalls, sometimes built by communities with external assistance, generally collapse after 12–18 months, after which they may be occasionally repaired, typically to the point when the costs become prohibitive and the community realizes that seawalls are not the sustainable solutions they initially believed (Figure 4C). It is far better for communities to plant (or re-plant) vegetation along vulnerable shorelines (Figure 4D) and/or to remove themselves from these. Besides seawalls, some communities have physically shifted, usually by planting a buffer zone of appropriate vegetation between the seaward periphery of the village and the shoreline. Other communities have sought to raise those buildings most at risk. Responses have in general been uncoordinated, uninformed and unsuccessful, which have implications for the development of future responses.

### **The next 100 years of sea level change in the Pacific Islands**

The most recent IPCC projections of sea level, involving a maximum of 59 cm by 2100 (relative to 1980–99 mean),<sup>4</sup> were published in the IPCC's 4<sup>th</sup> Assessment Report in 2007 (IPCC, 2007). The exclusion of future rapid dynamical changes in ice flow from the calculations of these projections led to a flurry of alternative projections being published subsequently, most of which involved significantly greater maximum sea level projections for 2100 that have been accepted by most climate change scientists (Vermeer & Rahmstorf, 2009; Overpeck & Weiss, 2009; Nicholls *et al.*, 2011). The most credible projections for 2100 (relative to 1980–99) involve 1–2 m of sea level rise but also emphasize the high degree of uncertainty in these figures, particularly around the incidence of tipping points such as the collapse of land-grounded ice sheets. Data on observed sea level changes from most parts of the world suggest that sea level is currently rising faster than the 2007 IPCC projections, lending credibility to the alternative projections (Rahmstorf, 2012).

While there are different views on how much higher global average sea level in 2100 is likely to be (compared to 1980–99), a figure of 1.2 m is considered realistic. The effects of such a rise in sea level, which is much greater than IPCC (2007) projections, on Pacific

Island coasts and livelihoods are consequently more serious than planners and politicians in the region have been led to believe, and require adaptive responses that are more widespread, inevitably more disruptive, and altogether more complex than hitherto anticipated.

Most people in the Pacific Islands live along the coasts of higher islands, their settlements, infrastructure, communications and their proximal food-producing systems all being located there (FAO, 2008; Barnett, 2011). As has been experienced in the past 200 years along most such coasts, shoreline erosion will continue and is predicted to accelerate along some soft-sediment coasts (Dickinson, 2009). The effects of inundation (coastal flooding), especially during storm surges, will continue and are expected to have increasingly severe effects as sea level rises. Such effects are likely to be compounded by increases in the incidence of the strongest tropical cyclones (Knutson *et al.*, 2010). The extent of salinized groundwater within coastal lowlands will increase. Overtopping by sea level of nearshore coral reefs and associated increases in lagoonal sediment mobility will impact reef-lagoon ecology and bioproductivity.

For a combination of such reasons, on many islands, it is likely that people occupying coastal settlements large and small will experience increased disruption to their activities as the century progresses. The specific reasons for this increasing loss of habitability will relate to declining productivity of coastal ecosystems (both offshore and onshore) as a result of water-chemistry changes (like ocean acidification and groundwater salinization) and increased frequency of coastal flooding, accompanied by loss of useful land arising from increased water levels and more prolonged extremes (floods).

One example is that of the island of Tongatapu, the largest and most populous in the Kingdom of Tonga (Figure 5). Tongatapu is a raised limestone island, tilted south to

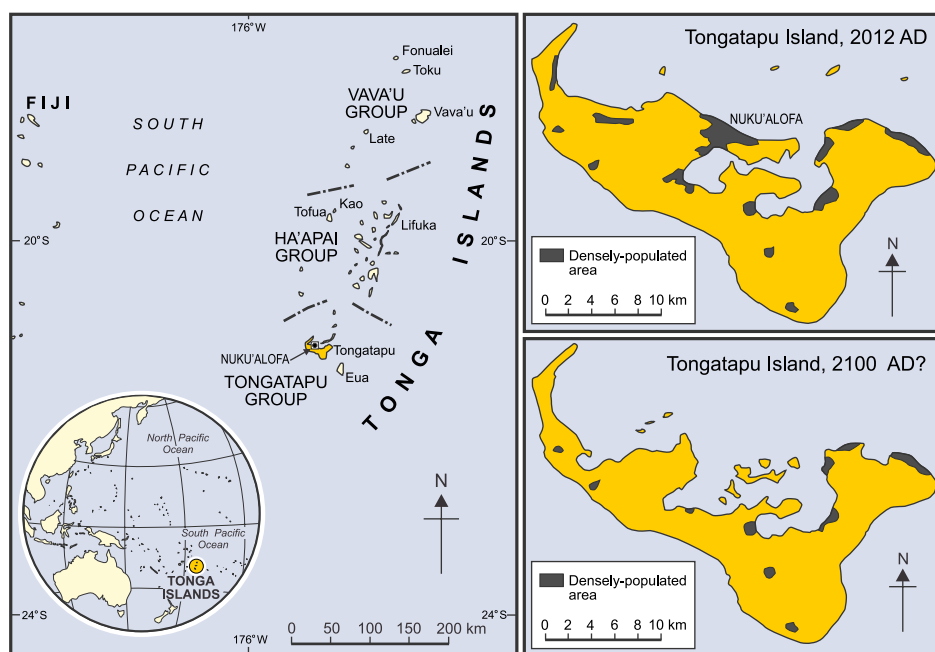


Figure 5. Maps of Tongatapu Island (Tonga). The upper map is of the modern island showing densely-populated areas; the lower map shows how the geography of the island might change, conceivably by AD 2100, with a sea level rise of some 2 m (after Nunn, 2007a).

north; most of the people live along the low-lying reef-fringed north coast of the island, with high population densities along the coastal periphery owing to the unavailability of land elsewhere on the island. Figure 5 shows what might happen if sea level were to rise about 2 m; not only would there be direct flooding but also associated rises in the freshwater lenses that would render large areas of the island, including the capital Nuku'alofa, underwater at high tide and probably therefore uninhabitable.

