Empowered lives.
Resilient nations.

Climate Change and Pacific Island Countries

Asia-Pacific Human Development Report Background Papers Series 2012/07

Abstract

Since being first settled by humans more than 3000 years ago, the Pacific Islands region has experienced innumerable changes in climate that have affected livelihoods, something that underlines the sensitivity of such comparatively small and resource-constrained landmasses to extraneous change but also helps explain why their inhabitants developed resilience strategies that remain important today.

During the past 100 years, the region has been affected by increased temperatures and sea-level rise, together with other climate-linked changes including variability in ENSO periodicity and tropical-cyclone frequency. Owing to the increasing pace of globalisation in the region during the same period, together with growing populations and demands on island resources, it is difficult to isolate changes ascribable to climate change; some of the clearest of these are the increases in coral bleaching, incidences of coastal flooding and shoreline erosion. Despite knowledge about the causes and effects of climate-related environmental (and related) changes in the region, supported by considerable financial aid and other external assistance, the awareness of most Pacific people about climate change and the extent of community buy-in to appropriate adaptation agendas have been negligible. Many governments have been unable to effectively disseminate awareness about climate-change stressors and adaptive solutions; most community-level decision-makers are unable to make informed decisions about long-term adaptation to observed changes.

Warming and sea-level rise are both expected to accelerate within the next 100 years or so, causing profound changes to environments, societies and development aspirations within the region. Re-location of people from vulnerable to less-vulnerable locations within the region is unavoidable and should be planned for sooner rather than later. International partners of Pacific Island nations should become more aware of the pathways for embedding effective adaptation in the region. Regional agencies and governments should challenge and re-define their roles in promoting and disseminating climate-change adaptation strategies within the region. Awareness-raising should focus on persons of influence in Pacific Island communities to allow them to make informed and sustainable decisions about the environments they occupy.

Key words: Pacific Islands, climate change, vulnerability, resilience, adaptation

The views expressed in this publication are those of the author(s) and do not necessarily represent those of the United Nations, including UNDP, or the UN Member States.

*This paper was commissioned by the Human Development Report Unit as a technical background paper to inform the Asia-Pacific Human Development Report, "**One Planet to Share**". The data may differ from that finally presented in Asia-Pacific Human Development Report. Readers may contact the author directly for any clarifications, queries on data, inferences, and conclusions or to engage in discussion. This paper has not been copy edited.*

Peer Reviewers:

External: John Connell, Sharon Bhagwan Rolls

UNDP: Anuradha Rajivan, Caroline Borchard, Thomas Jensen, Rohini Kohli, Niranjan Sarangi, Omar Siddique, Bishwa Nath Tiwari, Susan Wong

Table of Contents

Executive Summary

Future climate change poses a set of fundamental challenges to livelihoods in the Pacific Islands region. During their more than 3000-year occupation of these islands, people have developed an understanding of their natural environments, their production potential and their vulnerabilities, and the variations in these through time as forced by climate change. Within the past 150 years or so, globalization (through periods of both colonization and independence) has reconfigured human interactions with natural environments on many islands, rendering many of these less sustainable than in the past. In addition, within recent decades, Pacific Island countries have become part of the global community, now focused on development and economic growth, dependent on trade with other countries, and aid from these for most initiatives associated with improving environmental sustainability.

Over the past 100 years, temperature has exhibited a net rise within the Pacific Islands region of about 0.6°C, as a result of which sea level has risen about 17 cm causing widespread coastal flooding and shoreline erosion. There has also been a measurable drop in sea-surface pH (more acid), which is implicated in coral-reef degradation, and a general increase in both the frequency and intensity of tropical cyclones which has brought proportionately more destruction by wind and storm surge to an increasingly larger part of the region. Since the 1970s, ENSO has become stronger and more regular, currently occurring every 3-5 years and generally associated with a drought in the western tropical island groups. Within the past 10-15 years, there have been accelerations in the rates of both temperature rise and sea-level rise.

Responses to these changes have been generally inadequate, not least because of problems associated with recognizing them as regional (rather than local) and a product of climate change (rather than climate variability). Much international assistance to the region has failed to either increase awareness or produce appropriate and sustainable adaptation. Regional agencies represent national interests but have proved largely reactive not proactive in setting agendas for environmental sustainability. While generally adhering to international preoccupations around climate change, national governments in the Pacific region have generally failed to engage their populations in adaptation strategies. Most communities in the region remain largely unaware of climate-change challenges although many are actively responding to its manifestations. While it is desirable to drive adaptation to climate change at the community level, there are barriers to this associated with culture (particularly the perception of climate change as a foreign preoccupation) and belief systems (role of Divine providence in environmental futures) that lead to widespread denial of long-term climate-change projections.

For the next 100 years, temperatures are expected to rise 1.4-3.7°C in the Pacific Islands region, which is thought likely to cause sea level to rise 120-200 cm by the year 2100. Warming is likely to have impacts on a range of livelihood factors, from food security to disease, while a sea-level rise of this magnitude will result in major changes to the habitability of Pacific Island coasts, where most people live today in this region. Coral-reef degradation will result from increased incidences of bleaching as well as ocean acidification.

The present high frequency and intensity of tropical cyclones will continue into the foreseeable future, as will the current ENSO periodicity.

It is likely that food security in the Pacific region will be challenged from many directions by climate change over the next few decades. The probable loss of food productivity from nearshore marine ecosystems is perhaps of greatest concern. The aspirations of many Pacific Island countries to economic development are also likely to be stymied by climate change, particularly as the costs arising from changed geography (from sea-level rise) are absorbed. Over the next few decades, it seems unavoidable that large numbers of people will be displaced from their present homes and livelihood bases by sea-level rise and forced to re-locate these in less vulnerable locations elsewhere. It is argued that the key to reducing the impacts of such changes is effective communication of scientific agendas and appropriate adaptation options to a range of stakeholders.

Recommendations are as follows.

Recommendation 1: It is recommended that international partners of Pacific Island nations make far greater efforts to ensure the effectiveness of their assistance for climate-change adaptation.

Recommendation 2: Regional agencies and governments should realistically examine the effectiveness of their present aspirations around climate-change adaptation, and re-define their roles accordingly.

Recommendation 3: Persons of influence in Pacific Island communities should be empowered to make informed and sustainable decisions about the environments they occupy.

Preamble

Located in the world's largest ocean, which covers almost one third of the Earth's surface, the Pacific Islands comprise only a comparatively small land area. While this is indisputable when formally measured, it is worth noting at the outset that in most Pacific Islander traditions, the land is subordinate to the ocean in terms of its reputation as a sustainer of lives; many such traditions characterize the Pacific as "a sea of islands" (Hau'ofa, 1993) rather than an ocean dotted with islands as it is viewed through most non-Pacific eyes (Ward, 1989).

People began to occupy Pacific Islands more than 3000 years ago, crossing open ocean distances of more than 1000 km at a time when people elsewhere in the world rarely sailed more than 10 km offshore. This remarkable fact underlines the point that the Pacific Ocean has long been regarded by the people of its islands as friendly: as a provider, a sustainer, a constant in the development of their cultures. It could be that the point at which this view began to be undermined was at the first meeting about climate change in the Pacific Islands ever held; this was in 1988, at Majuro in the Marshall Islands, and it was opened by the President, Amata Kabua, who said

> "It is truly frightening to think that our ocean will turn against us. We have been sustained by the ocean for two millennia. It has been bountiful and continues to yield to us its bounty. We have learned that this harmony may be interrupted by the action of nations very distant from our shores. 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."

Since that time, the degree to which Pacific people, encouraged by global climate-change rhetoric, have turned against "their" ocean has been remarkable in turn. As Tamari'i Tutangata, the Director of SPREP[1] in 2000, mused

> "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 we 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?"

In today's Pacific Islands, the ocean is commonly an enemy, an aggressor threatening to attack the land, a false friend delinquent in providing the same degree of sustenance it provided in the past to the increasing numbers of people living along its borders. Yet as the traditional view has become dislodged, so a new era of realism, particularly amongst younger Pacific Islanders, has been born. Today the Pacific Islands and Ocean are discussed as objects of management, their drivers modelled, their processes simulated, their states projected from the present into the past and into the future.

[1] Secretariat of the Pacific Regional Environment Programme

It is in the context of this changed Pacific world that this report is presented. Climate change poses a formidable set of fundamental challenges to life in the Pacific Islands but, like most such challenges, they could be managed so that their impacts are minimal. Such management is commonly known as adaptation and for this to be effective, it is necessary for all people living in the islands (or having their interests at heart) to subscribe to and sustain effective adaptation strategies.

Twenty years ago in the Pacific Islands region, as elsewhere, there was much despair around what kinds of adaptation to climate change would be effective and could be sustained. Today there is less of this; scientists are mostly agreed on the solutions needed to sustain livelihoods in the Pacific Islands in the face of future climate-driven stresses but there is increasing despair that these solutions will be adopted and sustained because of a lack of understanding and support from national and subnational decisionmakers (Alley, 1999; Barnett and Adger, 2003; Turnbull, 2004; Nunn, 2009b).

In addition, owing to its conspicuous vulnerability to future climate change, the Pacific Islands region has come to the forefront of the world stage. In many quarters, it is envisaged as being on the "front line" of climate change, "the canary in the coalmine", with entire islands apparently being destined to "disappear" or "sink" within the next few decades. Such hyperbole masks the reality of the situation of many Pacific islands which, while not iconically vulnerable in the sense that the atoll islands of Tuvalu have become (Farbotko, 2010), have still to meet profound challenges.

1. Setting the Scene: The Pacific Islands

This section establishes a baseline for understanding climate-change impacts on the Pacific Islands and their peoples. Section 1.1 discusses the nature of climate in the region, particularly how it has defined the resource base, as well as the nature of past (long-term) climate change and (shorter-period) climate variability. Projections for future climate change in the region are presented.

Section 1.2 looks at the islands' human inhabitants. People have lived for more than 3000 years in the Pacific Islands, developing subsistence lifestyles that remained little changed until the 20th century when nascent globalization began to have an ever-increasing effect. Understanding human attitudes towards the natural environment and the forces that make it change are crucial to developing effective strategies for climate-change adaptation. So in this section are explored culture and cultural diversity, the persistence and loss of tradition, and land tenure. All Pacific Island nations are "developing", some of them among the "least developed". All have traditionally democratically-based systems of governance. Most have economies that have registered negative annual growth for the last few years, a few slightly positive. Few Pacific Island nations are on track to achieve any of their Millennium Development Goals (MDGs); most Pacific Island nations have Human Development Index (HDI) scores that have increased slightly in the past decade. Projections for future changes in population, economy and governance are presented.

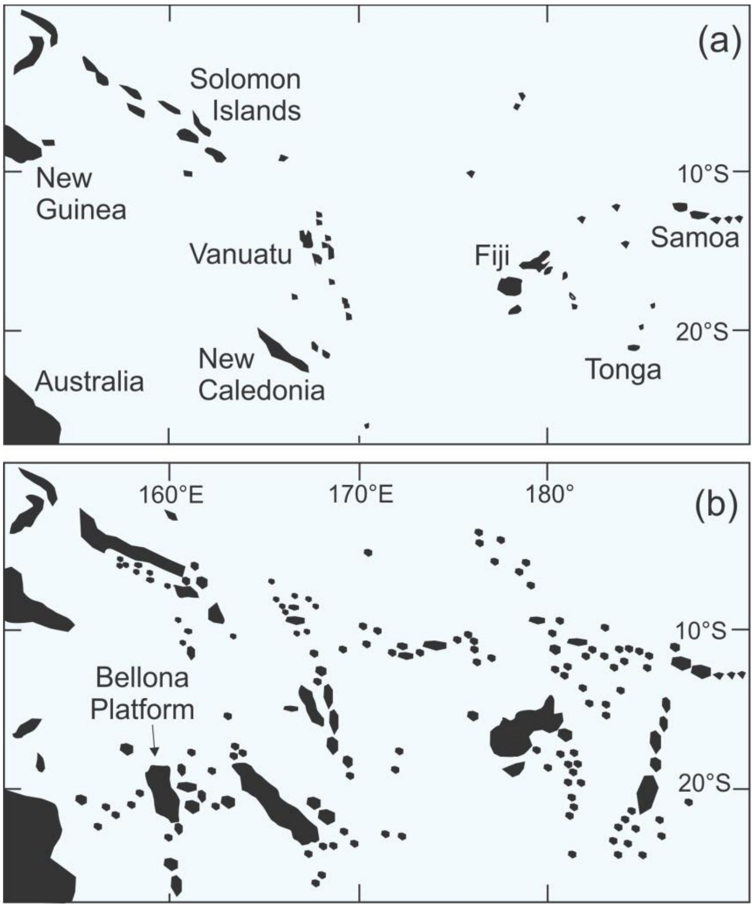
Section 1.3 examines the sensitivity to climate change of the Pacific Islands and their main livelihood-linked exposure. It begins by examining the last millennium and explains how climate-driven environmental changes did impact traditional societies in the region, identifying those traits that continue to compound the vulnerability and resilience of modern societies in the region. Special attention is paid to the last 100 years or so in which societies in the Pacific Islands region have evolved rapidly, generally amplifying their vulnerability to extraneous change. A general account of the sensitivities of the islands and their inhabitants to future climate change is presented.

Section 1.4 focuses on the inherent resilience of natural and human systems in the Pacific Islands region. In the latter context, it is important to understand the cultural resilience of societies in the region, as well as the effects of external assistance (ODA) to their capacity to develop and sustain effective strategies for climate-change adaptation.

1.1 Climate change and climate variability in the Pacific Islands region

When climate change is considered for the Pacific over tens of thousands of years, even longer, it is clear that the region's climate has varied significantly. During the coldest part of the last ice age (20,000 years ago), temperatures in the tropical parts of the Pacific may have been 3-4°C cooler than today; coral reefs were consequently less extensive and less diverse. Beyond the Pacific tropics, the cooling was generally greater. In addition to this cooling, sea level at this time was around 120 metres lower than today, which led to a strikingly different geography in many parts (Figure 1.1). Large islands existed where only (groups of) smaller islands exist today, something that would in turn have affected climate and ocean circulation.

Figure 1.1. Contrast in the geography of the Southwest Pacific Islands region during the past 20,000 years



Source: Nunn, 2009a.
Note: Map (a) shows the southwest Pacific region as it is today, Map (b) the way it appeared 20,000 years ago during the coldest part of the last ice age when sea level was 120 m lower. The difference is striking. Not only were there more islands 20,000 years ago, but those that exist today were larger and closer together. Some large islands like the Bellona Platform have disappeared altogether.

The present climate of the Pacific Islands region was in place about 4000 years ago and, while comparatively minor changes have been registered since that time, the region's climatic configuration has remained essentially unchanged since. Each island in the Pacific Islands region is so small that maritime influences overwhelm its climate and have largely done so since those islands first emerged above the ocean surface. The general pattern of Pacific Basin climate is most easily understood by the presence of two gyres (large-scale systems of air and surface-water circulation).

Movement in the South Pacific gyre is anticlockwise, with air and surface water being driven from west to east in the Southern Ocean, northwards off the west coast of South America, east to west across the tropical South Pacific, and then south to north off eastern Australia. Key elements in this gyre are the strong, generally stationary, high-pressure centre (anticyclone) in the Southeast Pacific (around Easter Island), and the seasonally-variable South Pacific Convergence Zone (SPCZ) that develops in the Southwest Pacific.

This convergence zone, where two air masses converge, is a zone of atmospheric instability, as is the longer Inter-Tropical Convergence Zone (ITCZ) which extends across the equatorial Pacific between the two gyres. The seasonal movements of the ITCZ, where the two tradewind belts converge, are important in bringing rain to many islands in this part of the Pacific that might not otherwise receive sufficient rainfall to be habitable.

Movement in the North Pacific gyre is clockwise, with air and surface water moving from east to west across the tropical North Pacific, north off the coast of East Asia and Japan, west to east in the northernmost Pacific, and south off the west coast of North America.

The principal variations to this simple picture are caused by short-term climate variability, the understanding of which has improved substantially in the past few decades. The main causes of variability are inter-annual changes, the best-known of which is the El Niño Southern Oscillation (ENSO) which involves a breakdown of the gyres, especially in their low-latitude parts, resulting in drought and or unusually-high rainfall on different island groups, as well as sea-level changes that may be sustained for several weeks. There are other oscillations such as the Pacific Decadal Oscillation that are less readily detectable than ENSO yet which have the potential to amplify or dampen its effects. The principal short-term climate phenomena to affect the tropical Pacific are tropical cyclones[2]; these are usually confined to the western tropical Pacific but become more frequent and develop beyond this region during ENSO-negative (El Niño) events. Tropical cyclones have the potential to severely impact livelihoods on Pacific Islands.

Owing to the dominance of maritime influences in the Pacific Islands, most experience little seasonal variation in climate. The main cause of variation on many is the increased cyclonic rainfall during the high-sun season; on many equatorial islands, rainfall is seasonal because of the movements of the ITCZ. The widespread lack of annual climatic variation means that food-production systems in the Pacific Islands have not been as complex as in subsistence societies elsewhere. For while there have been periods of less (and periods of plenty), most island societies in the past 200 years or so have become accustomed to living in a period of adequacy.

This view has been bolstered by the rich marine-food supplies that can be obtained from the coral reefs that surround many islands in the tropical Pacific. As noted above, marine foods have been a part of islander diets ever since people first ventured into this island world. Since that time, coral reefs (and their associated lagoons) have generally remained viable and productive ecosystems, although many are currently showing signs of stress associated with recent sea-surface warming.

The past 100 years in the Pacific has seen a gradual rise in temperatures of about the same magnitude as elsewhere in the world. This warming has in turn driven (steric) sea-level rise. Most parts of the tropical Pacific experienced temperature rise of 0.6°C and sea-level rise of

[2] Tropical cyclones are known elsewhere in the world as hurricanes or typhoons.

15 cm during the 20th century (Hay et al., 2003; Church et al., 2006). Both rates have accelerated within the past 10-15 years.

If the relationship between climate change and people in the Pacific has been generally a sustainable one for the past 3000 years or so, the same cannot be said for the next 100 years or so. This is not solely a result of the likely rate of future climate change but also the heightened degree to which people in this region have become vulnerable to climate change. Over the past 100 years, most people in this region have altered their lifestyles, changing from traditional interactions with their environments (that were generally more sustainable by virtue of being more adaptable) to interactions that are less sustainable and more dependent on outside, even globalized, forces.

One of the most widely-discussed examples of this comes from the deterioration of traditional food systems which has increased malnutrition and food dependency in the Pacific Islands (Thaman, 1982; Murray, 2001). Another good example has been the accelerated erosion of many Pacific Island beaches associated with both their mining (for aggregate) and the removal of associated vegetation, especially mangrove forests (Wong, 2003; Thaman, 2002). A final example would be the myriad impacts of the growing importance of the cash economy in once almost wholly subsistence societies, something that had particularly visible impacts in the agricultural, forestry, mining and tourism sectors during the past 100 years (Murray, 2001; Connell, 2010).

While there are no specific projections for the Pacific Islands region available for the next 100 years, it is clear that temperatures are likely to rise here (as elsewhere) by as much as 4°C by the year 2100 (2090-2099 relative to 1980-1999 – see section 2.1.a). This is expected to cause a sea-level rise of more than one metre, perhaps around two metres, above present levels by the year 2100. What is very important to note is that, whatever global action is taken now to mitigate the causes of this climate change, the effects of this are unlikely to have any significant impact on temperature rise and sea-level rise to AD 2100 (Overpeck and Weiss, 2009) and probably well beyond this time.