It is likely that the next 20–40 years will see many smaller coastal communities on Pacific islands try to adapt *in situ*, perhaps by building artificial coastal protection structures (like seawalls) or otherwise tinkering with the natural environment of affected areas, but by the middle of this century it is probable that most such communities will realize that relocation of their settlements (and associated infrastructure and terrestrial food-production systems) is the only option if the community desires to remain together and sustain their livelihoods. Alternatively communities may fragment, with those families/groups most affected moving independently elsewhere, many perhaps to urban centres, as is happening already in some places as a result of rural livelihoods stressed by climate change (Locke, 2009).

Larger communities (including towns and cities) will not be affected uniformly by rising sea level, some parts being affected sooner than others, some perhaps not at all. The nature of the response by these communities will largely depend on the effects of sea level rise on the main economic activities that sustain them. Most medium-sized towns in the Pacific Islands are market centres and transport hubs that may also receive revenue from industrial, mining or tourism activities, for example. The degree to which these are impacted by climate change (and other factors) will largely determine the affected community's response, as will the efficacy and responses of local government (Hassall & Tipu, 2008).

An example is provided by Nadi Town (Viti Levu Island, Fiji) which has experienced floods of increasing frequency, magnitude and extent over the past 10–20 years, something that has been variously attributed to river-channel infilling, catchment deforestation, artificial coastline construction and poor drainage. Most analysts have ignored the likely contribution of sea level rise despite a record from a nearby tide gauge (Lautoka) showing sea level has been rising on average at 4.9 mm/year during the period in question (Figure 6). Other factors have clearly exacerbated the effects of sea level rise but it is likely that large parts of Nadi Town will be rendered uninhabitable in 15–20 years' time (Figure 7). Resistance to the idea of sea level rise is an important factor in Nadi. Flooding has led to short-term responses such as river dredging and slope reforestation in the hinterland; a recent proposal is to divert the mouth of the Nadi River away from the town, but this is unlikely to bring much relief. Within the next 10–15 years, the mounting inconvenience caused by increasingly frequent and severe floods in Nadi will likely convince decision makers that relocation of at least the most vulnerable parts of the town is inevitable, and appropriate action will result.<sup>5</sup>

Most cities in the Pacific Islands are also national capitals, the imperative for which to preserve is greatest, being a nationwide concern as well as an international priority. It is likely that many such cities will be increasingly protected by artificial structures as the century progresses, but will also shift landwards and upslope where possible. There is potential for this in many high-island capital cities in the region, including Apia (Samoa), Honiara (Solomon Islands) and Suva (Fiji). Other capitals may find this more difficult, given the steep nature of their hinterlands, such as Avarua (Cook Islands) and Pagopago (American Samoa).

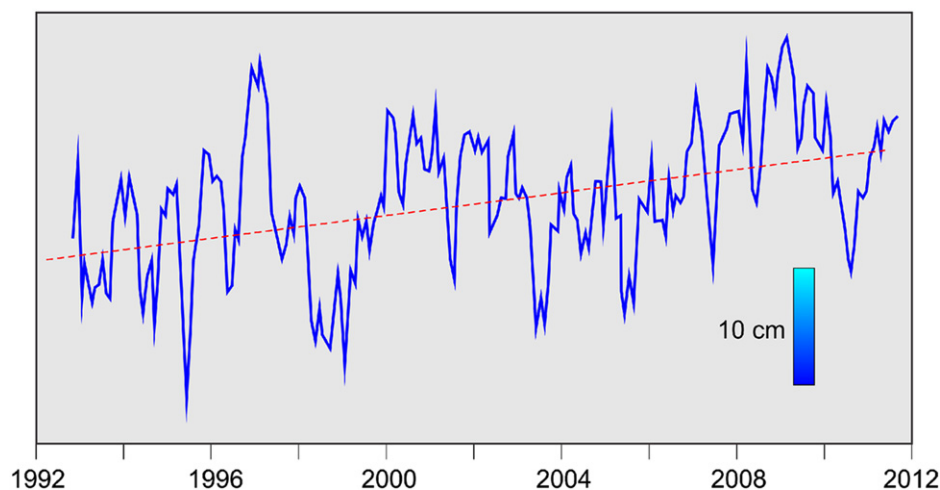


Figure 6. Recent sea level change 1992–2011 at Lautoka (Fiji) averages 4.9 mm/year. Data from the Permanent Service for Mean Sea Level ([www.psmsl.org](http://www.psmsl.org)).

Although far smaller than densely populated deltas elsewhere in the world, those in the Pacific Islands are important foci of settlement and food production, often for nearby urban centres. Examples are the Rewa Delta close to Suva, the capital of Fiji, and the Lungga Delta close to Honiara, the capital of Solomon Islands. Such deltas are already showing signs of environmental stress linked to sea level rise and will be among the first places in the Pacific Islands region to experience major disruption as a result of future climate change, perhaps within two decades. Atoll islands are likely to be severely affected by future sea level rise; some also likely to be rendered uninhabitable within two decades. This will have significant implications for the people and even the sovereignty of nations like Kiribati, Marshall Islands, Tokelau and Tuvalu (Maas & Carius, 2012).

For planning purposes, it is clearly unsatisfactory to look at sea level impacts in isolation. Most Pacific Island nations already have growing populations and significant rates of urbanization, and most existing food production systems are being utilized increasingly unsustainably. These are issues that need solutions of their own, either independent of or integrated with sea level rise (Storey & Hunter, 2010). Parallel threats to livelihoods from climate change include temperature rise which will stress current food producing systems, changes in precipitation and in the frequency and intensity of extreme events, particularly tropical cyclones (Barnett, 2011; Knutson *et al.*, 2010; Hay & Mimura, 2010). Combined with ocean acidification, the effects of increasing sea-surface temperatures in increasing the incidence of coral bleaching are likely to render many nearshore (reef-lagoon) food-producing ecosystems far less productive by the middle of the twenty-first century with potentially profound and widespread consequences for coastal subsistence in the tropical Pacific Islands (Hoegh-Guldberg, 2011).

### Key issues for the present

There are a number of issues which, if effectively and promptly addressed, will significantly reduce many deleterious impacts of sea level rise on livelihoods in the Pacific Islands this century. Yet despite numerous expressions of positive intent about the



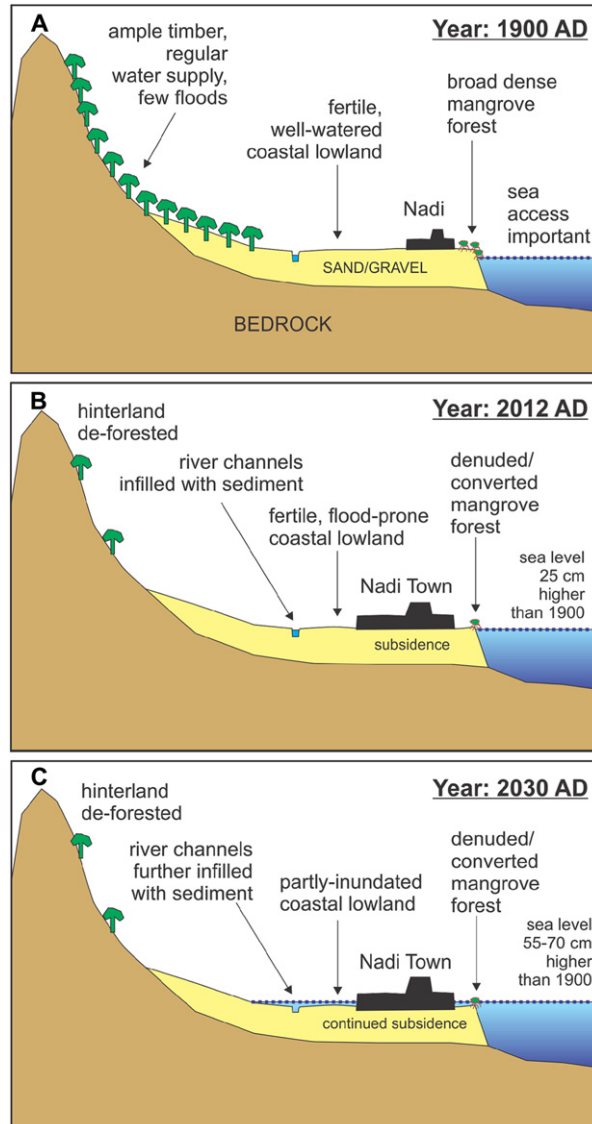


Figure 7. Parts of Nadi Town (Fiji) will be rendered uninhabitable in the next 15–20 years as a result of increasing flood frequency, magnitude and extent associated with rising sea level (see Figure 6).

A. Nadi developed originally at a time during the colonial history of Fiji when land transport was limited and the sea provided the main conduits for imports and exports. Owing to its well-vegetated hinterland at the time, Nadi experienced few floods and agriculture burgeoned in the fertile lowlands around, contributing to the growth of the town. Sea level was also lower at this time, and the mangrove fringe far more extensive, both of which meant that activities in Nadi were only occasionally disrupted by flooding.

B. In recent years, Nadi has experienced increasingly frequent flooding. River channels have become filled with sediment, largely owing to deforestation of the hinterland. Sea level is considerably higher and much of the mangrove fringe has been sacrificed for developments of various kinds. Like all river deltas, that on which Nadi is located is subsiding, probably at about one-tenth of the rate at which sea level has been rising recently. Nadi is becoming more prosperous owing to its role as Fiji's principal tourism hub.

C. Within a few decades, sea level will have risen higher off the Nadi coast, making it impossible for rivers to carry floodwaters away.

increasing exposure of Pacific Island nations to sea level rise, effective and sustainable adaptation has not been forthcoming and currently seems as elusive as ever. Given that the most important food producing systems for coastal dwellers in the region are being increasingly impacted by sea level rise and other stressors, a particular issue exists around food security. The relocation of coastal settlements and infrastructure vulnerable to sea level rise to safer locations is a highly emotive issue, but one that Pacific Island decision makers need to engage with soon, given its inevitability this century in thousands of populated coastal locations throughout the region.

### *Articulations of concern*

The ability of most people (and for subsequent generations) living in the Pacific Islands to weather the effects of sea level rise on livelihoods will largely be determined by the nature of the responses they make. To date the responses from Pacific Island leaders have been largely benign and ineffective: hand-wringing and supplicant rather than inward-directed and energized.

In 1989 at the first meeting ever held in the Pacific Islands to discuss climate change, the President of the Marshall Islands, Amata Kabua expressed the embryonic concerns of many in the region when he said that

It is truly frightening to think that our ocean will turn against us . . . I hope that the appeal of the peoples of the Pacific can help convince the industrialized nations to discontinue their profligate contamination of the atmosphere (Kabua, 1989).