How future warming will affect short-term climate variability is uncertain, although it seems likely that tropical-cyclone intensity will increase in the region in the future; recent modelling results suggest that there will be intensity increases of 2-11% by the year 2100 (Knutson et al., 2010). The same study suggests that there will be a decrease in the frequency of tropical cyclones by 6-34% within the same period although there will be 'substantial increases' in the frequency of the most intense tropical cyclones. There is little doubt that warmer sea-surface temperatures will increasingly expand the area of the low-latitude Pacific within which tropical cyclones form as the present century progresses. Some studies suggest that ENSO-negative (El Niño) events will become stronger in a warmer world.

These projections pose a range of challenges for livelihoods in the Pacific Islands. But it is important not to regard these challenges in isolation. Climate change may not be the greatest threat to traditional lifestyles on some islands, where there is rapid population growth, deforestation, or other kinds of environmental degradation.

1.2 Peoples of the Pacific Islands: tradition and change

The earliest people to settle in the Pacific Islands entered the region from its western tropical rim, from the islands off the coast of New Guinea. From there about 1350 BC, they voyaged eastwards, occupying each of the main island groups as far as Samoa and Tonga by 950 BC. There was probably a contemporaneous migration from the Philippines to the islands of Micronesia although this is less well documented.

Once established in these islands, people gradually settled the remainder of the Pacific Islands, occupying all the main groups before the Pacific was known to people in Europe. There is irrefutable evidence that the ancestors of the modern Pacific Islanders crossed the entire ocean from west to east, reaching the west coast of the Americas in perhaps three places before 1513 when Balboa became the first European to sight the Pacific Ocean.

It has been argued that favourable climates facilitated the west to east (against the wind) exploration of the Pacific by the first islanders (Anderson et al., 2006). It has also been averred that sea-level fall during the period of initial island settlement created the coastal environments that could sustain the pioneer settlers (Nunn, 1994; Dickinson, 2003). Specifically, it is clear that most Pacific Island groups were not permanently settled by people until the time at which island coastlines had emerged sufficiently for coastal plains to develop and fringing coral reefs – critical as a food resource – to begin growing at low-tide level.

Given that the earliest Pacific islanders had had to cross such large ocean distances, it is little surprise that there are not only ancient traditions of seafaring and navigation but also that marine resources played such a major role in islander subsistence. Early Pacific people were clearly adept at obtaining food from the sea.

Many classifications of Pacific people talk of Melanesians, Micronesians and Polynesians but these are properly references to the inhabitants of geographical sub-regions of this vast ocean and not culturally distinct groups of people. That said, there is livelihood diversity in the region that is attributable to the nature of the islands that particular groups settled.

Perhaps the starkest example of environmentally-determined livelihood diversity is between the people of large high islands and those of smaller lower islands (atolls). The former generally have a far greater range of wild foods available to them, a far greater diversity of food production potential. The latter have generally to depend on seafood and birds with agriculture being generally marginal and unreliable. The main reason for this is that atoll soils, having developed on a limestone bedrock base rarely rising more than one metre above mean sea level, are nutrient poor and thin. This helps explain why the terrestrial biodiversity of atolls is so comparatively impoverished (Thaman, 2008; Bridges and McClatchey, 2009) and why early experiments with agriculture were evidently far more challenging than on higher islands (Weisler, 1999, 2001).

While the history of the Pacific Islands, particularly in the last millennium, demonstrates the development of polities and chiefdoms, there do not appear to have been any rigid land divisions on particular islands for most of this time. It is this fact that made it comparatively easy for the first foreign settlers on these islands to own land; ownership was an alien concept so land was "sold" by titular chiefs for far less than its monetary "value". The other major impact of foreign settlement, mostly from the mid-19th century onwards in most island groups, was the massive depopulation as a result of introduced diseases to which most indigenes had no resistance. On some islands, 80-90% of the people are thought to have died, leaving empty whole settlements and huge tracts of once-utilized land. The first foreign settlers were thus encouraged by their impressions of empty (apparently uninhabited) islands to settle these and claim ownership of large tracts (Banner, 2007).

All Pacific Island groups (except Tonga) were colonized by European powers during the 19th and 20th centuries, most becoming independent subsequently within the last 40 years. While a few benefits of colonization might be acknowledged (McNeill, 1999; Feyrer and Sacerdote, 2009), this was largely about exploiting the islands' natural resources, typically for plantation agriculture or mining, and the cheap labour represented by their inhabitants. Colonization not only resulted in quite fundamental landscape changes on the larger islands but also in changes to the people's way of life. Urban centres developed and have grown rapidly. Subsistence agriculture has become less important than cash cropping in many islands, especially in areas adjoining urban centres. As other forms of income generation have developed, particularly around tourism, mining, forestry and manufacturing, so people have become more aware of the monetary value of land. Once perceived as a provider for all who were in need, the land is now perceived as a personal (or communal) possession.

The legacy of colonialism in most now-independent Pacific Island groups is a mix of private (individually-owned) and communal (group-owned) land, a situation that has gradually increased inequality. In some island nations, private land is so scarce (and so expensive) that few can afford to buy it; persons with no rights to communal land may therefore always have to lease land, which means that they have little interest in its sustainability. Another extreme is represented by Tonga where the vast majority of the land above the high-water mark is owned by the nobility; "commoners" can hope only to be allotted land to farm or to live (Campbell, 2001; Halatuituia, 2006). The situation in most Pacific Island countries in which there is so little land privately-owned has been identified as a hindrance to development and to effective urban and rural planning (Connell and Lea, 2002; Crocombe, 1987, 2001).

Most people in the Pacific Islands region live in rural areas, almost all along island coasts where there is an abundance of protein-rich marine food and fertile lowlands suitable for agriculture (FAO, 2008). Urbanization is increasing rapidly with a few countries having more than 40% of their population in urban areas. Most rural dwellers routinely subsist – at least in part – from foods (either wild or cultivated) obtained from their surrounding environment (Table 1.1). That said, "basic staples such as rice and wheat for flour are key substitutes of traditional diets that are now part and parcel of a Pacific Islander's daily diet" (FAO, 2007: 9).

Table 1.1. Importance of subsistence production in households in the Pacific Islands

	Federated States of Micronesia	Kiribati	Palau	Samoa	Solomon Islands	Tonga	Tuvalu
Subsistence production as % of household income	23%	21%	3%	26%	37%	17%	55%
Sales of own produce as % of income	n/a	11%	n/a	3%	6%	14%	2%
Range of contribution of home production (subsistence and sales) to	15-36%	19-50%	n/a	7-42%	7-71%	14-36%	30-65%
Subsistence agricultural production as a contribution to GDP	22%	48%	n/a	11%	n/a	7%	13%

Source: Lal et al., 2009a

The subset of Pacific Island countries shown in Table 1.1 show a range of representative situations in the region. Palau, for example, is representative of a handful of more-developed such countries that, because of their access to wage employment and because of links with metropolitan countries, have little need to supplement diets with subsistence activities (3%). At the other extreme, the average household in Solomon Islands (including those in urban areas, where opportunities for subsistence are comparatively few) has a 37% subsistence contribution, which is clearly much higher in most rural areas.

Most Pacific Island nations are functioning democracies to some degree, the others comparatively benignly with declared aspirations to democracy. While there are indubitably problems associated with national governance, few governments in the region over the past half-century have been ruinously corrupt (Hassall, 2008). Most problems of governance are associated with the comparative smallness of the land areas and populations of some countries, particularly when matched with the total (land and sea) area they occupy. For example, countries like Kiribati have a population of some 108,000 persons spread across 21 islands (total land area of 811 km^2 including 12 uninhabited islands) within a total ocean area (Exclusive Economic Zone) of 3.55 million km^2. In such situations, it is very difficult for governments to service all parts of the country as they do the centre (Duncan, 2008).

One weakness of all national governments in the Pacific Islands region is their emphasis on top-down centralized governance, something inherited from colonial systems (Hook, 2009). Not only does the geography of many countries, particularly the archipelagic ones, militate against the effectiveness of such a system of governance, but also the lack of sufficient funds to reach out to all their citizens as they aspire (Hassall and Kennedy, 2008). This situation means that many inhabitants of a country, sometimes even the great majority, feel little influence of central government (Duncan, 2008).

While all Pacific Island governments aspire to growing their economies, there are obvious constraints to doing so. The foremost of these is that most island nations are so far from (continental) markets that anything they produce for export is almost certain to be too expensive to sell there unless favourable trade agreements are put in place. The few extractive industries in these islands can generally only become commercially exploitable if governments give generous tax concessions or other incentives to logging companies or mine operators. For many countries (certainly not all), tourism has become a beacon of hope for ailing economies. The performance of Pacific Island economies is shown in Table 1.2 below.

Table 1.2. Real GDP growth of Pacific Island Nations

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cook Islands	4.9	2.6	8.2	4.3	0	0.7	9.5	-1	
Federated States of Micronesia	0.8	1.1	1.6	-3.6	3	-0.4	0.1	-3	
Fiji	1.9	3.2	0.8	5.4	-1.3	1.9	-0.5	0	-2
Kiribati	-3.1	7.4	3.7	-0.7	2.4	0.3	-0.03	4	
Marshall Islands	2.7	3.8	3.4	5.6	1.7	1.3	2	-2	0
Nauru					-14.5	6.3	-27.3	1	0
New Caledonia	2	2.5	4.8	3.9	3.6	5.7	6.2	1	2
Niue				-3.7	8.9	3.4			
Palau	1.3	-3.5	-1.3	4.9	5.5	3	5.7	2	
Papua New Guinea	-0.04	2	4.4	0.5	3.9	2.3	7.1	7	5
Samoa					5.3	0.5	6.6	-3	-2
Solomon Islands				8	5	6.1	10.3	7	-2
Tonga		3.6	2.6	1	-1	0.5	-1.2	2	0
Tuvalu	13.2	5.5	4	4	2	1	2	2	
Vanuatu	-2.1	-7.8	3.1	5.4	6.5	7.4	6.8	7	4

Source: SPC n.d..

It is difficult to generalize about economic growth rates in the Pacific Islands over the past decade or so; they have been "erratically unstable" (Prasad, 2008: 905) and most of the good performance years are due to local forcing factors. For example, the high growth years experienced by Papua New Guinea are linked to mining booms; the good years for Samoa are explainable by unsustained growths in the tourism sector. The consistent performance of New Caledonia is largely because it is a French territory and heavily subsidised, although a new nickel mining boom has helped, while the crash of Nauru is due largely to unwise investments of the high revenues it once received for its phosphate (Connell, 2006b).

Although urbanization in the Pacific Islands region has been rapid in the past few decades (Connell and Lea, 2002; Duncan, 2008), most inhabitants of this region live in non-urban areas and are (at least in part) routinely dependent on wild foods or foods that they cultivate for themselves. Furthermore, while increasing numbers of households occupy land for which they have paid (or pay), most people in this region occupy land that is theirs or their clan's without monetary cost. These facts are both important when considering the nature and efficacy of potential climate-change adaptation solutions.

Measures of poverty for many islanders are problematic because they often fail to acknowledge that a large majority of people are (at least in part) outside the cash economy yet still manage to live well and remain healthy. Human development indices for Pacific

Island countries are likewise questionable although they provide a crude measure of relative prosperity and development (Table 1.3)

Table 1.3. Human development indicators for Pacific Island countries.

Country	Life expectancy ind	Education index	GDP index	HDI value 2006	2006 HDI rank
Cook Islands	0.77	0.95	0.65	0.79	1
Palau	0.73	0.92	0.68	0.77	2
Niue	0.75	0.91	0.57	0.74	3
Samoa	0.80	0.94	0.45	0.73	4
Tonga	0.76	0.95	0.44	0.72	5
Tokelau	0.75	0.92	0.37	0.68	6
Federated States of Micronesia	0.70	0.84	0.50	0.68	7
Fiji	0.69	0.85	0.46	0.67	8
Marshall Islands	0.71	0.88	0.40	0.67	9
Tuvalu	0.64	0.94	0.38	0.65	10
Nauru	0.51	0.86	0.59	0.65	11
Kiribati	0.65	0.88	0.24	0.59	12
Vanuatu	0.71	0.76	0.30	0.59	13
Papua New Guinea	0.49	0.50	0.25	0.41	14
Solomon Islands	0.60	0.63	0.00	0.41	15

Source: Prasad, 2008

This table ranks the countries of the Pacific Islands region according to their 2006 Human Development Index. The top performers (Cook Islands, Palau, Niue, Samoa) all have close links with metropolitan countries (New Zealand in particular) which allow their nationals unrestricted access that results in large amounts sent back to the home country in the form of remittances. Of the truly independent countries, Fiji is probably the highest ranked, its quality of life due largely to a comparatively healthy and diverse economy and an abundance of land for food production. It is noteworthy that the three bottom performers are all countries where malaria is widespread.

Turning now to the future, it is clear that many Pacific Island countries have challenges that are not only more immediate than those associated with climate change but also potentially more damaging to the long-term development plans of these countries; these include population growth, loss of natural resources and ecosystem services owing to exhaustion or unsustainable exploitation, and limited economic growth owing to the distance to markets. None of these challenges can be considered in isolation from that posed by future climate change; indeed this will only exacerbate most such challenges by reducing livelihood opportunities and environmental productivity in many parts of the region.

Population growth is one of the most widespread concerns, especially in those countries where – generally because of barriers to accessing metropolitan countries – there is comparatively little out-migration to balance high birth rates. 21st-century populations and population projections are shown in Table 1.4.

Table 1.4. Present populations (mid-2010) and population projections for Pacific Island nations

Country	Mid-Year 2010 Total	Mid-Year 2020 Total	Mid-Year 2030 Total	Mid-Year 2040 Total	Mid-Year 2050 Total
American Samoa	65,896	74,611	83,673	90,676	98,271
Cook Islands	15,529	15,939	16,261	16,234	15,977
Fed States of Micronesia	111,364	116,512	121,051	127,798	137,554
Fiji Islands	847,793	890,438	946,320	1,008,214	1,060,706
French Polynesia	268,767	297,557	321,841	337,862	348,778
Guam	187,140	224,238	243,094	257,006	267,820
Kiribati	100,835	119,923	137,471	150,754	163,266
Marshall Islands	54,439	59,486	62,414	62,386	61,217
N Mariana Islands	63,072	70,276	74,579	77,656	80,137
Nauru	9,976	11,974	13,672	15,023	16,283
New Caledonia	254,525	291,211	323,206	345,550	359,406
Niue	1,479	1,225	1,213	1,260	1,283
Palau	20,518	21,796	22,604	22,710	22,459
Papua New Guinea	6,744,955	8,246,247	9,899,549	11,625,769	13,271,057
Pitcairn Islands	66				
Samoa	183,123	188,357	197,689	204,759	209,740
Solomon Islands	549,574	703,534	876,394	1,064,801	1,245,774
Tokelau	1,165	1,151	1,171	1,160	1,148
Tonga	103,365	106,493	111,731	118,030	123,008
Tuvalu	11,149	11,781	12,488	13,080	13,858
Vanuatu	245,036	312,480	386,066	462,757	538,707
Wallis and Futuna	13,256	13,124	13,363	13,465	13,570

Source: SPC n.d..

While there are clearly innumerable subtleties hidden within these data, it is worth noting that those countries with large rural populations and little access to metropolitan countries for employment are those that have the highest population growth rates. The best example is Solomon Islands where population is expected to double within a few decades. Countries with generally better-educated populations, especially those where there is widespread buy-in to population control measures, exhibit slower growth rates; Fiji is the best example. Countries where births are to some extent compensated by out-of-country migration show, as expected, low growth rates; examples include the Cook Islands, Niue and Samoa.

Loss of natural resources and ecosystem services is becoming more widespread throughout the Pacific Islands region as these are traded for short-term profit. Good examples come from Solomon Islands where whole islands have been effectively stripped of their forest cover for export with insufficient regard for the continuing needs of the island people (Hviding and Bayliss-Smith, 2000). As island nations increasingly see opportunities for such transactions, it is likely that they will continue and that the associated, often irreversible, environmental degradation will become more widespread.

While some economists are cautiously optimistic about some island economies, most are projected to continue to shrink or – at best – exhibit only sluggish growth over the next decade or so (Prasad, 2008). The basic problem is neither the will to produce nor the availability of appropriate workers, but the cost of transporting products for sale to markets. That said, this problem is not insurmountable, as well demonstrated by Fiji Water although the success of this enterprise is considerably aided by massive government tax concessions (Connell, 2006a; Reddy and Singh, 2010). Tourism is the only economic sector in the Pacific Islands for which there is a consensus around potential expansion and revenue generation (Narayan et al., 2010) although often as much as 90% of the profits from island tourism ventures goes offshore (Singh, 2008).

There are several regional groupings of Pacific Island nations at present, the largest and longest-lasting being the Pacific Islands Forum (PIF) that is essentially the same as the Pacific Small-Island Developing States (Pacific SIDS) bloc at the United Nations. A more recent grouping is the Melanesian Spearhead Group (MSG) that is pondering an economic role as well as a political one.

While it is difficult to predict trends in future governance in the Pacific Islands region, there is the possibility of increased federation – perhaps even the emergence of a Pacific Islands Union (akin to the European Union). The first step in this direction might be the adoption of a single currency in the region (Jayaraman, 2007). The problem in the recent past of governments being unable to govern effectively or even being overthrown is expected to continue in the future, particularly as the populace becomes more aware and national governance becomes more complex, and even as problems associated with daily subsistence become ever more acute. It is likely that there will be an increased need for outside intervention in the governance of Pacific Island countries, intervention in terms of both peacekeepers (like the RAMSI mission in Solomon Islands) and finance to keep island economies afloat (as in the case of Nauru, the first failed Pacific state – Connell, 2006b).

Most countries in the region could not remain viable in the sense of continuing to provide basic services to those of its population that enjoy them currently without routine injections of external funding (Gani, 2009). Government revenues for the region are shown in Table 1.5.

Table 1.5. Government revenues (US$'000), broken down by source

Country	Year	Total Revenue	Taxes	Grants	Other
American Samoa	2005	182,014	50,396	88,310	43,308
Cook Islands	2009	116,665	80,963	21,174	14,528
Fed States of Micronesia	2008	149,800	29,300	94,300	26,200
Fiji Islands	2009	1,410,555	1,321,936		88,619
French Polynesia	2008	116,492,000	26,948,000		89,544,000
Guam	2008	513,200	25,133	488,067	0
Kiribati	2008	61,831	29,835	0	31,996
Marshall Islands	2007	98,900	24,700	62,900	11,300
Nauru	2007	22,288	8,646	6,773	6,869
New Caledonia	2009	162,686,000			162,686,000
Niue	2009	20,441			20,441
N Mariana Islands	2008	162,760	125,920		36,840
Palau	2006	83,671	29,224	44,948	9,499

Papua New Guinea	2004	4,962,600	3,208,800		1,753,800
Samoa	2009	492,000	324,700	110,700	56,600
Solomon Islands	2009	1,704,900	1,488,900	101,600	114,400
Tonga	2005	114,577	87,013	0	27,564
Tuvalu	2008	45,357	6,772	28,567	10,018
Vanuatu	2009	16,835,000	10,855,000	4,529,000	1,451,000
Wallis and Futuna	2005	2,623,000			2,623,000

Source: SPC n.d.

There is clearly a contrast between those countries that survive without such large injections of external funding (like Fiji, where 94% of government revenue is obtained from taxation) and those that do. Of the latter group, there is a political distinction between those countries having formal ties to metropolitan countries (such as French Polynesia and New Caledonia, which are French Overseas Territories) and those where ties are less so (like the Cook Islands and Samoa).

It is widely accepted that the Millennium Development Goals (MDGs) are good indicators of national human development. Data for Pacific Islands are shown in Table 1.6 below.

Table 1.6. Status of Pacific Island Countries with regard to performance against key Millennium Development Goals

	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5	Goal 6
	Poverty and hunger reduction	Universal primary education	Gender equality in education	Reduced child mortality	Reduced maternal mortality	Access to water and sanitation
Indicator	% population under nourished	Children reaching Grade 5 as a proportion of Grade 1 pupils	Secondary school enrolment ratio	Children under 5 deaths per 1000 live births	Deaths per 1,000,000 births	% rural population with access to improved water
Melanesia						
Fiji	4	95.8	1.07	18	75	51
Papua New Guinea	13	58.2	0.79	74	300	32
Solomon Islands	20	78	0.82	29	130	65
Vanuatu	12	70.6	0.86	38	32	52
Micronesia						
Federated States of Micronesia						
Kiribati	6	81.4	1.13	65		53
Marshall Islands			1.05	58		96
Nauru		25.4	1.07	30		
Palau			1.08	11		94
Polynesia						
Cook Islands			1.02	20		88
Niue			0.95			100
Samoa	4	95.9	1.12	29	15	87
Tonga		94.6	38		100	
Tuvalu		62.6	0.93	38		82

Source: Lal et al., 2009a based on UNESCAP et al. 2007.
Note: Shaded boxes are areas of concern. Empty boxes indicate no data available.

It can be seen that while there are numerous countries that have been unable to report particular MDGs, those that have exhibit considerable variability, but are generally falling short of what was anticipated when the goals were set and agreed.

1.3. Sensitivity of the Pacific Islands region to climate change

The Pacific Islands are different from most other parts of the world when their sensitivity to climate change is considered. The most obvious expression of this is that islands by definition have much longer coastlines (relative to total land area) than larger landmasses. Thus, in terms of calculating likely or actual impacts of sea-level rise or increased storm-surge incidence on particular countries, clearly those with the longest coastline-to-land-area ratios will be more affected than others with shorter coastline-to-land-area ratios (like most continental countries). Within the community of islands, smaller islands have longer coastlines (relative to total land area) than larger islands. The measure of this is the insularity index (Nunn and Kumar, 2006) which is shown for selected Pacific Island nations (and others for comparison) in Table 1.7.

Table 1.7. Characteristics of coasts in the Asia-Pacific region

Group/Nation	Land area (km2)	Coastline length (km)	Insularity index (coastline length/land area) x 100	Population density (persons per km2)	GDP per capita (US$)
Tokelau	10	101	1010	142	1058
Federated States of Micronesia	702	6112	871	154	-
Palau	458	1519	332	43	-
Northern Marianas Islands	477	1482	311	168	-
Marshall Islands	181.3	370.4	204	311	2038
Nauru	21	30	143	599	4773
Kiribati	811	1143	141	122	802
Tuvalu	26	24	92	435	1079
French Polynesia	3,660	2525	69	72	4959
Tonga	718	419	58	151	2182
Cook Islands	240	120	50	88	4998
Wallis and Futuna	274	129	47	57	1907
Niue	260	64	25	8	3543
Vanuatu	12,200	2528	21	16	2823
Solomon Islands	27,540	5313	19	18	1571
Samoa	2,934	403	14	61	5612
New Caledonia	18,575	2254	12	11	14,231
Fiji	18,270	1129	6	48	5551
Papua New Guinea	452,860	5152	1	12	2051

Source: NationMaster n.d.

Pacific Island nations are listed in this table by their Insularity Index, so that Tokelau – a group of three atoll islands with long sinuous coasts and small land areas – comes out on top. Countries with larger islands like Papua New Guinea and Fiji understandably come out at the bottom of this table. The Insularity Index is a crude proxy for exposure to coastal impacts like sea-level rise. It does not of course allow resilience factors like coastal type (hard rock versus soft rock), vegetation and protection by mangroves and offshore coral reefs to be factored in. It is nevertheless useful for assessing relative vulnerability to future climate change in this island world.

In the context of the Pacific Islands, environmental sensitivity to climate change is best separated from human (or societal) sensitivity. Environmental sensitivity includes not only the various components of the physical environment (such as land, soil, water, oceans) but also variables such as ground-surface temperature, sea-surface temperature, sea level, and precipitation. Human sensitivity is centred on subsistence, specifically a sufficient supply of the food resources needed to sustain a particular number of people per unit area. But under the umbrella of human sensitivity, there also needs to be acknowledgement of cultural sensitivity as well as resilience; the ability of a group of people to adapt to a particular change is a measure of their resilience.

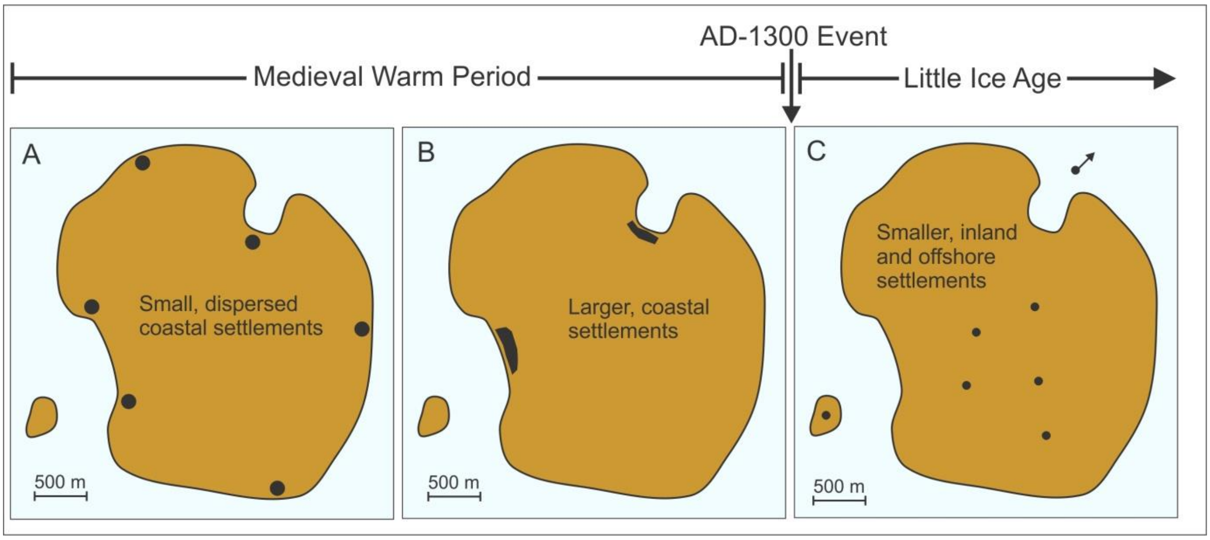
Sufficient is now known about the Pacific Islands during the last millennium to be able to understand how their environments and societies responded to climate change (Nunn, 2007a). The earliest part of the last millennium (AD 750-1250) is known as the Medieval Warm Period (MWP). This was followed by a short period of rapid cooling and sea-level fall (AD 1250-1350) known as the AD 1300 Event. This in turn was succeeded by the Little Ice Age (LIA - AD 1350-1800) and the period of Recent Warming (AD 1800-present).

Some examples of environmental sensitivity during the last millennium in the Pacific Islands occurred during the AD 1300 Event when rapid cooling forced a rapid sea-level fall (~60-80 cm) which transformed coastal environments. Embayments (bays) that had existed during the MWP typically became brackish coastal wetlands during the LIA; good examples come from Tikopia Island in Solomon Islands and Kosrae in Micronesia (Nunn, 2007a). As a result of this physical consequence, the environment exhibited several sensitivities. These included the loss of coral-reef bioproductivity associated with exposure (caused by sea-level fall) of the uppermost parts of reefs: the associated reduction in aeration and water circulation within reef-bounded coastal lagoons: and the drop in coastal water tables linked directly to the sea-level fall. All these environmental sensitivities are believed to have had profound consequences for coastal dwellers throughout the tropical Pacific Islands and are implicated in the subsequent widespread abandonment of coastal settlements for others in more readily defensible locations (Nunn et al., 2007; Nunn, 2012; Robb and Nunn, 2012).

Human sensitivity during the last millennium was both directly climate-driven and driven through environmental proxies (such as coastal change). During the MWP, the periodicity of ENSO was comparatively low so that seasonal variations in weather were generally predictable year after year; this allowed human societies in the Pacific Islands to flourish and it is perhaps no coincidence that many developed increased complexity during the MWP, particularly in terms of the development of hierarchies and complex polities manifested by the development of larger-than-previous settlements and chiefdoms in many places (Nunn, 2007; Nunn et al., 2007). This situation changed radically and comparatively abruptly during the AD 1300 Event when cooling and increased storminess are likely to have affected tropical Pacific Islands. Yet the most important change at this time was the sea-level fall which, by exposing coral-reef surfaces and slowing lagoon circulation, reduced the amount of food available to coastal dwellers in the Pacific Islands. The sustained nature of this change eventually led to a food crisis on many islands, resulting in conflict, and the abandonment of (exposed) coastal settlements in favour of those in more defensible locations, typically inland and upland or on unoccupied offshore islands. This situation continued for most of the LIA when temperatures were low and climate variability was higher than it had been during the MWP (Nunn, 2007a).

As an illustration of climate-driven human sensitivity during the last millennium in the Pacific Islands, a general picture of settlement-pattern changes applicable to most island groups is shown in Figure 1.2. This shows that during the MWP, most settlements were coastal, becoming amalgamated as societal complexity increased. Following the AD 1300 Event and during the LIA, settlements were mostly inland or offshore, a geographical expression of human sensitivity to climate change.

Figure 1.2. Changes in settlement pattern during the last 1200 years on many high Pacific Islands



Source: Nunn, 2007a..
Note: Map A shows the situation at the start of the Medieval Warm Period, perhaps about AD 1000. Map B shows the situation at the end of the Medieval Warm Period, just prior to the AD 1300 Event about AD 1250. Map C shows the situation about AD 1500 during the Little Ice Age, after the end of the AD 1300 Event..

Since the LIA ended, temperatures and sea levels in the Pacific Islands region have been generally rising. While the net changes in temperature and sea level have been far less than is likely to have occurred during the AD 1300 Event (see above), these increases nevertheless demonstrated the sensitivity of both Pacific environments and societies (see Chapter 2 for more details). Examples of environmental sensitivities within this period of Recent Warming include increased coral-reef stress as a result of increased sea-surface temperatures, and accelerated erosion of sandy shorelines attributable to sea-level rise.

For the foreseeable future (to AD 2100), environmental stresses are expected to increase in magnitude if temperatures and sea level rise as projected (Nicholls et al., 2011). For the tropical Pacific Islands, perhaps the least disputed environmental consequence of temperature rise will be the impact on coral reefs. Corals are temperature-sensitive animals that often become bleached when sea-surface temperatures exceed 29-30°C for extended periods. It is predicted that most Pacific reefs will become largely devoid of corals by the year 2060 (Hoegh-Guldberg, 1999). The outcomes of this for coastal dwellers in the Pacific Islands who have traditionally (and today) depended routinely on coral-reef ecosystems for sustenance are immense and cry out for effective forward planning.

Coral bleaching is a phenomenon that not only affects coral organisms but also the entire ecosystems that they support (Glynn, 1993; Hoegh-Guldberg, 1999). Most coral reefs comprise a living veneer of organisms (mostly corals) on top of a reefrock edifice that is built from the skeletal remains of dead corals and other calcareous organisms. Widespread and sustained coral death resulting from bleaching will not only lead to degradation of coral-reef structures but will also reduce the supply of (ground-up) coral sediment to nearby island beaches, encouraging their erosion. Yet it is the ecological consequences of widespread and sustained coral bleaching that are most worrying from a human standpoint, for once corals cease to live on reef surfaces these tend to become dominated by monospecific groups of algae (typically *Halimeda* in the tropical Pacific) which create ecosystems that are far less diverse and bioproductive for human purposes than corals (Coles, 2008). The implications are that when reefs become bleached for long periods of time, the types of food on which coastal-dwelling humans throughout the Pacific routinely depend on will disappear which will create food crises (Turner et al., 2007).

Better-known examples of environmental stresses are the effects of sea-level rise on low-lying islands in the Pacific, especially those comprising (largely) the nations of Kiribati, Marshall Islands, Tokelau, and Tuvalu (Nunn, 2007b). Notwithstanding some signs of short-term resilience (Webb and Kench, 2010), it is likely that many of these will experience accelerated erosion of their coasts and some may be rendered uninhabitable by 2030 as a result of both the reduction in their land area and the shrinkage of the groundwater lens on which the populations of most such islands depend. The only adaptation option for some such people is to move to less-vulnerable off-island locations.

When considering current human sensitivity to climate change, it is convenient to distinguish the effects of slow, year-by-year changes and those of short-lived extremes. The greatest and most visible effects on food production, economic development, and livelihoods in the Pacific Islands come from extreme events and, while supporting data are difficult to isolate, it is probable that increases in the frequency and intensity of droughts and tropical cyclones over the past few decades have had increasing impacts on these aspects of life in this region. Table 1.8 below shows disasters reported in the Pacific Islands from 1950-2004. It can be seen that tropical cyclones have by far the greatest impacts on people and livelihoods while other climate-related disasters have considerably smaller effects.

Table 1.8. Reported disasters in the Pacific, 1950-2004 excluding Papua New Guinea

	Number	Reported fatalities	Population affected	Reported losses (in 2004 US$ million)
Windstorms (tropical cyclones and other storms)	157	1,380	2,496,808	5,903
Droughts	10	0	629,580	137
Floods	8	40	246,644	95
Earthquakes	17	53	22,254	331
Others (incl. landslides, tsunami, volcanic eruptions, wildfires, epidemics)	15	274	21520+	60
Melanesia	110	1,130	2,115,332	1,655
Micronesia	26	123	260,662	3,074
Polynesia	71	494	1,041,012	1,797
Total Pacific Islands	207	1,747	3,417,006	6,526

Source: Lal et al., 2009a.

Yet these data disguise recent trends suggesting that flooding in particular has been increasing in frequency and impact over the past 20 years (Lal et al., 2009b; Nunn, 2009).

Extreme events have serious, albeit generally short-lived, effects on food production, particularly in terrestrial environments. For example, during Tropical Cyclone Ami in 2003, Fiji lost over US$35 million in standing crops (Terry et al., 2004). The effects of recent climate change on other aspects of terrestrial (and nearshore) food production in the Pacific Islands are generally more difficult to assess, not least because increasing globalization has meant comparatively rapid dietary change, particularly a reliance on cheap imported foods rather than freely-available local foods that are difficult to obtain (in some places increasingly so as a result of climate change). The result of this has been a sharp rise in diet-related disease throughout this region (Popkin and Horton, 2001).

Several changes have observed in the Pacific Islands in the nature of wild food production that are attributable to recent climate change. For example, in the Temotu Province of Solomon Islands, changes have been observed in the fruiting patterns of breadfruit, the preservation of which has been a key component of food security for these outer island people (Lal et al., 2009a). In Papua New Guinea, various wild varieties of coconuts, mango, betel nut and breadfruits have been observed as growing at increasingly higher altitudes over the past few decades (Allen and Bourke, 2008).

As might be expected, fish are central to Pacific Islander diets (Table 1.9). Although growing, levels of subsistence consumption (and other practices represented in these data) appear to have been affected only slightly by climate change (Bell et al., 2009). Subsistence (or artisanal) fisheries in the Pacific Islands have, however, been affected by over-exploitation and the use of dynamiting or fish poison which produce short-term gains at the expense of long-term sustainability (Turner et al., 2007). This is in contrast to deep-ocean commercial fisheries, which have suffered from both rampant overexploitation by commercial fleets (often in collusion with island governments – Hanich and Tsamenyi, 2008) and climate change. It is considered that recent climate change has both contributed to a diminished stock of tuna, the principal deep-water fish caught, as well as a migration of the stock in the Pacific westward (Miller, 2007).

Table 1.9. Current annual fish consumption in the Pacific Islands

	Per capita fish consumption per annum (kg)	
	Rural	*Urban*
Melanesia		
Fiji	25	15
Papua New Guinea	55	11
Solomon Islands	10	28
Vanuatu	31	45
	21	19
Micronesia		
Federated States of Micronesia	77	67
Kiribati	58	67
Nauru	56	56
Palau	43	28
Polynesia		
Cook Islands	61	25
Niue	79	79
Samoa	98	46
Tonga	20	20
Tuvalu	147	69

Source: Lal et al., 2009a

A important additional source of stress on human systems in the Pacific Islands region is population growth (see Table 1.4) and urbanization. In most countries in the region where population is growing, there is also rapid urbanization (5-6% annually – Duncan, 2008) which is placing considerable strain both on governments to provide services and on existing infrastructure to accommodate increased traffic flows. While supportive data are generally lacking, it is possible that climate-change impacts on rural food-producing systems in the Pacific Islands have driven increasing numbers of people over the last two decades to move to urban centres. This does seem to be an important reason for migration from outer islands in Kiribati to the Bonriki-Betio urban complex on Tarawa Atoll (White et al., 2008).

As far as data are available, there do seem to be links between climate extremes and disease incidence in the Pacific Islands (Hales et al., 1999; Singh et al., 2001; Barnett, 2007). A compelling set of data from Vanuatu is shown in Table 1.10 below. These data show a rise in water-borne and insect-borne diseases during periods of frequent tropical cyclones, suggesting a causal link that has implications for the future.

Table 1.10. Incidence of water-borne and insect-borne diseases in Vanuatu (2001-2006) and the numbers of tropical cyclones affecting this country

	2001	2002	2003	2004	2005	2006
Number of tropical cyclones	2.00	1.00	4.00	1.00	1.00	
Total malaria cases	21,494.00	35,217.00	43,414.00	41,903.00	33,277.00	26,111.00
Dengue fever cases	20.00	15.00	122.00	21.00	2.00	7.00
Water-borne diseases	807.00	1,721.00	1,679.00	2,780.00	2,057.00	1,713.00
Diseases from polluted water contact	29,081.00	40,509.00	41,403.00	64,218.00	61,483.00	48,085.00
Fish poisoning	580.00	683.00	811.00	854.00	898.00	786.00
Total costs (low)	$24,395,440	$36,521,790	$40,499,570	$51,923,370	$46,469,240	$36,511,530
Total costs (high)	$30,544,270	$44,037,445	$48,252,925	$62,965,800	$57,051,160	$45,059,250

Source: Lal et al., 2009a.

Note: Costs are in Vatu. These figures suggest a connection between disease and cyclone frequency, which has implications for the future.

An important question to try and answer is "are certain groups of people in the Pacific Islands region more vulnerable to climate change than others?" The answer at current levels of understanding has to be an equivocal "No" yet this is largely because most people in the region are vulnerable to climate change, and all groups have the potential to have their livelihoods severely affected by future climate change. It is tempting to posit that Pacific Island people who occupy high islands or the interior parts of larger islands are less vulnerable to climate change. The effects of Tropical Cyclone Heta on the high island of Niue in 2004 illustrate that even such islands are not immune from such extreme climate events (Holland, 2008). People in island interiors whose subsistence depends only very marginally on marine foods might also be regarded as somewhat immune, yet most of their food is from rivers or grown on river floodplains which are also affected by extreme climate events (Nunn, 1998).

Yet environment and livelihood are causes of uneven vulnerability to climate change. Perhaps the most vulnerable are people in urbanized atoll environments while those people least at risk are those occupying the interiors of high islands where there is greater livelihood diversity than in most situations.