The despondency deepened and spread. In 1999, Tamari'i Tutangata, then Director of SPREP (then the South Pacific Regional Environment Programme) reflected that

As a ten-year-old, I used to look at the sea with awe, at the seemingly endless supply of fish that I could harvest . . . now when I look at it, I wonder how far into the new millennium it will be before it overwhelms our coasts . . . What is there to celebrate about a new millennium if the northern group of the Cook Islands, or the many islands of Kiribati, Tokelau, Tuvalu, the Federated States of Micronesia and the Marshall Islands are about to disappear beneath the ocean? (Tutangata, 1999)

While it is sometimes difficult to separate rhetoric from factual observations, it is clear that for some island residents, particularly on low atoll islands, the issue in the second decade of the twenty-first century is no longer one of *in-situ* adaptation, as was once discussed extensively, but of survival. In June 2008, the Prime Minister of Kiribati, Anote Tong, referring to climate change, stated that his people

may be beyond redemption. We may be at the point of no return, where the emissions in the atmosphere will carry on contributing to climate change, to produce a sea level change so that in time our small low-lying islands will be submerged . . . [for Kiribati] it's not an issue of economic growth, it's an issue of human survival (*The New Zealand Herald*, 2008).

There are concerns that cultures may not survive (Adger *et al.*, 2011) although such concerns may have arisen at this point in time even without sea level rise. There are also concerns – a source of great anxiety to many – that entire islands, perhaps entire nations, may not survive this century in the Pacific (Maas & Carius, 2012). In 2009, the Prime Minister of Tuvalu, Apisai Ielemia, stated that

For a highly vulnerable country like Tuvalu, we cannot just sit back and watch our homeland slowly disappear . . . time is running out fast. Climate change could well be the greatest

challenge that humanity has ever known. I make a very strong plea to all to act quickly and responsibly, to ensure that countries like Tuvalu do not disappear (MacLellan, 2009: 7).

In 2012, Anote Tong, the Prime Minister of Kiribati gave more perspective.

Over the years we have convinced ourselves that there is very little we can do as small island states to influence global events even though they will affect our lives so profoundly. Perhaps in our typical trusting Pacific Way, we have always believed that our bigger brothers will look after our interests in this highly competitive global community. And whilst that may be true to some extent, experience has shown us that each have their own priorities . . . that is the reality of this world and it is imperative that we understand that reality. The challenge of Climate Change has been the severest test of the international community's genuine desire and ability to redress imbalances wherever they occur; to ensure that democracy is truly applied universally not only when convenient; that the rights of all citizens of this planet to a good life is guaranteed (Tong, 2012).

The communiqué of the Pacific Island Leaders after their annual Forum in 2011 affirmed that 'climate change remains the single greatest threat to the livelihoods, security and well-being of the peoples of the Pacific' (Forum Communiqué, 2011).

Through international bodies (like the UNFCCC), the appeals of Pacific Island leaders, together with those of other nations deemed 'most vulnerable' to twenty-first century climate change and sea level rise, have resulted in considerable funds being made available by richer ('polluter') nations to help underwrite the costs of adaptation. For example, the (target) USD 10 billion Adaptation Fund, negotiated at the Copenhagen Climate Change Summit (COP-15) in 2009, is available to all independent Pacific Island nations. Such funding is welcomed by national leaders: a communiqué from the 2012 (Pacific Islands) Forum Economic Ministers' Meeting (FEMM), held in Tarawa, Kiribati stated that

Adaptation finance is critical and urgent to enable Forum Island Countries to respond to the adaptation needs of their people. In this context, Ministers reiterated the need for strengthened national systems to plan for, access, deliver, absorb and monitor climate change financing fund facilities (Forum Economic Ministers' Meeting, 2012).

Yet money is not the sole answer and, given the indifferent record over the past 25 years of Pacific governments and regional agencies using such funds to develop appropriate climate change adaptive solutions and ways of mainstreaming these, a non-partisan observer might question the wisdom of the belief of richer nations that continuing to direct adaptation funding of this kind to governments and regional agencies will significantly change the outlook for most people in the Pacific Islands in the foreseeable future (Nunn, 2010).

Pacific Island communities, especially those in more rural/peripheral locations, have long been accustomed to looking after themselves and making their own decisions, particularly about food producing systems and environments more generally (Bridges & McClatchey, 2009; Rasmussen *et al.*, 2009). Most importantly, they have done all these things largely without finance; work for the community good is considered part of every individual's responsibilities. The availability of finance can undermine such societal cohesion, which is a long-standing aspect of community resilience in island societies, although it clearly began to be eroded in places before climate change finance became widely available (Campbell, 1990; Ravuvu, 1988; Fazey *et al.*, 2011).

There is a groundswell of awareness in the Pacific Islands about the nature of climate change and the impotence of most of the adaptive solutions that have been tried thus

far (Kelman, 2010). Non-governmental organizations (NGOs) and communities are increasingly finding a voice and demanding effective and sustainable adaptive solutions that are appropriate to the environments and the cultures of the Pacific Islands (Nunn, 2009b; Lazrus, 2012). While there is much passion around such questions, the key issue is how best to act now so as to minimize the undesired effects of twenty-first century sea level rise.

### *Enabling effective and sustainable adaptation*

Over the past 25 years, there appears to have been little questioning of the efficacy or the sustainability of adaptation options proposed and/or trialled in the Pacific Islands region. In addition to the issue of many solutions being environmentally and culturally inappropriate (see above), it appears to have been generally unquestioned that these adaptation solutions will actually solve the issue they were designed to address, which is not always the case (Mimura & Nunn, 1998).