Clearly many of the current concerns around human sensitivity to recent climate change are also concerns for the future. Short-term impacts resulting from climate-related disasters, notably tropical cyclones, are likely to continue but it is probable that longer-term impacts resulting from slower climate change will become more visible and, most importantly from a response perspective, less contested.

While there will be massive impacts from future climate change on a range of food-production systems and economic drivers, there will also be effects on disease that are currently difficult to demonstrate. These include the spread of diseases carried by organisms (usually insects) whose habitat ranges expand or shift as a result of climate change. A good example is the expansion laterally and upwards of the malarial mosquito in high island countries like Papua New Guinea where highland populations have traditionally been immune from its influence. Another example of direct human sensitivity to future climate change in this region is the effect of increased warmth on human comfort.

1.4. Resilience of the Pacific Islands region to the effects of climate change

There is a tendency, particularly in the popular media, to overplay the negative effects of climate change on the Pacific Islands region, and to downplay its resilience. This is important because it has given rise to a victim syndrome and widespread despair in many Pacific Islands about their presumed inability to adapt to future climate change (Farbotko and McGregor, 2010). This in turn is sponsoring a culture of denial amongst communities in parts of the region: a belief that the changes they are witnessing are short-term climate variability not long-term climate change (Lata and Nunn, 2011). Many Pacific Island leaders routinely plead for assistance at international meetings on the unquestioned assumption that their countries are powerless to manage the challenges posed by future climate change without massive injections of cash to drive adaptation. Both these beliefs are flawed for, while Pacific Island countries may indeed be uncommonly vulnerable to many aspects of future climate change, many environments and communities (human groups) are also uncommonly resilient.

Perhaps the most fundamental aspect of environmental resilience in the Pacific Islands region comes from its natural production systems. Many of the ocean waters around Pacific Island coasts have been overexploited but with appropriate management their sustainable productivity can be restored (Johannes, 2002; Thomas, 2002; Aalbersberg et al., 2005) which attests to their innate resilience. The land is more problematic but there is little doubt that forests that are not logged continue to maintain the land in its present form and provide ecosystem services more effectively than forests that are logged, even selectively. The landscapes of deforested areas in the Pacific Islands change quickly, often to the point where they are unable to support a replanted forest (Lomo, 2001). The key to realizing this aspect of environmental resilience is informed and sustained management, perhaps for biodiversity conservation (Tisdell, 2008), perhaps for carbon sequestration (Kingsford et al., 2009). The Clean Development Mechanism (CDM) has been used to develop afforestation/reforestation (A/R) projects in parts of the Pacific Islands, notably in Fiji and Papua New Guinea. Such projects have the potential to increase these aspects of environmental resilience (McGregor, 2009).

Most aspects of resilience of the Pacific Islands region directly involve its inhabitants. In terms of human interaction with island resources for subsistence purposes, it is clear that despite increasing urbanization, there is still ample land in most high-island nations to sustain the subsistence needs of its existing population. In most archipelagic countries, most outer islands have experienced out-migration over the past 50 years that has rendered some islands almost empty (Connell, 2010). Yet their potential for sustaining much larger numbers remains and could be part of future national (and sub-regional) adaptation strategies. While many depopulated islands exist in larger archipelagos in the region, the only example in which a government has attempted to systematically relieve population pressure on the centre by re-locating people to the periphery comes from Kiribati, where there has been deliberate subsidised re-location from (overcrowded) Tarawa Atoll to outlying large Kiritimati (Christmas) Atoll (Locke, 2009).

Another aspect of resilience arises from the innate characteristics of Pacific Island societies, namely their emphasis on communal living and support that may have evolved as an adaptation to adversity in the past (Campbell, 2006). This mutual support system is most clearly manifested by the response of the community to a disaster that strikes one part of it (or a neighbouring community). Assistance is usually immediately extended and sustained as long as needed; it may extend beyond mere material assistance and labour to the adoption of orphaned children and the giving of land free of charge to newly-landless families. In the past, such responses were usually driven and coordinated by traditional leaders; today, it is common for religious groups to play a role in this (Rasmussen et al., 2009). Such a cultural trait, still very strong in most parts of the region, is also important to consider when developing and implementing adaptation strategies for future climate change (Nunn, 2009b; Barnett and Campbell, 2010).

Another long-standing aspect of resilience found in most parts of the Pacific Islands region is the tradition of community decision-making. While in places this has been weakened since foreign colonization by the establishment of centralized government, it is precisely the failure of central government in many island countries to effectively reach all parts that has strengthened the determination of communities, especially in a country's peripheral parts, to develop and sustain strategies for their future development. So any future plans for climate-change adaptation in the Pacific Islands region should recognize this trait yet also bear in mind that such communities are not always able to make decisions that are in the best long-term interests of their constituents (Nunn, 2009b). The specific issue is that such communities are usually understandably focused on short-term needs rather than long-term sustainable interactions with a particular food-production system, for instance (Turner et al., 2007; McGregor, 2009).

Finally we might consider the nature of most people living in the Pacific Islands today. Most are more aware of the vagaries of the natural environment than any urban dwellers because they subsist from this; this means that they are therefore more receptive to information about how and why the natural environment may change in the future, and what they can do about this. And most Pacific Islanders are literate: educated well above the average for most "developing" countries (Table 1.11).

Table 1.11. Adult literacy rates (English) in Pacific Island countries

			Literacy	Male literacy	Female literacy	Other language	
Melanesia							
Fiji			91.6	93.8	89.3	Fijian, Fiji Hindi	
Papua New Guinea			72.2	81	62.7	over 700 languages	
Vanuatu			90			French, Bislama, oth	
Micronesia							
Federated States of Micronesia			83			many others	
Palau			92	93	90	Palauan	
Polynesia							
Samoa			97			Samoan	
Tonga			100			Tongan	

Source: Smith and Long, 2000.

This last fact has many implications, including an improved ability to comprehend the need for effective adaptation to climate change as well as the ability to understand and drive (at individual and communal level) appropriate adaptation strategies. Should climate change create significant numbers of environmental refugees from the Pacific Islands region, the fact that these are comparatively well-educated people should aid their successful absorption into other societies, although other adjustment challenges will emerge (Bedford and Ho, 2003).

The last major aspect of resilience to be considered is around external assistance (aid). The dependence of Pacific Island nations on external assistance is shown in Table 2.1 below; many commentators have concluded that this degree of dependence is too great to truly enable recipient countries to determine their own directions, especially if these conflict with those of donor countries (Barnett, 2008); in other words, aid to Pacific Island nations "in effect remains budget aid" (Gani, 2009: 118). There are other negative aspects to this degree of dependency that refer specifically to climate change. These include the tendency to uncritically adopt (environmental) policies and legislation from donor countries, to accept inappropriate (often unsustained) adaptive solutions from donors, and to allow strategies to be developed by the international donor community which inhibit in-country community buy-in (Nunn, 2010). Among the many examples, the focus on developing policy and legislation to address environmental issues is perhaps the best example of wasted effort in that these tools – so effective in "developed-country" contexts – prove generally impotent in the Pacific Islands context. This is largely because legislation can be ignored because it can be neither effectively disseminated or enforced (Alley, 1999; Turnbull, 2004; Nunn, 2009b). This particular situation is illustrated in Figure 2.5.

Yet, despite such negative aspects of external assistance, it is clear that Pacific Island nations cannot do without this is they are to adapt their people's livelihoods to future climate change with minimal disruption. The fact that donors continue to be willing to support Pacific Island nations in this way makes them highly resilient.

2. The Last Hundred Years: Adapting to Climate Change

Many things have changed in Pacific Island nations during the past hundred years or so. Most nations have emerged from being colonies to being independent democracies. Most have become increasingly urbanized. Populations have increased. Commercial agriculture and fisheries and forestry have increased sharply in importance. Unprecedented demands have been made on the islands' natural resources, resulting in land degradation, water and air pollution. Against this background of comparatively rapid environmental and socio-cultural change has been climate change.

While it is reasonable to conclude that climate change has not been the major environmental or human (societal) stressor in every part of the Pacific Islands within this time period, it is fair to say that it has been that stressor which has had the most uniform impact across the region. Climate change has affected every part of the region within this period, underscoring the fact that it is undiscriminating in its general effects, that it is no respecter of national or geographical boundaries. Of course, in its specific impacts within this period of time, climate change has had more measurable impacts on those ecosystems and human systems that have been simultaneously stressed by other factors. Conversely, climate change has had less tangible impact on more resilient and more healthy ecosystems and human systems.

This chapter describes the nature of climate change in the Pacific Islands region over the past hundred years or so, its environmental and human consequences. Section 2.1 explains how climate has changed, focusing on the principal variables including and driven by temperature change. As part of this, it explains how observed climate change has been interpreted by key stakeholders and some of the associated controversies. Section 2.2 looks at how key monitored variables have accelerated recently in this region but also explains the uncertainties around the interpretation of particular datasets.

Section 2.3 discusses the effects of recent climate changes in the Pacific Islands region, divided into effects on natural environments and effects on human systems. Emphasis is placed on the effects of climate change on food-producing systems on land and in the ocean.

Section 2.4 is devoted to the human responses to climate change in the Pacific Islands region, ranging from those of the international community, regional agencies, national governments, community leaders, and individual decisionmakers. The agendas of non-government organizations are also discussed. The adequacy of these responses is reviewed.

Section 2.5 is a case study from two islands in Kiribati intended to describe the effects of two outer-island communities which are grappling with the effects of climate change on their livelihoods. This case study illustrates the nature of international, national, and community priorities.

Section 2.6 focuses on the ways in which culture and (religious) beliefs have been used to deny the reality of climate change and to undermine the credibility of future climate projections for the Pacific Islands region.

Section 2.7 is a case study of Nadi Town in Fiji which is intended to illustrate the threats posed by flooding to a medium-sized settlement in the Pacific Islands region and the possible responses being discussed at various levels.

Section 2.8 examines available datasets to determine whether recent observed changes in climate variables are truly a consequence of climate change or whether they could be classified as climate variability. Many decision-makers in the Pacific Islands region have argued the latter, and many communities regard climate variability as the principal reason for the changes they have observed.

Section 2.9 is a case study from a densely-populated river delta in Fiji about community perceptions of the cause(s) of increased river and ocean flooding on their traditional lands and the solutions that they perceive to be most effective. This case study is intended to illustrate the misfits between community-level perception of climate change and national priorities and scientific understanding.

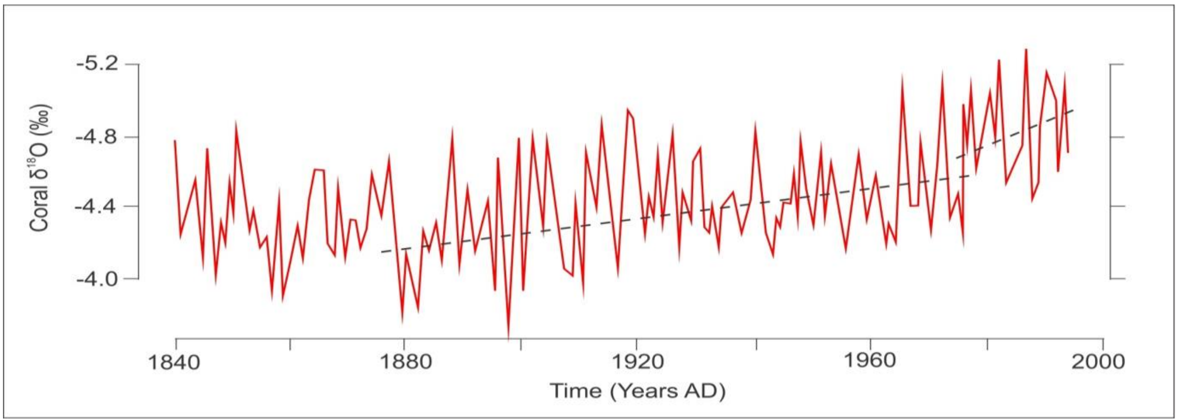
2.1. Observed climate change in the Pacific Islands region

There is abundant evidence of climate change in the Pacific Islands region in the past hundred years. The principal observed variable is (ground-surface) temperature, the changes in which are assumed be similar to those in nearshore sea-surface (not deep ocean) temperature, for which there are far fewer datasets. Recent data on sea-surface pH (alkalinity-acidity) are also available. Sea-level datasets are available for most parts of the region. Precipitation datasets are also available yet, owing to the spatial variability of precipitation on many islands, it is sometimes difficult to translate these data into a regional picture. Data are also presented for ENSO and tropical cyclones.

2.1.a. Temperature

The period of Recent Warming, in which we are still living, began in the Pacific Islands region about AD 1800 when the Little Ice Age ended. Since that time, there has been a net increase in temperature throughout the region. Some of the least controversial data come from proxy sources, such as coral-core palaeoclimate records that use oxygen-isotope analysis to determine past sea-surface temperatures (Figure 2.1).

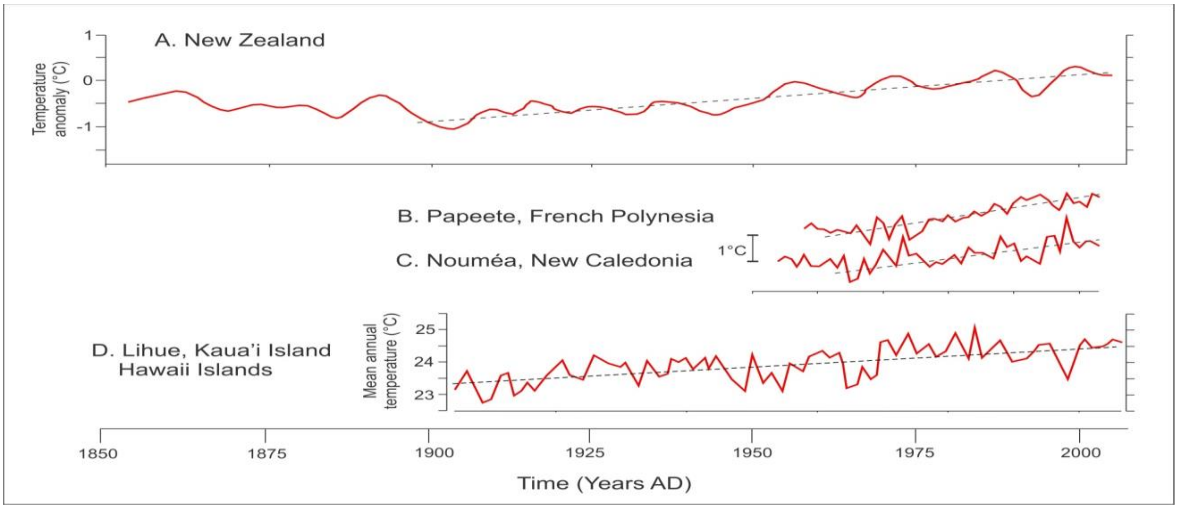
Figure 2.1. Oxygen-isotope data from a coral core at Maiana Atoll, Kiribati, show a 155-year trend towards warmer and wetter conditions



Source: Urban et al., 2000; Nunn, 2007a.
Note: The pre-1976 part of the record shows a gradual temperature rise, the post-1976 part shows this rise has accelerated. Trend lines added.

Several directly-monitored tide gauges have been operational in the Pacific Islands for sufficiently long to enable a long-term signal of sea-level change to be distinguished from the short-term noise. Four such series are shown in Figure 2.2.

Figure 2.2. Selected (ground-surface) temperature records from the Pacific Islands in which long-term trends can be identified.



Source: Nunn, 2007a. All trends are from the sources indicated.
Note: All trends are from the sources indicated.
A. Mean annual temperature over New Zealand 1855-2005 (NIWA n.d).
B. Temperature records 1959-2002 for Papeete, Tahiti Island, French Polynesia (eastern tropical Pacific) showing trend lines for 1976-2002 (supplied by Jean-Francois Royer, October 2006).
C. Temperature records 1953-2002 for Nouméa, New Caledonia (western tropical Pacific) showing trend lines for 1976-2002 (Meteo France, supplied by Jean-Francois Royer, October 2006).
D. Temperature record 1905-2006 for Lihue, Kaua'i Island, Hawaii (NASA Goddard Institute for Space Studies n.d.

.

These data are in broad agreement with those quoted by the IPCC (AR4) of 0.56-0.77°C for southern hemisphere land areas in the period 1901-2001.

The Pacific Ocean has warmed during the past 60 years or so. For the period 1955-1996, the upper 3 km warmed by 30%: more in the North Pacific (37%) than the South Pacific (16%) (Levitus et al., 2000). Direct measurements of sea-surface temperature also show that the Pacific has warmed over the past century (Hoegh-Guldberg, 1999), something confirmed by the IPCC (AR4) which found that southern hemisphere oceans had warmed 0.68-0.69°C in the period 1901-2001.

2.1.b. Sea-surface pH (alkalinity-acidity)

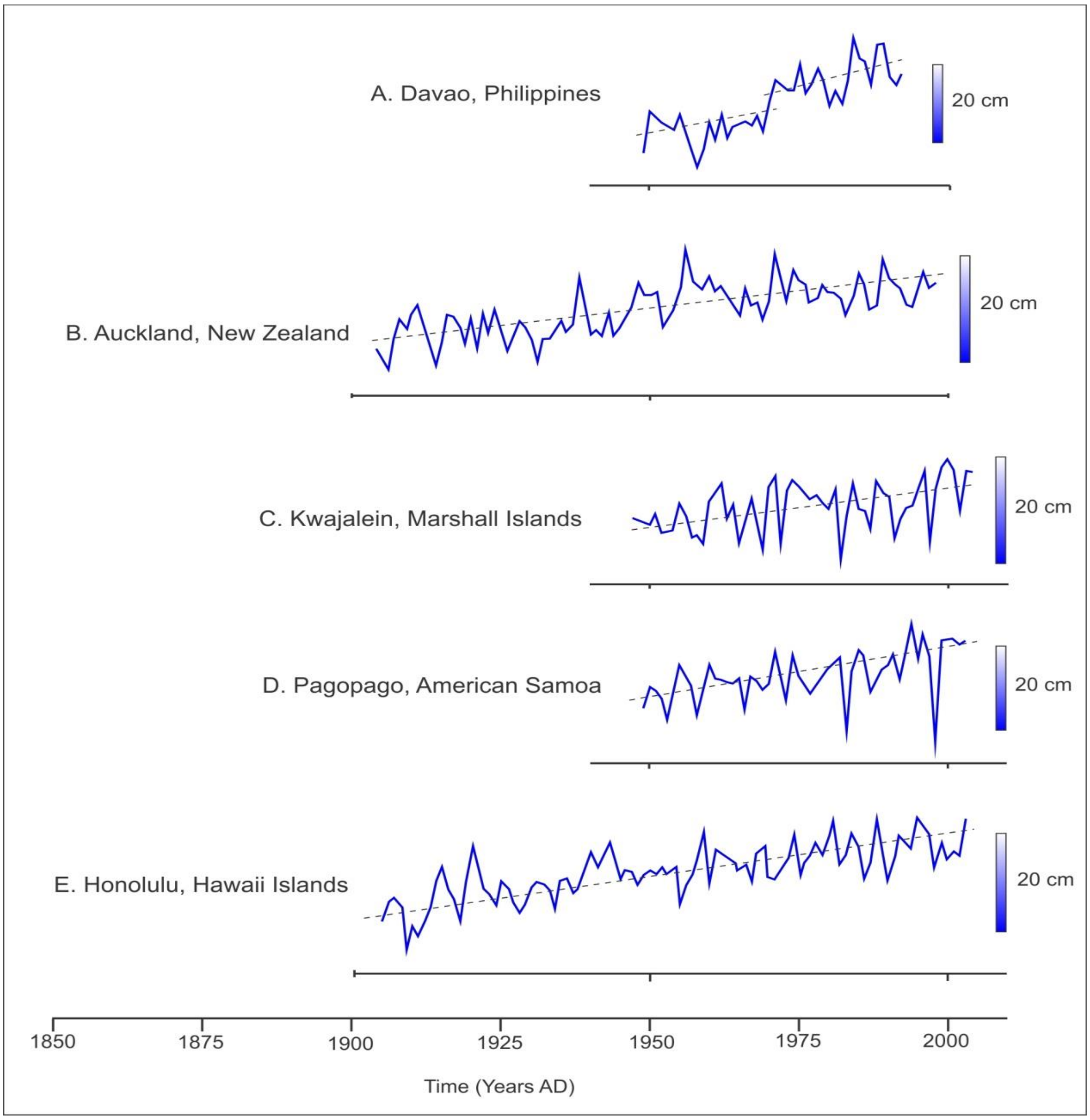
It has become clear in the past decade that the uptake of anthropogenic carbon (CO_2) from the atmosphere by the ocean has caused it to become increasingly acidified (Doney et al., 2009). Between 1750 and 1994, there was a decrease of 0.1 in the pH of the global ocean (Raven et al., 2005). Increased sea-surface temperatures may also have decreased pH.

An increase in the amount of dissolved CO_2 in seawater means that there is a concomitant decrease in the amount of dissolved $CaCO_3$ which is taken up, particularly in tropical oceans by plankton and reef-forming organisms. Thus the effect of lowered ocean pH is that more energy is required by these organisms to extract $CaCO_3$ from seawater to build their skeletons, which on coral reefs translates into slower reef-growth rates. $CaCO_3$ deposition in tropical oceans is estimated to have decreased 6-11% from pre-industrial levels (Kleypas et al., 1999). At the same time, because the ocean water has become more acidic, rates of $CaCO_3$ dissolution increase; on coral reefs, this means that coral skeletons are subject to more rapid dissolution. Both effects imply significant problems for corals and other calcifying organisms in the ocean.

2.1.c. Sea-level change

During the period of Recent Warming, there has been a net rise of sea level in the Pacific Islands region (Church et al., 2006). Several long-term series are shown in Figure 2.3 to illustrate this.

Figure 2.3. Records of recent sea-level change in the Pacific Basin



Source: Nunn, 2007a.

Note: All data from the Permanent Service for Mean Sea Level n.d. [www.psmsl.orgwith minor discontinuities interpolated and trend lines added. All series plotted have been standardized by the PSMSL to RLR (revised local reference) form.

A. Davao, Mindanao Island, Philippines, 1948-2004, is regarded as unaffected by significant tectonic activity or subsidence associated with groundwater extraction by Siringan et al. (2000).

B. Auckland (II), North Island, New Zealand, 1903-2000, is a record from which minor tectonic influences have been subtracted (Hannah, 2004).

C. Kwajalein, central Marshall Islands, NW Pacific Ocean, 1946-2004, is regarded as a valid record of long-term sea-level change (Wyrtki, 1990).

D. Pagopago, Tutuila Island, American Samoa, central Pacific Ocean, 1948-2003, is regarded as a valid record of long-term sea-level change (Wyrtki, 1990).

E. Honolulu, O'ahu Island, Hawaii Islands, NE Pacific Ocean, 1905-2003, is regarded as a valid record of long-term sea-level change (Wyrtki, 1990; Nunn, 1994).

These data are in broad agreement with those quoted by the IPCC (AR4) which show that sea level in the past century rose 15-20 cm (1.7±0.5 mm/year). There are considerable regional variations in sea-level rise within the Pacific Islands region which can be ascribed to changing wind effects (Timmermann et al., 2010). It is important to note that in some places these effects oppose but cannot cancel the regional sea-level rise signal.

2.1.d. Precipitation change

It is generally thought that there are too many factors influencing precipitation for it to be clearly demonstrated to have changed within the past century. Certainly some places have become demonstrably wetter or drier but it is uncertain whether this is part of a sub-regional trend or local factors such as deforestation and urbanization.

2.1.e. Change in ENSO frequency and intensity

Currently, ENSO-negative (El Niño) events affect the Pacific Islands every 3-5 years. They last as long as 18 months and vary in intensity. While earlier variations in ENSO periodicity, which measures the frequency of El Niño events, have been detected, the period 1920-1960 was one characterized by irregular and weak ENSO. Since 1970, there has been a shift to strong and regular ENSO (Nunn, 2007a).

2.1.f. Change in tropical-cyclone frequency, intensity and geographical spread

Tropical cyclones develop in the Pacific Islands region usually only in ocean areas where sea-surface temperature is more than 27°C. In most years, this condition is met only in the western Pacific warm pool. During El Niño events, another warm pool may develop farther east.

During the past few decades, the western Pacific warm pool appears to have expanded eastwards as a result of sea-surface temperature warming. This may explain the observed increase in tropical-cyclone frequency in the Pacific Islands region within this period (Nunn, 1994) as well as the steadily increased incidence of tropical cyclones reaching countries in the central South Pacific (like Niue and Samoa) that have traditionally regarded themselves as beyond the geographical reach of these phenomena.

2.2. Recent acceleration of key variables

There is good evidence that within the past 10-15 years, there has been an acceleration in the rates at which temperature and sea level have been rising in the Pacific Islands region and elsewhere (Merrifield et al., 2009).

In looking at the previous century, the IPCC (AR4) identified two periods of temperature rise. The earliest (1910s-1940s) showed a total of about 0.35°C while the more recent (1970s to 2006) showed a total of 0.5°C. The IPCC also found that there had been a an increasing rate of warming within the past 25 years with 11 of the 12 warmest years on record having occurred within the past 12 years. This trend has continued since 2007 when the AR4 was issued. This global trend is also reflected in Pacific Islands datasets (Mataki et al., 2007b).

In terms of sea-level change, satellite altimetry data (available since 1992) have consistently shown faster rates of sea-level rise than the average for the past century. A good example is the figure of 3.1±0.7 mm/year obtained by Cazenave and Nerem (2004). The suggestion that this represents a recent acceleration in the rate of sea-level rise is supported by recent trends, albeit short-term, obtained from tide gauges in the Pacific Islands; for example, the gauge at Lautoka (Fiji) is showing a recent rise trend of 3.2 mm/year, well above the range of projections of the IPCC in AR4.

In a general sense, it is likely that tropical-cyclone frequency has increased in the Pacific Islands region in the past few decades as temperatures have increased, but it is difficult to demonstrate this unequivocally because of large natural variability. Empirical studies have found that since 1970 (when a strong ENSO period began) there have been more tropical cyclones worldwide, particularly in the North Pacific and in the Southwest Pacific (IPCC, AR4); in the latter region, the numbers of severe tropical cyclones doubled between 1975-1989 and 1990-2004 (Webster et al., 2005). In addition, the average intensity of tropical cyclones has increased in these regions, with the number of category 4 and 5 storms increasing by 75% since 1970 (IPCC, AR4).

2.3. Effects of recent climate change

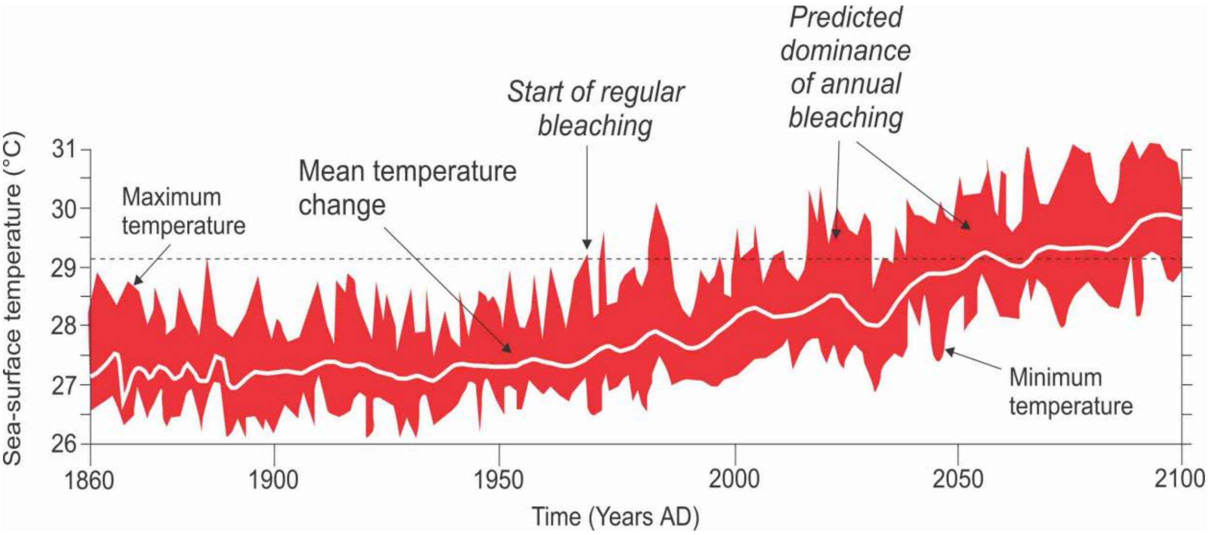
While it is clear that recent climate change must have had innumerable and varied effects, there is inevitably some controversy around identifying these with certainty because of all the other factors that might have caused (or at least contributed to) these effects. With such caveats in mind, this section attempts to identify the nature of impacts of climate change on Pacific Islands within the past 100 years.

2.3.a. Temperature

Temperature rise is likely to have had many effects on food-production systems in the Pacific Islands region but because these systems have been changing so much – typically as a consequence of new crops and new methods of farming being introduced – it is very difficult to isolate these effects. It is likely that increasing temperatures have stressed particular groups of plants but it is also likely that any signs of this stress have been more readily interpreted as a result of human impacts, such as the introduction of alien competitors, predators and diseases (Denslow et al., 2009).

Where the effect of temperature rise is less equivocal is in terms of its effects on coral reefs. As noted earlier, most reef-building corals live in shallow ocean water which warms and cools every day. Corals are also very temperature-sensitive, able to live comfortably between 20-29°C. Should the sea-surface temperature exceed 30°C for an extended period of time, corals are liable to eject their symbiotic algae (which give them their colour) and die (becoming bleached). Coral bleaching is a phenomenon which has been witnessed increasingly in the tropical Pacific since the early 1970s and is largely attributable to the increased sea-surface temperatures (Figure 2.4).

Figure 2.4. Sea-surface temperatures AD 1860-2100 for Tahiti incorporating ENSO effects compared to the thermal tolerance of corals (dashed line)



Source: Based on Hoegh-Guldberg, 1999; Nunn, 2009b.
Note: Note how for the first 100 years of record, sea-surface temperatures in Tahiti never rose above the coral tolerance limit, so there was no bleaching. Yet beginning around 1970 when mean sea-surface temperature had begun rising, temperature maxima during El Niño events reached above the coral tolerance limit and resulted in bleaching. By around 2050, it is expected that mean sea-surface temperature around Tahiti will have reached close to the coral tolerance limit, so that bleaching episodes will become annual occurrences.

The effects of recent coral bleaching in the Pacific Islands have centred around the loss of species diversity and habitat on the affected coral reefs (Coles, 2008). On most reefs, there has been little or no recovery of corals and the reef surface has become colonized by algae. The implications for those people who depend for sustenance on such reefs and the linked ecosystems they support (such as shallow lagoons) have been immense (FAO, 2008).

2.3.b. Sea level

The effects of sea-level rise on Pacific Islands over the past century are far less controversial today than 20 years ago when scientists were readier to deny the region-wide nature of sea-level rise and attribute its apparent effects at particular places to local factors, such as sand mining or the construction of artificial structures along the coast. Today it is clear that the effects of sea-level rise have been felt along most Pacific Island coasts for most of the last century and have been particularly apparent within the last 30 years. This discussion of the effects of sea-level rise is divided into its three principal effects: (i) coastal flooding (inundation), (ii) shoreline erosion, and (iii) groundwater salinization.

(i) Coastal flooding (inundation)

Since sea level has been rising in the Pacific Islands region throughout the past century, one would expect the lowest-lying parts of the region's coast to have become slowly flooded (inundated) within this period. While there are local factors that may mask this effect (such as increased coastal sedimentation), it is clear that there has been an increase in coastal flooding in most parts of the region. Much of the evidence is anecdotal and regrettably little has appeared in the published literature. Some exceptions are Mimura and Nunn (1998) who gave examples of inundation from Fiji's coasts, Rasmussen et al. (2009) who worked on smaller outer islands in Solomon Islands, and Nunn and Mimura (1997) who gave examples from throughout the region.

(ii) Shoreline erosion

As the mean sea level rises along sandy shorelines, so their equilibrium profiles change (the Bruun Effect). Sand is moved from the upper (back-beach) areas to the sea floor where it accumulates. The main effect of this is erosion of beaches as a result of sea-level rise, something that has been observed in every major Pacific Island group (Kaluwin and Smith, 1997; Nunn and Kumar, 2006).

In certain circumstances, shoreline erosion can proceed very rapidly; several coastal communities in Fiji have reported losses of as much as 30 m of land in 30 years (Mimura and Nunn, 1998).

Much has been made by the media recently of work on atoll-island coasts (Webb and Kench, 2010) which shows that some are actually growing (prograding) rather than eroding. This is a consequence of local factors, specifically the movement of sediment within an atoll lagoon or along an island's perimeter, and is not a reason to deny the impact of region-wide sea-level rise on shoreline erosion, now and in the future.

At this point it is also worth pondering some of the effects of shoreline erosion. The first is that the sediment which is eroded is commonly moved into reef-bounded lagoons where it increases water turbidity that can also contribute to coral bleaching and have other serious ecosystem impacts. The other is that for many coastal communities the back-beach area is important, perhaps for buildings and infrastructure, but also for vegetation. Many Pacific Island coastal communities reserve the coastal strip for coconut forest, maybe for pandanus or *Casuarina* forest; all these species are used fully by traditional communities and their loss may have serious implications for particular activities such as housebuilding (Mimura and Pelesikoti, 1997; Mimura and Nunn, 1998).

(iii) Groundwater salinization

Most coastal plains in the Pacific Islands are composed of sediment, the product of both terrestrial sedimentation from rivers and slope downwash and marine sediments being driven onland by waves, especially during storms. Owing to their soft-sediment composition, these coastal plains are permeable and maintain a freshwater lens within them that is important to plants growing in these locations. As sea level rises, so saline (sea-) water penetrates into these coastal plains reducing the horizontal extent and thickness of the freshwater lenses. This means that the roots of many plants in these locations come to tap into saline not fresh water, which means that most cannot survive. Good examples come from Fiji where sugar cane is a favoured cash crop in many coastal lowland areas; sugar cane will not grow well when the groundwater is saline, so many farmers have reported poor crops in recent years in such places (Barnett, 2011). Examples also come from atoll islands where, owing to the absence of any higher ground for agriculture, groundwater salinization has serious consequences for whole-island subsistence (Lobban and Schefter, 1997). Explicit links between salinization and sea-level rise are apparent in such locations; the example of Niutao Atoll in Tuvalu was discussed by Webb (2007).

As explained in the case study in section 2.5, much of the groundwater salinization on atoll islands occurs when large waves cross over these low-lying islands dumping saltwater on top of the freshwater lens, rendering it unsuitable for agriculture for some time. It has been argued that the loss of freshwater lenses from salinization associated with sea-level rise is the most serious climate-linked threat for people in atoll nations like Kiribati (Hunt, 1996). Loss of traditional sources of potable water on such islands is having a disproportionate impact on females whose usual role is to obtain this water (Kallmeyer, 2008).

It is worth expanding on some of the effects of salinization on freshwater lenses on atoll islands, not least because these effects are currently threatening the sustainability of human life on some such islands (White and Falkland, 2010). Freshwater lenses in such locations are found at levels that are controlled by sea level, so that as mean sea level rises, so does the water table (the surface of the freshwater lens) which can produce freshwater flooding on atoll-island surfaces. Mean sea-level rise will also enable increased penetration of saline groundwater into freshwater lenses, causing them to shrink laterally. These kinds of natural salinization effects can be exacerbated by groundwater extraction on atoll islands, besides a number of other polluting activities including fertiliser and pesticide use, and waste (White and Falkland, 2010).

2.3.c. Tropical cyclones

While there is evidence that the frequency and possibly the intensity of tropical cyclones has been increasing in the Pacific Islands region over the past few decades (Emanuel, 2005; Webster et al., 2005), there has been no attempt to relate this to the increasing impacts (in both human and monetary terms) of these events (although see Table 1.10). Between 1950 and 2004, the Pacific Islands region experienced 207 natural disasters, of which tropical cyclones comprised 76% of all natural disasters (Lal et al., 2009a). Yet tropical cyclones accounted for 90% of the total costs of these disasters and 79% of the fatalities.

It is only at the national scale that the economic cost of natural disasters like tropical cyclones is clearly visible (Holland, 2008). For example, the Pacific Island nation of Samoa reports average economic impacts during disaster years of 46% of GDP. When Tropical Cyclone Heta hit Niue in 2004, it led to losses of more than five times GDP in that year.

2.3.d. Extremes

It has become increasingly clear over the last two decades that the most serious manifestations of climate change in recent years in the Pacific Islands region (as elsewhere) are associated with extremes. These are not extreme events (like tropical cyclones) but extremes of key variables (like temperature or precipitation or sea level). It is these extremes that are having the greatest impacts on human and environmental systems because they represent maxima of particular variables that are associated with increased (rising) means.

In the case of temperature, extremes are manifested as prolonged periods of high temperature (heat waves) that have effects on all living things. At a global scale, one might refer to the observation that 2010 was the 34th consecutive year with temperatures above the 20th century average (NOAA 2011) – a clear sign of climate change – as evidence for this. Prolonged periods of above-average temperature may force environmental system across particular thresholds resulting in long-term system change. A good example from the Pacific Islands region is provided by the record of sea-surface temperature from Tahiti (illustrated in Figure 2.4). Before the early 1970s, sea-surface temperature maxima all fell below the upper temperature tolerance threshold for corals (the broken line in Figure 2.4) but after this time, owing to the rising mean sea-surface temperature, the maxima began increasingly to exceed this threshold, in this case causing coral bleaching.

Prolonged periods of intensive rainfall can also force long-term change, particularly as landslides, but more often cause only temporary disruptions. The case may be different with prolonged periods of high or low sea level, which in the tropical Pacific are typically associated with El Niño events. In cases where sea level dips below its present level, the impact on shallow-water ecosystems (like coral reefs) may be only temporary but, should the event continue for weeks rather than days, is likely to have much longer-term effects (Chowdhury et al., 2010).

The point about extremes is worth bearing in mind when we consider the debate about whether or not recent environmental changes are indicators of climate change or climate variability (see section 2.8). For with most variables, the greatest extremes occur infrequently, certainly not regularly. So once what is labelled as an extreme event begins to occur regularly, perhaps every year, then it is a sign of climate change. This is what is happening with floods in Nadi Town (Fiji) where what was considered to be an extreme event (perhaps a 1 in 50 year flood) in 1990 is now occurring every 1-2 years (Lal et al., 2009b). This is a clear sign that the mean has shifted, so that probabilistic labels for such events are becoming increasingly meaningless and unhelpful as a planning tool.

2.4. Responses to the effects of recent climate change

Until about 25 years ago, there was hardly any understanding among people in the Pacific Islands that their environments were being affected by climate change. This is not to say of course that people had not noticed change occurring and responded to it.