For example, the utility of building a seawall in one place may simply transfer the problem of shoreline erosion elsewhere; there are many examples of poorly designed seawalls in the Pacific Islands that not only fail to solve this problem but also create new problems. Similarly, the use of fixed-term 'pilot' projects (funded externally) for climate change adaptation within particular communities may have helped the targeted problem over the life of the project, but have often led those communities to believe that such problems cannot be overcome without externally funded projects, resulting in a reduction of community resilience (increased community dependence).

Effective adaptation to climate change in the Pacific Islands needs to acknowledge the unique environmental and cultural contexts in this diverse region (Duncan, 2008). With specific reference to the effects of sea level rise on livelihoods, most proposed adaptive solutions fail to acknowledge the nature of the insular reef-lagoon ecosystems, which are practically unique to the low-latitude Pacific Islands, and with which Pacific Island coastal dwellers continue to interact in largely singular ways (Foale *et al.*, 2011; Szabó & Amesbury, 2011). In addition, a lack of useful data concerning nearshore and coastal processes and their variability add a degree of uncertainty that should be factored into proposed solutions. Unless such differences are acknowledged, it is unlikely that proposed adaptive solutions can be effective.

The issue of how to sustain effective adaptation in the Pacific Islands has been little discussed by stakeholders. It has been assumed that showing communities what to do is going to result in them doing it indefinitely. One of the most significant barriers to sustaining effective climate change adaptation in the Pacific Islands is the almost universal perception of people living in the region that climate change is a foreign preoccupation, one that was created by people beyond the region who therefore have a moral duty to resolve it on behalf of the region. This perception is driven largely by the fact that almost all information received by people in the Pacific Islands about climate change over the past 25 years has been in a foreign language, mostly in English, and communicated in ways that do not acknowledge the cultural mores of the region's peoples (Nunn, 2009b).

For climate change adaptation to be effective and sustained in the Pacific Islands region, it is essential that its peoples take ownership of it, meaning that it is discussed in vernacular languages, familiar and appropriate cultural contexts and gender roles, and that the dependence on funding (particularly external aid funding) is reduced (Nunn, 2009b; Lane & McNaught, 2009; Rudiak-Gould, 2012). Some steps towards these goals have been taken, but these have been sponsored mostly by NGOs rather than

governments; one noteworthy exception has been the work towards producing an *iTaukei* climate change glossary in Fiji to enable the effective communication of the issues to rural dwellers.

A reduction in dependence by Pacific Island governments (and to a lesser extent, by beneficiary communities) on external funding for climate change adaptation (and environmental issues more generally) will not be popular with government leaders, who currently struggle to fund the range of national priorities from shrinking/stable revenue streams (Prasad, 2008). Yet, given that the costs of climate change adaptation for most current donor countries are themselves likely to escalate sharply in the next few decades, it is possible that donor contributions will be reduced proportionately, leaving Pacific Island nations to cope with the increasing costs of climate change adaptation with decreasing income.<sup>6</sup> The importance of Pacific nations owning the issue of climate change adaptation is clear; the fact that more will need to be done with less in the future should encourage governments and other local stakeholders in the region to think of adaptive solutions that are less expensive, perhaps resorting to traditional solutions based on unremunerated community-sponsored efforts using, wherever possible, materials freely available locally.

Leadership is key to the success of embedding and sustaining effective climate change adaptation in the Pacific Islands (Schwarz *et al.*, 2011). For much of their post-colonial (or recent) history, there have been well-documented tensions in many Pacific Island nations between the national (elected) government and communities, which are accustomed to making decisions on their own, particularly those that affect the land they own and the environments that sustain them. Around environmental and livelihood issues, the impotence of national policy and legislation in guiding behaviour in rural parts of the Pacific Islands is well known (Nunn, 2010). Today, the influence of most Pacific Island governments, particularly in archipelagic nations, dwindles from core to periphery (Nunn, 2008; Alley, 1999; Turnbull, 2004).

Most aspects of governance, particularly environmental governance, in non-core rural communities occur within traditional contexts in the Pacific Islands. In most situations, this means that decisions affecting the whole community in response to often-unprecedented environmental stressors (such as the effects of sea level rise) are taken by hereditary leaders, often elderly men, long-resident in these communities, with little formal education. While such a decision making apparatus may have been effective in times past when human-environment interactions were largely sustainable, it is generally poorly equipped to deal with contemporary issues such as climate change adaptation requiring long-term informed decisions with which all members of the community are engaged rather than simply compliant (Iati, 2008).

There are emerging tensions in many non-core communities around livelihood-related issues driven by climate change that threaten these traditional decision making structures (Schwarz *et al.*, 2011). An example comes from Butaritari Island (Kiribati) where younger adults are becoming increasingly frustrated by the short-term decisions of their traditional leaders, decisions that fail to acknowledge the likely effects of future sea level rise on food gardens and shoreline stability (Nunn, 2008).

It is likely that future environmental decision making in many rural communities will in the next few decades be driven increasingly by consensus, particularly as some stakeholders become more aware of the wider context of observed environmental changes (Nunn, 2008; Schwarz *et al.*, 2011). Rural dwellers in the Pacific Islands mostly ascribe the increasing frequency of ocean/river flooding they experience to short-term climate variability (Lata & Nunn, 2011; Lauer & Aswani, 2010) but it is likely that, as



flooding worsens over the next 10–15 years, it will be increasingly recognized as a manifestation of long-term sea level rise requiring an appropriate long-term solution that will likely be agreed by both traditional (elder) leaders as well as better-informed younger adults.