While there are no known examples of response to temperature change on the islands themselves, the earliest incidences of coral (-reef) bleaching in the tropical Pacific in the 1970s and 1980s led to a flurry of research that recommended a reduction in human impacts on the worst affected reefs (Glynn, 1993; Constanza, 1999). This contributed to the increase in the numbers of marine protected areas in the Pacific Islands region (Johannes, 2002; Bartlett et al., 2009).

The most widespread and noticeable effect of climate change along Pacific Island coasts for the past century has been sea-level rise to which people have responded in many ways. The most effective of these has been retreat: moving (that part) of an affected settlement inland, sometimes upslope, and out of immediate danger. There are examples of this that have been documented (e.g. Nunn, 1990; Nunn and Mimura, 1997). The response of many other communities has been to build, often with national or international funding assistance, artificial structures to protect unstable shorelines. While those structures that have been properly engineered, typically in urban areas in the Pacific Islands, have usually succeeded in maintaining the shoreline, those in more rural parts have often failed (Mimura and Nunn, 1998). The problem is the uncritical emulation by rural communities of urban solutions (something that has been called the "seawall mindset" by Nunn, 2009b); most such structures endure for 18-24 months before collapsing. Repair is often expensive, ineffective and eventually discontinued.

More than 25 years ago in the Pacific Islands, the widespread belief that coastal flooding and shoreline erosion were local (not region-wide) problems meant that local solutions were usually sought (Kaluwin and Smith, 1997). Within the past 25 years, the increasing appreciation of these problems as region-wide and having a global cause has changed perceptions. For some time, a few Pacific Island countries eschewed adaptation of any kind because they believed that, as the unwitting victims of climate change, it should be the countries that caused the problems which should come up with the solutions to them. The naivete of this position has gradually become clear with only one Pacific Island country in 2010 continuing to maintain a reluctance to consider necessary country-wide adaptation on the specious grounds that this would be unnecessary if effective reduction of greenhouse-gas emissions were to take place immediately[3].

[3] The author attended the Copenhagen Climate Summit (COP-15) and heard many such declarations firsthand.

A systematic discussion of responses to climate change in the Pacific Islands region over the past 25 years is given in the following sub-sections, divided by particular groups of actors. It should be noted that with respect to the following four sub-sections, generalization is necessary but should be recognized as such. There are often considerable variations in the ways that particular actors have approached issues of climate change in the Pacific Islands region; it is impossible to capture all this variation in this paper.

(i) Responses by the international community

While those countries that once had colonies in the Pacific Islands have maintained ties (France still has colonies), it is Australia and New Zealand that have been the major providers of aid to independent Pacific Island nations within the past 25 years (Table 2.1). In the last decade, other countries, particularly in East Asia, have been major contributors of aid as has the European Union.

Table 2.1. Aid per capita (current US$) to selected Pacific Island Countries

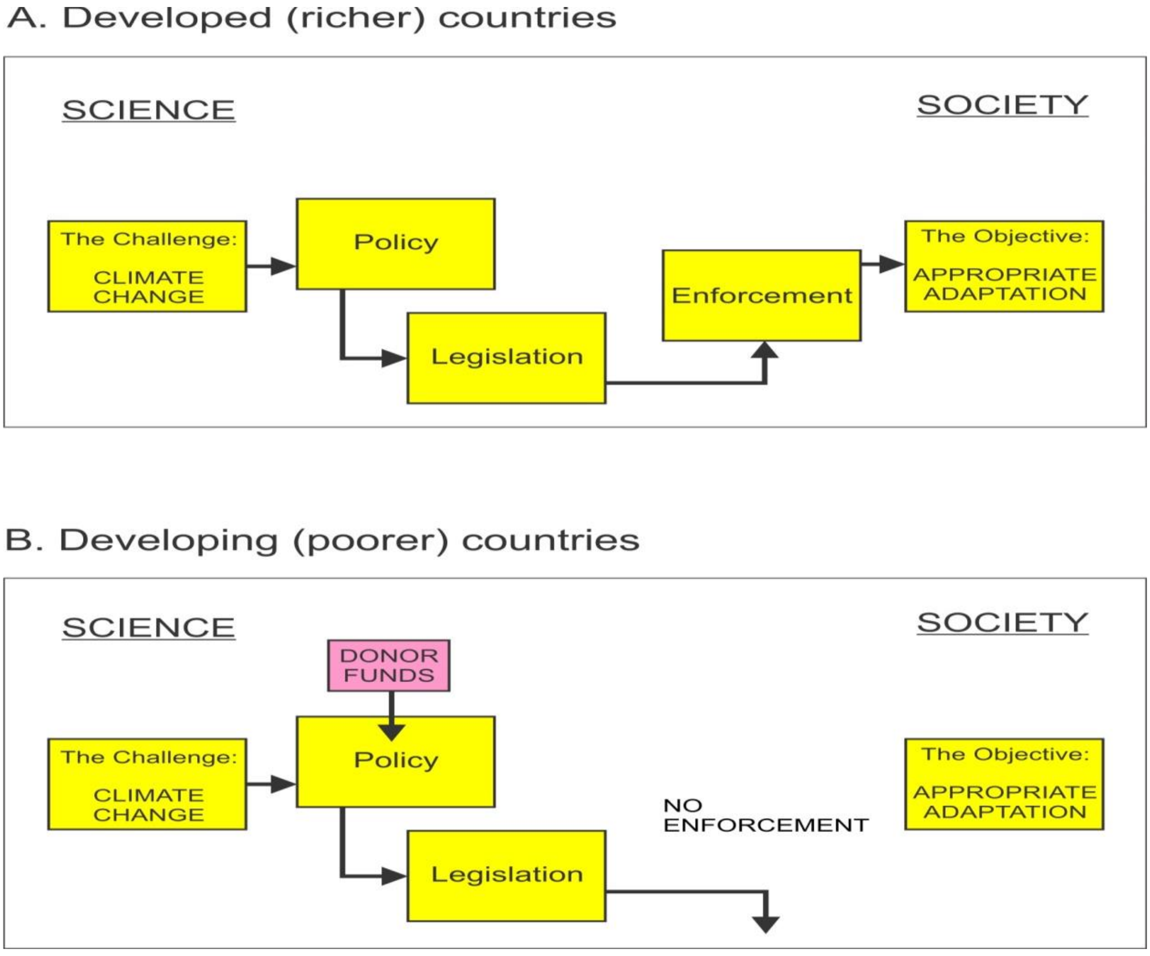
Country	**Aid per capita (current US$)**				
	1985	**1990**	**1995**	**2000**	**2004**
Fiji	48.5	67.9	56.4	36	71.8
Kiribati	185.1	279.8	192.1	210.2	185.7
Papua New Guinea	74.7	107.2	86	53	45.9
Samoa	121.3	297.4	262.1	161	170.9
Solomon Islands	77.2	140.9	122.7	162.9	259.9
Tonga	143.1	309.1	400.2	188.2	188.3
Vanuatu	168.5	337.9	270.8	241.1	177.3
average for low-income countries	7.6	12.4	12.4	9.3	14.7
average for lower-middle income countries	5.4	10.5	9.5	7.2	9.6

Source: Gani, 2008.

It is difficult to estimate the amount of aid that has come into the region in the past 25 years for climate-change adaptation and mitigation, but it has probably been several hundred million US dollars; this includes bilateral aid, assistance to multiple countries through regional agencies, and contributions held for this purpose by the World Bank, Asian Development Bank, and others. Much of this money has been to assist Pacific Island nations meet their obligations under particular treaties, such as the Montreal Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). Some of the money has been spent on mitigation projects, particularly around renewable energy and reafforestation, but most has (especially in the past decade) gone on adaptation. Policy and legislation have been developed in most island countries with the intention of enforcing environmental sustainability, innumerable attempts made at in-country capacity building, and large numbers of pilot projects run and reported on. While worthy and sincere, most of these initiatives have failed to either inform Pacific Island people about the need for long-term sustainable adaptation or to develop and mainstream appropriate solutions throughout the region. The harsh reality is that most people in the Pacific Islands today are no better prepared for climate change than they were 25 years ago (Barnett, 2008; FAO, 2008; Nunn, 2009b). It is worth examining briefly why this substantial investment has failed to deliver.

Policy and legislation are effective tools for persuading people in richer ("developed") countries to support climate-change adaptation, but the truth is that in poorer countries, especially those that are archipelagic in nature, most rural dwellers are either unaware of national policy and legislation or can choose to ignore it (Duncan, 2008; Nunn, 2010; Figure 2.5).

Figure 2.5. Schematic diagrams showing how the gulf between science and society is bridged in developed countries and why this solution fails in developing countries of the Pacific Islands region



Source: Nunn, 2010.
Note: A. National governments in developed (richer) countries recognize the challenge, research strategies for meeting this, develop appropriate policies and enact legislation which is effectively enforced resulting in appropriate adaptation.
B. National governments in some developing (poorer) countries are informed of the challenge, access donor (external) funds for developing policy and legislation that generally emulates those in donor countries. This legislation is unable to be effectively enforced, no appropriate adaptation occurs.

It would have been far more efficient for international donors to have first learned about the most effective ways of influencing environmental decision-making in Pacific Island nations before committing large sums of money.

Secondly, international donors have long assumed that by building capacity to manage climate change within Pacific Island countries, their ability to cope with the myriad challenges of the future would somehow be improved. By "capacity-building", it is meant increasing the numbers of qualified people working in Pacific Island governments by sponsoring these people to attain higher qualifications of relevance. Again, international donors might be regarded as culpable for their assumptions that building capacity was the same as sustaining capacity, for even today there are very few such qualified people in Pacific Islands governments; most have left for far better-paid jobs elsewhere or have been diverted into senior positions within their governments (by virtue of their superior qualifications) where they have little or no interest or influence on climate-change matters (Duncan, 2008; Nunn, 2009b).

This fact has not gone unobserved by some donors who have recently substituted "capacity development" for "capacity building". With assistance from UNDP/GEF (Global Environment Fund), most Pacific Island countries have undertaken National Capacity Self Assessments, which are worthwhile exercises for long-term capacity planning. Yet tensions remain around the fluidity of staffing in key areas of Pacific Island governments, particularly the numbers of government employees, usually in non-revenue generating areas, who are funded entirely by aid (Duncan, 2008; Gani, 2009; Hook, 2009).

Finally, because of the short-term cyclicity of donor funding, most money for on-the-ground adaptation has been spent on pilot projects in usually unrepresentative locations in the islands. Often community buy-in to these projects is high because they involve large sums of money reaching groups that are typically only partly within the cash economy. Yet as soon, as the money dries up, as it invariably does at the end of the 2-3 year projects, community support often tapers off rapidly. There seems to have been little genuine concern on the part of donors funding pilot projects to embed effective and sustainable adaptation solutions (Nunn, 2009b).

(ii) Responses by regional agencies

Since many Pacific Island governments are too small to have a full range of experts within them, the model in the region for the past 40 years has been to have inter-governmental regional agencies undertaking work on behalf of member governments. The principal agencies charged with environmental work are the Secretariat for the Pacific Regional Community (SPREP) and the South Pacific Applied Geoscience Commission (SOPAC), recently subsumed within the Secretariat for the Pacific Community (SPC). Both SPREP and SOPAC have suffered over the years from high staff turnover, employing persons from outside the region who often have little experience or understanding of its environments and cultures. But the main problem from a climate-change perspective is that these agencies have been largely reactive not proactive. They have translated international priorities into national responses often without questioning whether this was the correct approach for the Pacific Islands region[4]. Regional agencies have tended to view themselves as the mouthpieces of their member governments; for example, articulating their views for additional assistance for climate-change adaptation often without asking whether they should rather be encouraging greater ownership of climate change by governments.

(iii) Responses by governments

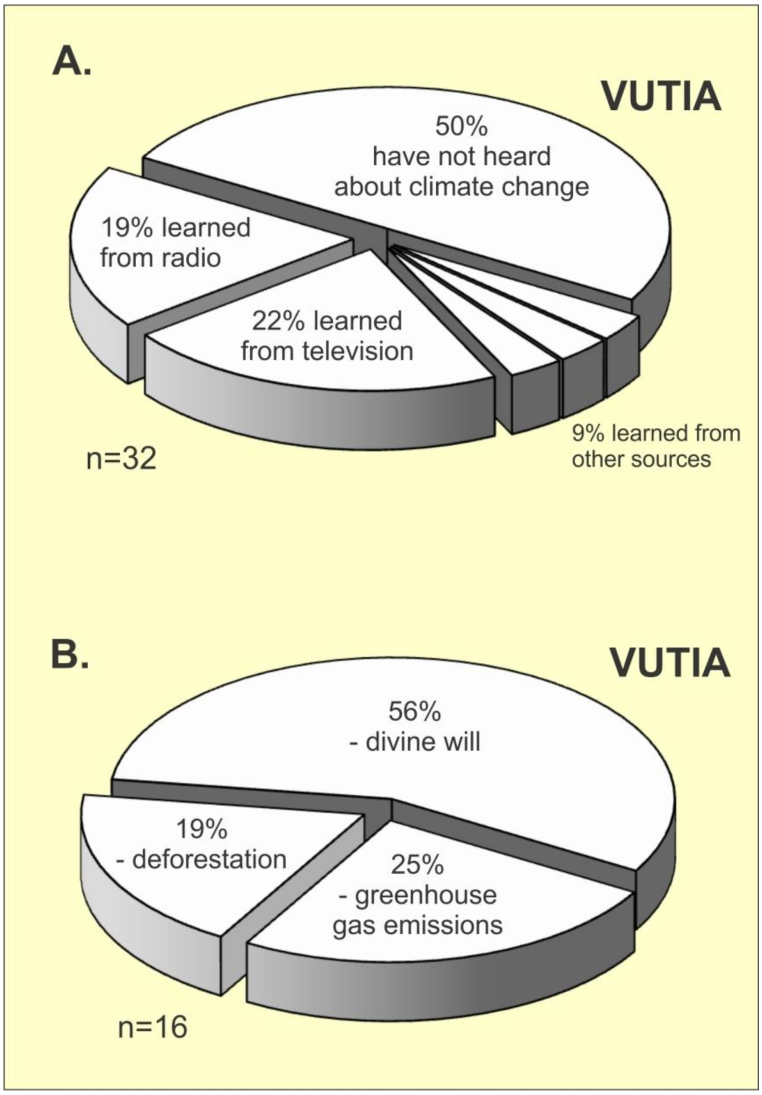
Most Pacific Island governments have acted in unison over the past 25 years in their responses to global initiatives. This is something largely orchestrated by regional agencies and international donor partners and is not necessarily what either the governments or their peoples want or believe; examples include the ratification of international treaties, the meeting of their obligations under these, and the subscription to the unrealistic 1.5°C global average temperature rise target at the Copenhagen climate summit (Nunn, 2009b; Farbotko and McGregor, 2010). Even today, there are huge gaps between the understanding of most Pacific Island government decision-makers about climate change and their counterparts from larger countries. Much policy and legislation around climate change in Pacific Island countries is often nothing more than a diluted version of what obtains in larger, richer countries. Climate change is not a matter of electoral dispute. Most national representatives from Pacific Island nations subscribe to the positions of those larger richer countries that contribute most to their recurrent budgets. It takes a courageous leader to make a stand against such a position and few do. As a recent FAO report concluded, "Overall, PICs' [Pacific Island countries'] response to climate change so far can be described as being, project-based, ad hoc and heavily dependent on external resources. Competing priorities, lack of national government commitment, limited capacity and the dominance of international priorities over national ones in the climate change agenda are some of the common justifications for such feeble response" (FAO, 2008: 14).

Most donors have assumed that any assistance for community-level (grassroots) adaptation to climate change in the Pacific Islands must be channelled through national governments. The implication of this is that top-down approaches to adaptation are effective which they manifestly are not in the Pacific Islands (Duncan, 2008). Especially in the larger, archipelagic nations, there is little effective outreach by national governments beyond the main centres. Peripheral communities on "outer" islands rarely receive a visit from government personnel and certainly have little knowledge or understanding of what government's current positions are on international issues like climate change (Kumar, 2007). A recent survey of outer-island communities in Fiji, Kiribati and Vanuatu found that most had no understanding of the term "climate change" although many reported environmental changes consonant with its effects (Nunn, 2008). Recent work on communities in the Rewa

[4] One feature of the response to climate change by Pacific Island countries has been "the dominance of projects led by regional organizations over projects led by individual countries and territories" (FAO, 2008: 14).

Delta in Fiji, about 25 km from Suva, the capital city, found that only 50% of people had heard about climate change; of those, 56% believed that the cause of climate change was the will of a divinity (Figure 2.6 - Lata and Nunn, 2011).

Figure 2.6. Results of questions about the awareness of climate change and its causes



Source: Lata and Nunn, 2011.

Note: A. Answers to the question "have you heard about climate change?" and, if yes, "from where?"
B. Of those who have heard of climate change, answers to the question "what do you believe to be its (principal) cause?"

It has long been acknowledged that most Pacific Islanders involve divine will "in support of a wide range of private and public goals, including national ones" (Douglas, 2002: 8).

That said, Pacific Island countries have often been vocal in international meetings about climate change and its potential to become a security issue in the region. The Pacific Island nations have been the dominant force in the Alliance of Small Island States (AOSIS) group that often votes as a bloc on climate change issues in the United Nations and sponsors meetings on behalf of the region.

(iv) Responses by community leaders

Beyond the main (urban) centres in Pacific Island nations, most environmental decision-making is the principal responsibility of the communities who occupy and generally subsist from the land. While most such communities are largely unaware of national and international priorities around climate change, many are also scornful of receiving advice from government (Duncan, 2008; Iati, 2008). Both these conditions reinforce the importance of community-level environmental decision-making in the modern Pacific Islands, something that has been recognized for some time but rarely acted upon by those with power at national, regional or international level (Alley, 1999; Nunn, 2009b; Barnett and Campbell, 2010). As an illustration, it was found that on three outer islands (Bellona, Ontong Java, Tikopia) in Solomon Islands, the people had developed the following adaptation solutions (Rasmussen et al., 2009).

Coastal protection – A few frail and informal structures, perhaps made from sticks or uncemented piles of rock, had been placed along eroding shorelines at the fronts of houses.

Construction methods – When tropical cyclones threaten Bellona and Tikopia, emergency shelters are rapidly constructed in designated places for shelter; traditional building styles and materials are used. Caves are also used. On the atoll islands of Ontong Java, house floors are raised above expected flood levels.

Food supply – After a cyclone has destroyed crops, the following strategies are adopted: (a) plant fast-maturing root crops, (b) preserve food using traditional fermentation, (c) exchange with people on neighbouring islands and clan members elsewhere, and (d) place more emphasis on fishing to counter loss of other foods.

Water supply – Rainwater tanks are now ubiquitous in these islands obviating the need to access dugout wells or depend on coconuts during droughts.

Re-location – There is a long history of exchange between these outer islands and others in Solomon Islands; it is an accepted response to climate stress.

Remittances – In times of hardship in particular, financial and other assistance from clan members elsewhere is given to the people in these islands. On Ontong Java, remittances are "the most important coping strategy in response to climate-related impacts on food availability" (Rasmussen et al., 2009: 10).

Community-level governance in most (parts of most) Pacific Island nations generally follows a traditional model, one that has evolved over long periods of time usually in order to moderate social issues rather than environmental ones (Iati, 2008). For this reason, the decision-making outlook is usually short-term and reversible rather than long-term and sustainable with respect to resources or environmental management strategies. But perhaps the most important factor to consider is that such traditional decision-making is typically hierarchical with a single unelected (often hereditary) leader having the final say. In many parts of the Pacific, this leader is the "chief" of a community; elsewhere a "big man"; in Kiribati, many islands are governed traditionally by the *unimwane*, an elderly man elected by his male peers as one who is most imbued with traditional values.

While this type of decision-making may be unsuited *per se* to the modern Pacific Islands region, it is its application to environmental decisions that is of concern here. Most such community leaders lack formal education because of their age. They also lack exposure because, ironically, they command greatest respect from their peoples by having remained in the community rather than spending time outside it. They make decisions based largely on perceived precedent – what they believe happens elsewhere – and these are often uninformed. Finally, while such leaders may listen to advice from others – typically other elderly males – they often make decisions without such inputs (Nunn, 2008, 2009b).

The result is that many decisions have been taken about the environment in the Pacific Islands that are ill-advised. Widespread examples include the decision to build seawalls, to clear vegetation that "blocks" a community's view of the sea, to reclaim land, or to uproot fledgling mangroves (Nunn, 1990, 2000). The imperative for better-informedcommunity-level environmental decision-making is the key to successful and sustainable climate-change adaptation in the Pacific Islands.

There are signs that this is happening with major aid donors like Japan signalling their intention to boost aid directly to Pacific Island communities. In addition, many non-government organizations are becoming active at raising awareness about climate change in rural parts of Pacific Island countries; among these are the Christian churches, which in 2009 articulated a helpful position in their Moana Declaration[5] and others like OISCA that sponsor coastal mangrove replanting schemes as an alternative to seawall construction.

2.5. Case Study: Beru and Butaritari Islands, Kiribati

Beru and Butaritari are both comparatively densely-populated atoll islands in the Republic of Kiribati. Like most islands in the group, they are experiencing the effects of climate change as well as threats to traditional livelihood sustainability (Locke, 2009). All details in this section come from the unpublished report by Nunn (2008)[6].

Most people on these outer islands in Kiribati grow or hunt/catch much of the food they consume. While they are concerned about overexploitation of key (nearshore marine) resources, this is something they feel that they can manage and that effective management will correct. Where the people of these islands are less confident is in the effects of climate change, which in these islands pose three main problems – coral bleaching (only on Beru), groundwater salinization, and shoreline erosion.

[5] Online at www.oikoumene.org/resources/documents/wcc-programmes/justice-diakonia-and-responsibility-for-creation/climate-change-water/pacific-church-leaders-statement.html

[6] Available online at www.apn-gcr.org/en/products/ project_reports/2007/CBA2007-03NSY-Nunn_Final%20Report.pdf

On Beru, several instances of coral-reef bleaching have been noted over the past decade and the local fisherfolk, who have an intimate knowledge of their nearshore marine resources, have noticed that such reefs rarely recover fully after they have been bleached. It may be that, in addition to higher sea-surface temperatures, bleaching is associated with pollution which is less readily diluted and dispersed on this dry island than on wet Butaritari.

Groundwater salinization on both islands is associated less with the reduction in size of the freshwater lens beneath the surface and more with wave overwash during storms and, increasingly, during high spring tides. At these times, waves can run across the entire island, which in some places is only a few tens of metres wide, and dump salt water on top of the fresh water lens. The salt water takes long to disperse but until this happens it affects the roots of the crops being grown on the island surface. This is more of an issue on (dry) Beru than (wet) Butaritari because the high rainfall on the latter island recharges the freshwater lens more often than on Beru.

Both islands have experienced worrying shoreline erosion over the past 20 years but this has generally been regarded by the inhabitants of these islands as a local problem requiring local solutions. This is not only because the people are generally unaware of what is happening elsewhere in the Pacific Islands region but also because they observe some coasts growing (prograding) while others are being eroded. This is a normal condition on atoll islands and makes the identification of the effects of recent sea-level rise often more challenging than on the coasts of higher Pacific Islands (Webb and Kench, 2010).

While both islands have traditional decision-making structures in place to deal with the environmental problems described, there are both differences and commonalities linked largely to their comparative proximity to the principal island in the group, Tarawa, where central government is located. The Island Councils on both Beru and Butaritari have made approaches to central government for assistance, financial as well as practical, with their problems. The response of central government has been unsatisfactory in the view of the islanders, with reports having not been acknowledged or acted upon. This is not solely a criticism of central government, but also a reflection of the lack of appropriately qualified government personnel who can help. The World Bank funded Kiribati Adaptation Project (KAP) was intended to address such problems, particularly the issue of equity of adaptation, but its first phase focused only on Tarawa Atoll; outer islands have yet to receive any benefits from it.

The upshot of this is that the people of these two islands have been largely forced to find their own solutions to these problems, which is something that largely involves the respective Island Councils. These are male-dominated, headed by the *unimwane* who has the power of veto over Council decisions with which he disagrees. On Beru, the Island Council has approved the construction of artificial shoreline-protection structures in several places and also initiatives to restore "life" to the reefs off the eroding shorelines in the belief that this will reduce the problem. Since Beru is farther from Tarawa than Butaritari, traditional mores are better entrenched and the Island Council still has final say over environmental decision-making.

Being closer to Tarawa and therefore marginally better informed about the causes and solutions of environmental problems, the people of Butaritari have placed less faith in the Island Council than those of Beru. The Butaritari people have discussed problems, particularly of shoreline erosion, at village level and developed their own strategies. One example comes from the village of Ukiangang where shoreline erosion was recognized as a climate-linked problem requiring a long-term sustained solution rather than a short-term response. So the Ukiangang people banned sand mining from the affected beach and built a solid seawall. The important point here is that this decision represented a departure from traditional procedures, one that was stimulated by dissatisfaction with these. It may represent a trend that will increase in the future in the Pacific Islands region as traditional governance is increasingly acknowledged by the affected people as impotent to develop appropriate solutions and sustain them.

2.6. Culture, belief, and denial: excusing adaptation inaction

A dispassionate outside observer might look at how many hundred million dollars have poured into the Pacific Islands region over the past 25-30 years and wonder at how little effect this money has had in raising awareness about climate change and both developing and sustaining appropriate adaptation options throughout the region. It would be correct to conclude that much of this assistance has been wrongly directed and used to fund initiatives that were ingenuous in their conception and were not sustainable (Nunn, 2009b). Yet it would be wrong to conclude that Pacific Island people are not able to rise to the challenges posed by future climate change.

As with anywhere in the world, the process of stakeholder engagement in the Pacific Islands will be successful only if it is filtered through the cultures and traditions of the people involved (Seacrest et al., 2000). A good example is language; most Pacific Island people speak English as a second, sometimes a third, language so both their ability and resolve to communicate in English for long periods of time can sometimes be strained. Yet almost all outside communication with Pacific Island people about climate change has been in English; almost nothing has been translated into vernacular languages with the understandable result that climate change is regarded by many Pacific Island people as a foreign concept. This view is strengthened for many people in the Pacific Islands when they learn of the causes of climate change and are told that they – the islanders – were not the cause of it. All such communication has discouraged the ownership of the climate-change challenge by Pacific Island people over the past 25 years.

The issue of ownership is an important one at national level for, as long as Pacific Island nations depend almost wholly on external (aid) funding to underwrite the costs of climate-change adaptation, the less effective this will be. This is because nations will only fund adaptation strategizing when external funding is available, not when it is not. And such nations will continue to allow inappropriate solutions for adaptation (ranging from policy development to seawall construction) to be foisted upon them because they are at no cost to themselves. The only way to mainstream effective and sustainable adaptation in the Pacific Islands is for the region's governments to declare their ownership of the climate-change challenge by funding the costs of this adaptation from their own resources (Nunn, 2009b).

Another cultural filter that many outsiders in the Pacific Islands fail to understand is the innate indisposition of subsistence-based cultures to plan too far ahead, especially at a time when traditional subsistence foods are becoming scarcer. This is perfectly understandable; in such a context, the imperative for an individual is to acquire enough food at the end of each day to feed himself/herself and his/her dependents. In the face of that, any considerations about long-term sustainability of food resources is secondary, something for academic discussion not daily action (Pollock, 1992; Novaczek et al., 2005).

But the "short-termism" that is characteristic of many Pacific Island people is perhaps cultural, explaining a preoccupation with short-term gain and a lack of interest in what might happen a year or a decade hence. Short-termism helps explain why long-term strategies for climate-change adaptation are unlikely to be successful in the modern Pacific Islands (Nunn, 2009b) and why various manifestations of climate change are actually regarded by stakeholders as climate variability (see next section) despite often overwhelming evidence to the contrary.

Another cultural filter that is common to all Pacific Island societies is religion; for any outside group (such as the international climate-change community) that wishes to mainstream a message about climate change effectively, it is necessary to acknowledge religious beliefs. Religion may be regarded as a hindrance to effective understanding of climate change but it is also an opportunity (Donner, 2007; Takesy, 2004).

As a hindrance, it could be argued that religious beliefs invite scepticism about scientific messages (like the reality of climate change) and encourage complacency about the need for responding appropriately. Certainly many communities in the Pacific (such as those in the Rewa Delta – section 2.8) are reluctant to admit that climate might be changing because they are god-fearing people who keep their religious obligations, for which reason they are confident that the divinity would not allow something as fundamentally affective as climate change to damage their livelihoods (Mortreux and Barnett, 2009). Throughout the Pacific Islands, from top-level national government to community level, religious beliefs pervade environmental decision-making and are often used as excuses for inaction.

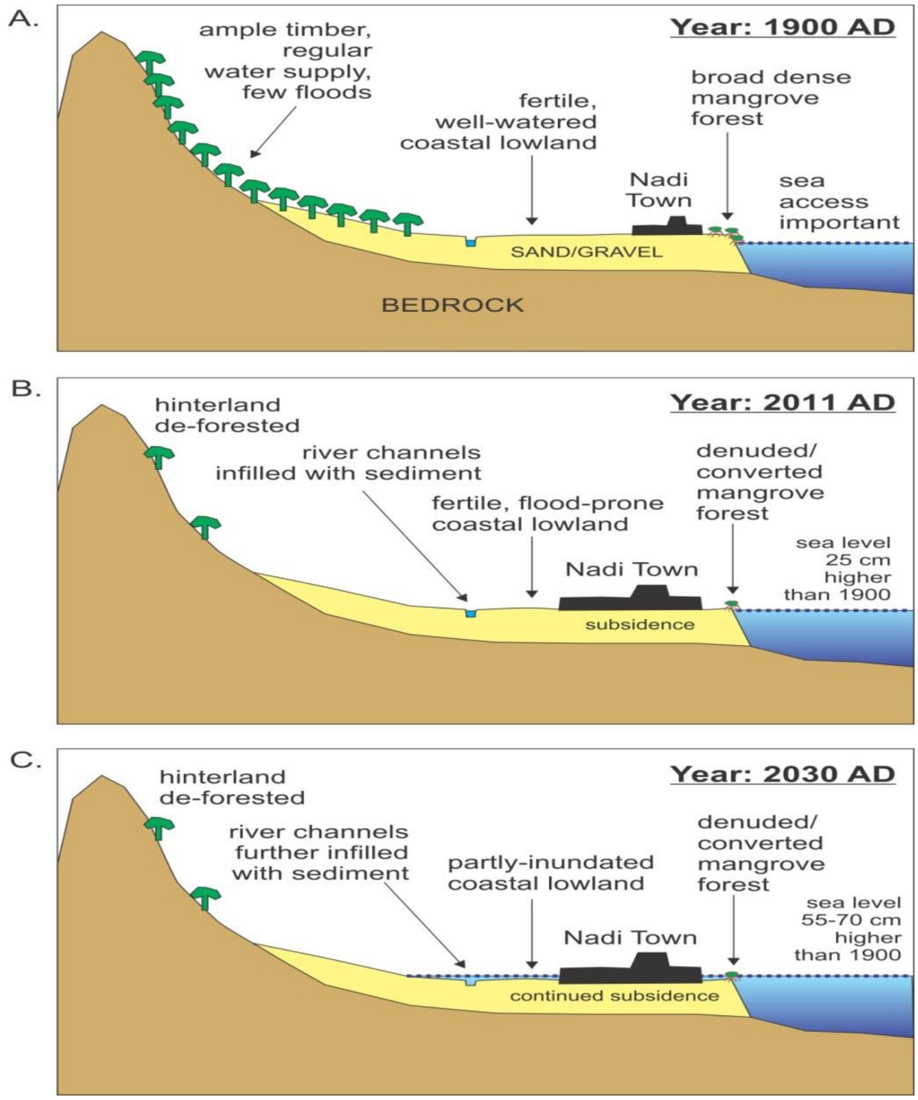
It is also worth noting that there is invariably a conspicuous misfit between stated government aspirations for dealing with climate change in Pacific Island countries and the will of civil society. Understanding that both entities are driven largely by differing agendas is important, but more so is the realisation that there is a massive gulf between science and society in this region. Effective solutions to climate-change challenges in the future must involve partnerships between governments and civil society, and must blend scientific solutions with the priorities of island peoples. Such a blended approach is widely recognized as key to successful adaptation (Mataki et al., 2007a; Iati, 2008; Mertz et al., 2009).

In summary, there are many reasons why climate-change effects and futures are being denied in Pacific Island countries today. There are cultural reasons - the perception of climate change as an alien concept and a foreign preoccupation; the deeply-rooted emphasis on short-term goals; and the widespread belief that a divinity will protect devotees from the worst effects of climate change. Denial is becoming widespread, particularly in the media (Iati, 2008; Nunn, 2009b). In common with much education (formal and religious) in the Pacific Islands, denial is simply required to be stated as factual by someone with authority (not supported with evidence) for many readers to agree with it. The views of extreme climate-change deniers from elsewhere in the world frequently get aired in the Pacific Islands media.

2.7. Case study: Nadi Town, Fiji

Decision-making for most townships in the Pacific Islands is also deficient, largely because these medium-sized settlements fall into a gap between the largest urban areas, which receive disproportionate attention from national government and external aid donors, and smaller rural settlements which generally have a greater inherent adaptive capacity (Mataki et al., 2007a; Hassall and Tipu, 2008). A good example is that of Nadi Town in Fiji, which is expanding largely because its role as a national tourism hub. Nadi had experienced floods of increasing frequency and magnitude over the past decade or so that have had significant economic impact on both the town and surrounding agricultural area (Lal et al., 2009b). Many explanations for this flooding have been advanced but it is plausible to suppose that the major contributory cause is sea-level rise (Figure 2.7).

Figure 2.7 Nadi Town (Fiji), an example of a town that will be severely impacted by sea-level rise in the next few decades



Source: Nunn, 2010.

Note: A. Nadi Town was built more than 100 years ago at a time when roads were few in Fiji and trade depended on sea transport. In the early years of Nadi's development, the location appeared sustainable because there were few floods owing to well-vegetated catchments. Sea level was lower than today so that sea flooding, particularly during storms, was not as much of a problem as it is today. A broad mangrove forest existed along the shoreline, adding to the resilience of the location. The fertile well-watered coastal lowland was ideal for commercial agriculture.

B. Today the situation of Nadi Town is quite different. The hinterland is largely deforested so that floods have become more frequent and attain higher average magnitudes than they did 100 years earlier. Lowland river channels have become choked with sediment. Sea level has risen significantly. Much of the former mangrove forest has been removed, often for tourism or for infrastructure purposes. Like all river deltas, the land on which Nadi is built has been subsiding as a result of sediment compaction, de-watering (groundwater extraction), and possibly structural (geological) downbowing. Despite all these problems, Nadi Town is growing and becoming more prosperous.

C. Thirty years from now, large parts of Nadi Town will be permanently underwater. The main reason for this is that sea level will be significantly higher so that town drains will be unable to carry flood waters away. Many rivers will be in a permanent state of flood because of the higher sea level. Storm surges will have far greater impact than they do today.

This places Nadi Town in the same group as other delta (and similar) towns and cities worldwide, including Shanghai (China), New Orleans (USA), and Venice (Italy), all of which have experienced similar problems in the past to those that Nadi is facing now (Syvitski et al., 2009). These problems were addressed for these cities largely by building extensive and expensive artificial structures to protect urban areas that are today well below sea level. Nadi is not yet in this situation but may be so in a few decades time. The cost of building and maintaining artificial structures around Nadi will prove prohibitive so that the only viable long-term solution for Nadi Town is for its vulnerable parts to be re-located.

The national government is reluctant to entertain this option because of the expense involved, so spend millions of dollars dredging the river channels around Nadi, and are considering whether or not to divert the mouth of the adjacent Nadi River away from Nadi Town. None of these solutions are likely to provide more than the temporary easing of the flood problem for Nadi Town.

A more recent initiative is the GEF Pacific IWRM Nadi Basin Demonstration Project which aims to manage flood risk in the Nadi Basin. Its goals, as currently defined, include flood management, early warning systems, river channel enlargement and diversion, but no mention of re-location of people from the most vulnerable areas. The Project is predicated on the belief that the cause of increased flooding in Nadi over the past decade is river-channel sedimentation not sea-level rise.

The Nadi Town Council and the Nadi Chamber of Commerce are the main decision-making bodies for Nadi Town and, although they are aware of the likelihood that sea-level rise is exacerbating the flooding problem and that it will not go away, they are reluctant to plan Nadi's future with this in mind. Part of the reason for this is that, because visitor arrivals to Fiji are increasing, Nadi is growing more prosperous and so future development plans are preoccupied with increasing revenue generation still further; there is an understandable reluctance to acknowledge and deal with such a profound problem in such a situation. But another part of the reason is that the costs of re-location, even partial re-location of the most vulnerable areas, are unthinkable to local decision-makers. To them, re-location could be considered only if national government developed a suitable site and put financial incentives in place to encourage re-location. As seen above, national government is not likely to undertake such a project, so it may be sensible for a foreign aid donor to step in and underwrite the base costs of Nadi re-location. In this way, the efficacy of such a solution may be demonstrated and encourage other similar-sized towns to follow suit.

Yet even though national and sub-national decision-makers in Nadi are generally reluctant to accept that much of Nadi will have to be re-located eventually, individual stakeholders (especially small-business owners) are often more far-sighted. Some, particularly those worst impacted by flooding in recent years, have been considering re-locating to higher ground. Whether this creates momentum that will eventually obviate the need for action by national or sub-national decision-makers is of great interest to those concerned with planning the region's future.

2.8. Climate change or climate variability?

Much inaction in the Pacific Islands to implement effective climate-change adaptation strategies arises from the belief that the climate is not changing *per se*, simply manifesting its usual variability. This view of observed changes in particular climate and climate-linked variables is commonest at community level (including individual stakeholders) but also widespread at sub-national (district) levels (Mataki et al., 2007a; Nunn, 2009b; Lata, 2010).

For subsistence communities, accustomed to routine interaction with the natural environment that surrounds them and equipped with traditional lore about its productivity, it is understandable that variations will be observed (Weber, 2006). Land occasionally disappears, land is sometimes flooded, river channels have been known to dry up, wild-food resources sometimes vanish from particular places or appear elsewhere. These happenings are well known to the people who inhabit such environments, much discussed in community gatherings where their most extreme manifestations are routinely recalled. So there is a lot of hesitation among such communities to admit that their observations in recent years are evidence for (long-term and irreversible) change rather than (shorter-term and reversible) variability (see next section).

Sub-national decision-making (local government) in Pacific Island nations is generally sympathetic to many local issues, including environmental ones, but handicapped to respond appropriately due to both a lack of funding and a lack of expertise (Mataki et al., 2007a; Hassall and Tipu, 2008). A good example was reported from Shefa Province on Efate Island in Vanuatu where environmental concerns (mostly increasingly frequent seawater flooding) of coastal settlements were not effectively answered by provincial government (Nunn, 2008). The specific issue was that calls for assistance in stopping logging (causing reef degradation) and helping coastal communities resist shoreline erosion and sea flooding were made with the agreement of all district authorities but were stonewalled by provincial authorities which were the only ones with access to the necessary funding and expertise. Examples from Kiribati and Fiji are given in the case studies above.