Religious beliefs are widespread among many people living in the Pacific Islands and guide their decision making and everyday behaviour to a degree that often surprises outsiders. While effective solutions to climate change linked issues need to acknowledge such beliefs (Mortreux & Barnett, 2009), it is also clear that religious leaders have influence that allows them to be effective agents for climate change adaptation in the Pacific Islands (Thornton *et al.*, 2012). The ecumenical Pacific Conference of Churches issued its Moana Declaration, which deals with various climate change issues, in April 2009 and has since set up a climate change unit.<sup>7</sup>

A final issue in the development of effective and sustainable adaptation to climate change in the Pacific Islands is the dissemination of solutions. Given that most rural communities are dispersed and operate sometimes almost exclusively within traditional contexts, it is not always straightforward for national bodies to make contact with them (Lazrus, 2012). Indeed, given that traditional contexts for communication with such communities are comparatively time-consuming and optimally require face-to-face discussion in preferred vernacular languages, other methods of disseminating information about climate change adaptation rather than a top-down approach are more likely to be effective, particularly in more populous, archipelagic countries in the region. More effective methods may involve production of visual materials in vernacular languages and oral broadcasts for radio.

Studies of the spread of a belief in seawalls as appropriate solutions to shoreline erosion (see above) show that many communities emulate solutions that they adopted elsewhere. Emulation of this kind has also proved to be an important way of spreading information about locally managed marine areas and similar conservation initiatives, and could be an useful model for spreading information about effective and sustainable climate change adaptation (Aalbersberg *et al.*, 2005; McLeod *et al.*, 2008).

### *Food security*

Throughout the last 50 years or so along many inhabited Pacific Island coasts, unsustainable human-environment interactions have been increasing to the point where some coastal ecosystems have experienced significant losses in useful bioproductivity. Together with other aspects of climate change, sea level rise will be an additional stressor for many of these ecosystems. It seems unlikely that current trends of useful bioproductivity loss can be reversed while such pressures continue to grow and multiply. Two important food producing ecosystems – reef-lagoon ecosystems and coastal-plain ecosystems – are of particular concern, principally because human dependence on them is almost ubiquitous in the Pacific Islands.

Most coastal and near-coastal rural communities subsist to some degree from foods obtained from nearshore reef-lagoon systems. In many places, coastal communities generate surpluses for trade or sale, leading to increased pressure on production systems which have also likely been stressed by changes in sea level (McGregor *et al.*, 2009; Turner *et al.*, 2007). Losses of useful bioproductivity of reef-lagoon systems are likely to be exacerbated mid-century by increased coral bleaching and the effects of ocean acidification (Hoegh-Guldberg, 2011). Coastal plains are important to most coastal communities because of the food crops grown there, many of which (like coconuts and most root crops) are intolerant of saline groundwater. As more land is lost along the

fringes of such coastal plains as a result of sea level rise in the next few decades, the spread of saline groundwater will further reduce the utility of these areas for food production.

The net effects will be that by the middle of this century, many coastal communities in the Pacific Islands region will be unable to produce enough food locally to feed their inhabitants, many of whom do not have enough money to routinely purchase food. This may lead to food crises for many coastal communities and it would be better to anticipate these situations and take appropriate steps sooner rather than later (Barnett, 2011). Improved management of existing food producing ecosystems is clearly desirable but perhaps impractical in most places, given the multiple stressors confronting them at present. Innovative approaches are needed in many places, including better utilization of upland areas for food production, perhaps involving (re-) development of terrace and raised-field systems (Thaman, 2008). Fishponds are not widespread along Pacific Island coasts but are innovations that could be used to supply fish (and other seafoods) for individual communities which would clearly apprehend the need for effective and sustainable management.

#### *Relocation of vulnerable people and infrastructure*

When it appeared likely that sea level was going to rise only around 50 cm this century (IPCC, 2007), talk about the need to relocate coastal settlements and infrastructure was regarded as extreme by many stakeholders, both within and beyond the Pacific Islands region, in all but a few cases.<sup>8</sup> While this position was debated, the situation has now changed with reliable projections of 1–2 m of sea level rise this century (see above) and a continuation of the upward trend thereafter for at least several decades, probably far longer (Jevrejeva *et al.*, 2012). Most low-lying coastal settlements in the Pacific Islands region can no longer hope to remain where they are currently for more than a few decades; many will have to be relocated, wholly or partly, within this timeframe (Campbell, 2010).

Such predictions have been discussed by scientists for some time but, owing largely to the resistance of individuals and communities to relocation, there has been hardly any recognition among stakeholders in the Pacific Islands region about the inevitability of relocation. This is understandable, particularly as recent changes in society have cemented the views of most people that coasts are unchangeable and therefore suitable for investing money in to build dwellings and infrastructure, as well as planting crops. Yet, as shown by the historical examples discussed earlier in this paper, nature is no respecter of human preferences. Coastal zones are changeable by definition; most coastal plains and all atoll islands in the Pacific became inhabitable only as a result of sea level fall 4000–1000 years ago (Dickinson, 2003; Nunn, 1994) so it should be no surprise that their habitability is now under threat from sea level rise.

At present, some coastal settlements are migrating slowly inland and upslope where possible (Campbell, 2010) but many others are adapting *in situ*, their inhabitants often believing that the effects of sea level rise they have witnessed are short-term and will shortly be reversed<sup>9</sup> (Mortreux & Barnett, 2009; Lata & Nunn, 2011). *In-situ* adaptation often involves building artificial shoreline-protection structures and elevating the foundations of buildings and key infrastructure (Figure 8). In Nadi Town (Fiji), the overwhelming belief amongst affected people is that deforested catchments instead of sea level rise have led to an increased flood frequency and severity. Yet, as discussed above, sea level rise is indeed likely to be the major cause of this, an interpretation that is resisted because of the more general long-term implications, particularly the societal



Figure 8. *In-situ adaptation in coastal villages is not a long-term option, but is currently favoured because of people's belief that the flooding experienced is a manifestation of climate variability not climate change: this view is of (A) elevated dwelling, (B) river-bank structure to combat erosion, (C) elevated pathway, and (D) elevated water tank in Muanaicake Village, Rewa Delta, Viti Levu Island (Fiji). [Photos A, B and D by Shalini Lata, used with permission]*

and economic ones; trees can be replanted on grassy slopes, river channels can be dredged, but sea level rise cannot be readily stopped. It has been proposed that the flooding trend will be reversed if the mouth of the Nadi River, from which most floodwater derives, is diverted (Chandra & Dalton, 2010). This will not succeed if sea level continues rising, which seems inevitable. Far more effective would be to develop an inland upland site for a new Nadi Town and induce residents to move there. Socio-economic practicalities of this have been discussed for the Pacific Islands (Campbell, 2010).

More detailed projections of the impacts of sea level rise this century have been made for the Rewa River Delta (Viti Levu Island, Fiji), the lower part of which is home to some 28 000 people, at least 60 per cent of whom are likely to be forced to move this century as a result of sea level rise (Figure 9). Discounting population growth, the actual number affected is likely to be greater because of associated changes in flood frequency and magnitude in the upper parts of the modern delta (Lata & Nunn, 2011).

The situation for atoll islands has been studied by many scientists (Woodroffe, 2008; Terry & Chui, 2012; Dickinson, 2009; Barnett & Adger, 2003). Most such islands are

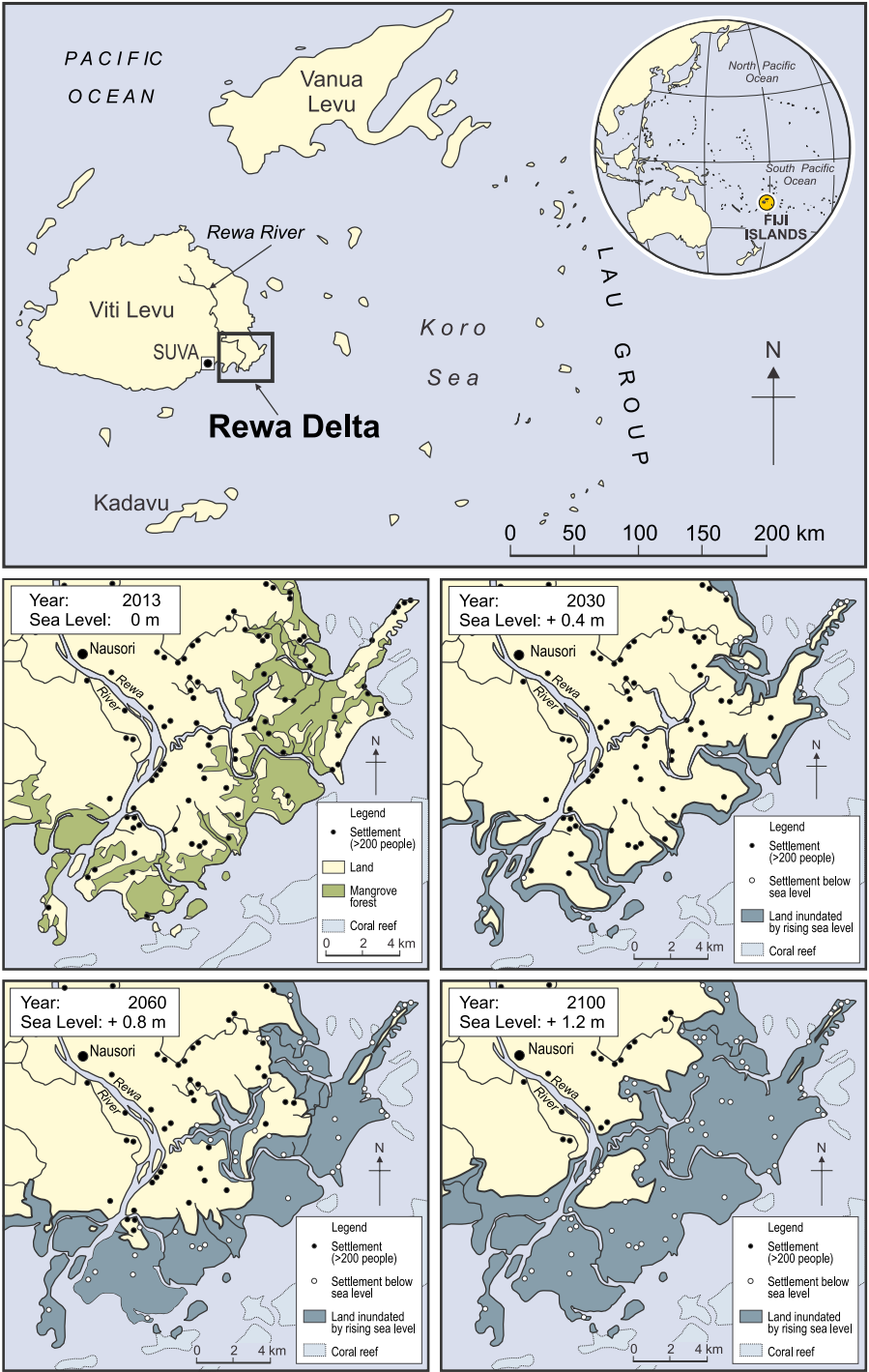


Figure 9. Scenarios for inundation of the Rewa Delta, Viti Levu (Fiji) (updated from Lata & Nunn, 2011). Top left map shows the lower part of the Rewa Delta today with all principal settlements, mangrove forests and coral reefs. The other three maps show scenarios for direct inundation by rising sea level in 2030, 2060 and 2100; open circles in these maps denote settlements that will be below sea level by particular times.



built on a foundation of emergent reef-rock that is cloaked by largely unconsolidated sediment. Once sea level at high-tide rises above the surface of this reef-rock, lateral erosion of the sediment cover will be rapid. Based on historical data, it has been estimated that such islands will become uninhabitable as a result of sea level rise as early at least as the year 2050 in the case of atolls in the Caroline Islands (Micronesia) and northern Cook Islands (Dickinson, 2009).<sup>10</sup> Since atoll livelihoods depend so heavily on the freshwater lenses within these islands, it is possible that many atoll islands will be unable to sustain human life well in advance of these dates, particularly as a result of increasingly frequent seawater overwash (Terry & Chui, 2012).

### Conclusions: the end of the Pacific?

History demonstrates that sea level change fundamentally alters the habitability of islands; the effects of postglacial drowning are more pervasive in island regions than elsewhere. Sea level fall in the past few thousand years allowed tropical island coasts to grow seawards and nearshore reef-lagoon environments to develop. This sea level fall also led low (atoll) islands to form. This sensitivity explains why today, as sea level has been rising for some 200 years and is projected to continue to do so for the foreseeable future, most island coasts are experiencing erosion and more frequent flooding that threaten livelihood sustainability, and even in some cases, the habitability of entire islands. This will spell the end of today's Pacific in many ways: a radical change in geography spawning fundamental changes in settlement patterns and communications infrastructure, subsistence systems, societies and economic development. Breakdowns in the social fabric of the societies of the region threaten their essentially pacific character (Weir & Virani, 2011). Cultural identities are at risk (Adger *et al.*, 2011).

Such changes may be unavoidable but their degree and impacts could be lessened by effective long-range anticipatory planning and no-regrets interventions (Kates *et al.*, 2012; Hay & Mimura, 2010). Coastal settlements could be relocated sooner rather than later, available land in less vulnerable locations being earmarked for particular communities and appropriate infrastructure created to induce them to move. Livelihood developments could be mapped for particular communities, with new sources of food production gradually replacing the old. Societies could be realistically informed about what is likely to happen in the future, based on the best possible scientific information, and stakeholders empowered to act appropriately. Persons of influence at community level (rather than in national governments) should be given the information they need to make informed and sustainable decisions within their communities (Iati, 2008).

### Acknowledgements

More than 25 years of living and researching in the Pacific Islands has led me to the positions I take in this paper. I am grateful to the University of the South Pacific, to countless of its staff and students, as well as innumerable persons of influence in rural communities throughout the Pacific Islands region for helping me frame those positions. Dr Michael Carson (Australian National University) helped compile Figure 2, our intention being to develop this argument for a focused publication elsewhere. An anonymous reviewer made numerous insightful comments that improved the first draft of this paper.

### Endnotes

- 1 Without its fringing seas, the Pacific Ocean covers an area of some 165 million km<sup>2</sup>. The land area totals about 67 700 km<sup>2</sup> and for the purposes of this paper refers to the 13 sovereign



nations confined to the Pacific Ocean, namely Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. For reasons of geographical and cultural similarity, the Commonwealth of the Northern Marianas Islands and the territory of Tokelau are also included. Papua New Guinea is not included because it is geographically different from the other nations considered. Population data for the nations studied were obtained in August 2012 from 2010 data in the PRISM database ([www.spc.int](http://www.spc.int)).

- 2 Permanent inundation (flooding) in this context means a landward movement of the shoreline, not necessarily one associated with shoreline erosion.
- 3 I cannot resist stating my long-held view that the overwhelming majority of such projects have been in communities which are less than two hours drive from a four-star hotel, something that to my mind speaks to the degree of engagement by most donor representatives, but which also has ensured that the core-periphery gradients of awareness and assistance in Pacific Island nations have been steepened.
- 4 This was based on Scenario A1F1, which assumed a best estimate temperature rise of 4°C (2.4–6.4°C), and is the upper limit of the range 26–59 cm for 2090–99.
- 5 On 22 November 2008, the author made a presentation to the Nadi Chamber of Commerce about the likely impacts of future sea level rise on the continued viability of the town in its current location. The audience was polite, although the Lord Mayor reminded me that I did not know the mind of God, who would determine Nadi's fate, and several developers of coastal projects accused me of undermining their drive to prosper.
- 6 This is a general comment regarded as correct for the longer-term, even if it does not accurately capture the present situation in which climate change finance for adaptation by Pacific Island nations is greater than ever. Under the terms of the UNFCCC, 'polluter' nations with a high-level of greenhouse-gas emissions are required to contribute to a fund to underwrite adaptation costs by the most vulnerable countries, which includes all Pacific Island nations.
- 7 Details of the Climate Change and Resettlement Programme of the Pacific Conference of Churches are available at: [www.pcc.org.fj/climateresettle.aspx](http://www.pcc.org.fj/climateresettle.aspx)
- 8 Relocation is something with innumerable precedents in the history of the Pacific Islands; particularly prior to the start of the twentieth century, settlements and communities were not fixed, often moving in response to particular events.
- 9 There is some truth in the belief that the rapid rate of sea level rise in some (western) Pacific Island groups will decrease in the next two decades as a result of cyclical changes in various interannual climatic phenomena in the Pacific (Timmermann *et al.*, 2010). This decrease may give renewed hope to planners in the Pacific Islands but will not alter the long-term (end-century) projections.
- 10 Dickinson used sea level projections from the 4<sup>th</sup> Assessment Report of the IPCC, which are considered underestimates, so his actual dates for island uninhabitability should now be considered as unduly optimistic.

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