To counter the view that it is climate variability that is being experienced in the Pacific Islands region rather than climate change, it is most persuasive to look at single variables to demonstrate long-term trends of change (signals) that are distinct from shorter-term variability (noise). It should be noted that to separate signal from noise, it is generally necessary to have at least 30 years of regularly monitored data; any less than that and there is a danger that erroneous trends will be recognized (Pugh, 2004).

Three variables are discussed below in some detail to demonstrate that observed changes constitute climate change not climate variability: temperature, sea level, and tropical-cyclone frequency/intensity. Other variables exhibit similar trends but the long-term signal is more difficult to isolate.

2.8.a. Temperature

Figure 2.2 shows temperature data series of more than 30 years for four Pacific Island locations. In each, it is possible to identify long-term trends (shown as broken lines) that are distinct from the noise. These show that for the past 50-100 years, temperatures at these stations have been rising, a clear indication of climate change distinct from variability. The implications of this are twofold.

First, it would be expected that the direct effects of this temperature change (0.56-0.77°C from 1901 to 2001) would have impacted Pacific Island environments and societies. Yet, as explained above, because of simultaneous changes to these systems during the past 100 years, the direct effects of temperature change have been generally more difficult to isolate. It is only in with the associated rise of sea-surface temperature and its widespread effect in causing coral bleaching (illustrated in Figure 2.4) that there is clear evidence for the impact of temperature rise on Pacific Islands.

Second, there is a well-understood causal link between temperature change and sea-level change (Vermeer and Rahmstorf, 2009) so it would be expected that, as temperature has been rising, so too has sea level. Thus the empirical evidence for sea-level rise (illustrated in Figure 2.3) from the Pacific is exactly what would be expected had temperature been rising during the same time period (see below). There is also a causal link between temperature rise in parts of the Pacific and tropical-cyclone frequency which helps explain the observed increases in tropical cyclones in these areas over the past few decades (see below).

2.8.b. Sea level

Figure 2.3 shows that sea level has been rising in the Pacific Islands region for perhaps 100 years at rates of 1.7±0.5 mm/year. There is no mistaking the long-term trends in each of the datasets plotted underlining the point that, as for temperature, there has been a serial change in sea level superimposed on significant variability. A strong correlation exists for the Pacific between sea-surface temperatures and sea level (Chowdhury et al., 2008) demonstrating the validity of the expectation that, if temperatures are rising, then so too is sea level (see above).

2.8.c. Tropical-cyclone frequency/intensity

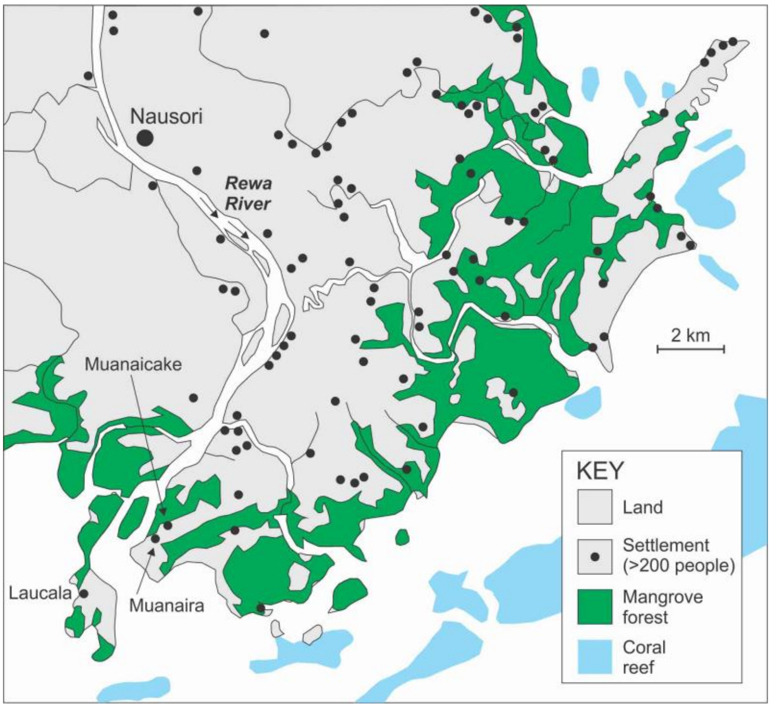
Several aspects of tropical cyclones in the Pacific, specifically its Southwest and North parts, show strong correlations with sea-surface temperatures (Emanuel, 2005; Mertz et al., 2009) although these correlations are not as clear as for sea level (Knutson et al., 2010; Yeh et al., 2010). As sea-surface temperatures have been rising since the 1970s, so too have the frequency, intensity, duration and spatial reach of tropical cyclones increased.

2.9. Case study: Rewa Delta, Fiji

An intensive study of climate-change perceptions among the inhabitants of the Rewa Delta, the largest in the Fiji Islands archipelago, allows insights into the gulf that exists between scientific imperatives and community priorities in a representative rural community in the Pacific Islands (Lata, 2010; Lata and Nunn, 2011). The results are also applicable to subsistence coastal and delta communities elsewhere in the "developing" world. This case study is intended to illustrate both the degree to which such communities understand and interpret what is happening to their surroundings, and how this in turn informs their preferred adaptation options.

Figure 2.8 shows a map of the Rewa delta, most of which is less than 4 m above mean sea level. The delta is composed of sediments carried downstream from the centre of Viti Levu Island by the Rewa River. Throughout the past 150 years or so, there is evidence that river channels have shifted within the delta while, for most of this time, the delta front has been growing seawards. This has changed in the past 20 years, with many signs that the delta front is being eroded.

Figure 2.8. The Rewa Delta (Fiji Islands)



Note: Study sites within the delta are shown; Nausori is the only town while Muanaicake, Muanaira and Laucala villages comprise the traditional community of Vutia.
Source: Lata and Nunn, 2011.

Almost all people in the delta subsist to some degree from wild foods or crops grown locally. In order to understand the nature of changes that such people have observed in the natural environment, surveys were carried out in the Vutia community, a group of three traditional villages – Laucala, Muanaicake, Muanaira. The locations of these villages, which house some 900 people, are shown in Figure 2.8. What was found was that the observations of the Vutia people about what was happening to their environment were almost exactly the same as scientists would have predicted for such an area. Foremost among the environmental impacts was increasingly frequent inundation of lands that had traditionally been only occasionally flooded. Associated with this, the Vutia people recognized that seawater was penetrating into the freshwater lens in which they have grown their crops for generations, a largely unprecedented occurrence. And then the Vutia people recognized that the river was changing in ways that were also beyond their experience (and those enshrined in their oral traditions), namely that the river was becoming ever more turbid, that channel-floor sedimentation was increasing, shoreline and river-bank erosion was becoming more widespread, and – most importantly – favoured fishing grounds were becoming unproductive.

The Vutia people had responded to these changes in various ways. In response to inundation, they had raised their dwellings and the cement paths connecting them. In response to salinization of croplands, they had adopted a raised-field system that creates perched water tables. And they had responded to bank erosion by building protective structures (stick-and-wire fences backfilled with domestic garbage), to the loss of fishing grounds by sailing farther afield but also trading crop surpluses for seafood. And they have been requesting the provincial council for many years to find a sustainable solution to these problems.

For the Vutia people, a sustainable solution would be a return to normality, for they firmly believe that the changes they are witnessing are but a temporary aberration and that within a few years normality will be restored. This belief that the cause is climate variability and not climate change arises in several ways. First, as noted earlier, subsistence communities are accustomed to fluctuations in food-resource productivity which understandably leads them to interpret all observed changes in this way. Second, the short-term outlook that defines many such communities (see above) also supports this view. But finally and possibly most importantly, the world view of people in Vutia prevents them from conceptualizing climate change and its consequences in the same way as visiting scientists do. The Vutia world view is one that is filtered through one form of Christianity, which teaches that the world was created for the benefit of humans and that it is unthinkable to suppose the world no longer functions for this purpose.

Over the next hundred years (see below), it is almost certain that the Rewa Delta will shrink markedly in size and that many currently-occupied settlements will be drowned, their inhabitants forced to move elsewhere (see Figure 3.1). How this impacts their current world view will be instructive for people in comparable situations elsewhere in the world.

3. The Next Hundred Years

Much of the media hyperbole that currently surrounds the issue of future climate-change impacts on Pacific Island nations suggests that they are on the “front line” of climate change, entire islands may “sink” or “drown”, whole countries may “disappear” (Connell, 2003;

Farbotko, 2010). While regrettable, this kind of rhetoric has forced world attention on countries in the region, particularly those atoll groups (in Kiribati, Marshall Islands, Tokelau and Tuvalu) where indeed entire islands are likely to be abandoned by their human inhabitants within a few decades.

But planning for the future cannot proceed on the basis of exaggeration, so this chapter is intended to explain what might happen in this uncommonly vulnerable region over the next 100 years. Section 3.1 explains how the climate of the region is projected to change by the year 2100, particularly with reference to five key variables: temperature, precipitation, ocean acidification, sea-level change, and tropical cyclones. It also explains uncertainties around these projections and their implications.

Section 3.2 looks specifically at the effects of projected 21st-century climate change on food production in the Pacific Islands region. It focuses on the traditional food-resource bases for Pacific Island peoples, their key vulnerabilities but also the opportunities. It is important to understand that climate change is only one of a number of future stressors on food resources, so that any prediction of its impacts must factor these in as well.

Section 3.3 examines the likely effects of climate change on the future economic development of Pacific Island countries, arguing that much depends on the degree to which they anticipate the necessary adaptation solutions. Discussions are given of the effects of climate change on tourism, agriculture and the other principal revenue-generating activities in the region.

Section 3.4 proposes that large numbers of coastal dwellers and activities will have to re-locate from vulnerable to less-vulnerable locations over the next few decades in the Pacific. There is a discussion of the timetables for re-location and some of the key issues involved.

Section 3.5 is based on the assumption, currently quite reasonable, that in most situations the need for communities and/or key infrastructure to be re-located will not be anticipated sufficiently far in advance to prevent disruption to livelihoods. In such a situation, there are likely to be flashpoints[7] associated with extreme events of extreme duration that will see communities and/or key economic activities in distress. This section attempts to predict where these flashpoints might be situated.

Section 3.6 argues that the single most important key to effective and sustainable adaptation by Pacific Island people to the challenges of 21st-century climate change lie with effective communication by scientists of scientific agendas. Learning from the problems around such attempts at communication over the past 25 years, it is clear that for future communication to succeed it must acknowledge various cultural and linguistic protocols.

[7] In this context, a flashpoint is defined as a situation in which a climate-driven natural disaster causes rapid loss of services and livelihoods, rapidly increases food insecurity, and has a high chance of leading to civil disorder.

3.1. Future climate change in the Pacific Islands region

While acknowledging that our understanding of the Earth's climate is imperfect, great confidence can be placed in projections from the IPCC and other groups of credible scientists, given that global climate models can successfully simulate recent climate change. Yet there will always be elements of uncertainty associated with future projections; much of this uncertainty is around the effects of interactions between changing climate variables. At present, most projections of future climate change are linked to particular variables and this section follows this by presenting projected 21st-century changes in temperature, precipitation, ocean pH, sea level, and tropical-cyclone incidence.

3.1.a. Temperature

The best-available projections of future temperature in the Pacific Islands region are those of the IPCC AR4 (Mimura et al., 2007) which are summarized in Table 3.1 below.

Table 3.1. Projected future climate change (2000-2100) for the Pacific Islands region

	Months	Temperature response (%)			Precipitation response (%)			Extreme seasons (%)		
		Minimum	*Median*	*Maximum*	*Minimum*	*Median*	*Maximum*	*Warm*	*Wet*	*Dry*
North Pacific	Dec-Feb	1.5	2.4	3.6	-5	3	17	100	20	2
	Mar-May	1.4	2.3	3.5	-17	1	17	100	14	-
	Jun-Aug	1.4	2.3	3.9	1	6	22	100	43	1
	Sep-Nov	1.6	2.4	3.9	1	6	22	100	31	1
	Annual	1.5	2.3	3.7	0	5	19	100	35	1
South Pacific	Dec-Feb	1.4	1.8	3.2	-6	4	15	100	19	4
	Mar-May	1.4	1.9	3.2	-3	6	17	100	35	1
	Jun-Aug	1.4	1.8	3.1	-2	3	12	100	27	3
	Sep-Nov	1.4	1.8	3	-8	2	5	100	-	-
	Annual	1.4	1.8	3.1	-4	3	11	100	40	3

Source: Mimura et al., 2007.

Note: These figures represent regional averages of temperature and precipitation projections from 21 global models for the A1B scenario. The frequency of extremely warm, wet and dry seasons is also shown.

Temperatures are projected to rise 1.4-3.7% by 2100 compared to 2000, perhaps slightly more in the North Pacific than the South Pacific. Extreme warm seasons will become twice as frequent as they are today within this time period. This increased warmth will have implications for many aspects of life in the Pacific Islands region. Perhaps the most extreme will be the increasingly regular bleaching of coral reefs (perhaps an annual event by 2055 – see Figure 2.4) that will eventually see most shallow-water coral reefs dieback and be replaced by less diverse algal reefs, with massive consequences for nearshore marine ecosystem productivity (Guinotte et al., 2003).

Warming will also impact many other aspects of food production in the region, as discussed in the following section. The implications of warming on disease distribution and human comfort are difficult to predict precisely but these are clearly variables that will need to be monitored closely as the century progresses.

Recent research (January 2011) suggest that an increase in temperature of 4°C by the year 2100 is now entirely possible (New et al., 2011). While being touted only as a possibility, it is now clearly important for planners and policy-makers to revisit their previous assessments of the impacts and adaptation needs of their countries. In the Pacific Islands, a 4°C temperature rise would have massive and profound impacts on the entire gamut of human and environmental systems. One broad-brush study suggests that around two million people could be displaced from the locations (not necessarily the islands) they currently occupy in the Pacific Islands in such a scenario (Nicholls et al., 2011).

3.1.b. Precipitation

Although precipitation is highly variable, the projections (Table 3.1) suggest a slight overall increase. There are however high degrees of uncertainty around these projections (-4% to +19%) and they also suggest that there may be significant changes in precipitation seasonality (for example, -17% to +17% in the North Pacific in March-May). While it is not necessary to discard these projections, they are clearly of limited use as they stand for the purpose of predicting impacts of precipitation change on the region.

What is slightly more apparent is that extreme wet seasons will increase quite significantly (35-40%) over the next 90 years while extreme dry seasons will probably become less frequent (Table 3.1).

3.1.c. Ocean pH

In the past decade, it has been increasingly realised that ocean acidification is perhaps more of a threat to coral reefs (and other calcifying organisms) than coral bleaching (Doney et al., 2009), although this has not become any less of a threat to food supplies (see section 3.2). Increasing ocean acidification (decrease of pH) in recent years is thought to have reduced rates of calcification and increased seawater dissolution of existing marine organisms (Kleypas et al., 1999).

In the future, owing to increased uptake of anthropogenic carbon by oceans, there will be a continued decrease in ocean pH, perhaps by a further 0.1 by the year 2050 (Doney, 2006; IPCC AR4, 2007).

3.1.d. Sea level

It is now widely regarded that the IPCC AR4 estimates of sea-level rise by 2100 (relative to 1990), which envisaged a maximum of 59 cm, were too conservative and that it is far more probable that sea level will exceed 1 metre by 2100, perhaps well above that (Rahmstorf et al. 2007; Vermeer and Rahmstorf 2009). It is now believed that an increase in sea level of perhaps 2 metres by 2100 is more likely than 1 metre (Nicholls et al., 2011).

This will pose challenges to Pacific Island nations far greater than those that they have become accustomed to contemplating. Most coastal plains will be permanently flooded and those people and activities that are currently located thereon will have no option but to re-locate. The principal implication for climate-change adaptation planning in the Pacific Islands region is that, while livelihoods in some low-lying areas might have been able to adapt to a sea-level rise of less than 1 metre, they will not be able to do so when confronted by a sea-level rise of twice that amount.

Of particular concern are atoll islands, which by definition rarely rise more than 2 metres above mean sea level and are composed mostly of materials (sand and gravel) that are readily eroded by waves. Some work on Tuvalu atolls has concluded that there are already signs of significant erosion of their superficial (sediment) cover which may herald the end of human habitability on affected islands (Dickinson, 1999, 2009). In the latter paper, current projections of 21st-century sea-level rise were used to estimate the years when particular atoll clusters in the Pacific region would effectively become uninhabitable (Table 3.2). The reasoning was based on a comparison with the time when these islands likely became habitable, a time marked by the emergence of dry coastal land suitable for human settlement.

Table 3.2. Years when selected clusters of Pacific atolls will have become uninhabitable

Atoll cluster	Earliest date	Latest dat
western Caroline Islands	2050	2100
central Caroline Islands	2060	2120
eastern Caroline Islands	2050	2100
Marshall Islands	2080	2160
Kiribati-Tungaru chain	2070	2140
Tuvalu	2070	2140
Tokelau	2080	2160
Phoenix Islands	2070	2140
northern Cook Islands	2050	2100
Line Islands (Kiritimati)	2050	2100
northern Tuamotu Archipelago	2070	2140
Society Islands	2070	2140
southern Tuamotu Archipelago	2080	2160
Gambier Archipelago	2070	2140
Cook-Austral chain	2050	2100

Source: Interpreted from Dickinson, 2009.

It is emphasized that these kinds of predictions are fraught with uncertainty and that it is likely that islands will become practically unable to be permanently inhabited long before the times shown. That said, this Table does show which groups of atoll islands are more sensitive to this than others. Those in the central Pacific and in the Caroline Islands (belonging to both the Federated States of Micronesia and the Marshall Islands) appear to be the most vulnerable while those in the main group of Marshall Islands, Tokelau, and parts of French Polynesia (Tuamotu Archipelago) appear least vulnerable. Yet the clear message of this table is that, even by this comparatively crude method of assay, no atoll group in the Pacific is likely to be habitable by the end of the century. And it is worth noting that

Dickinson (2009) used the IPCC AR4 estimates to produce his figures not the considerably higher ones that have been produced since that time, by Nicholls et al. (2011), for instance. Were these figures applied to Dickinson's metric, it is likely that 20-30 years would need to be shaved off each of the years in Table 3.2.

3.1.e. Tropical cyclones

Since tropical cyclones develop only where sea-surface temperatures exceed 27°C, it is likely that more tropical cyclones will develop in any one season when the region within which sea-surface temperatures exceed 27°C expands. It will also be expected that tropical cyclones will endure longer and be able to attain high intensity more frequently, as well as reaching places that have historically been unaffected (or only rarely affected) by them.

Specific research on Pacific tropical cyclones suggest something slightly different (Webster et al., 2005; Knutson et al., 2010). They suggest that it is the intensity of tropical cyclones that will increase in the rest of the 21st century. The total number of tropical cyclones will decrease although the number of the strongest such events (Category 4 and 5) will increase and endure longer.

These projections are not good news for Pacific Island nations, and it is now more opportune than ever for them to consider increasing resilience to tropical cyclones, especially in their most vulnerable parts and peripheral areas.

3.2. Effects of climate change on food production in the Pacific Islands region

Food security is perhaps the single greatest concern for Pacific Island governments this century, not simply because of the looming threats from climate change but also because of the numbers of food-production systems that are already being managed unsustainably or have become degraded (FAO, 2008). Future management must focus on sustaining food-production systems in the face of these myriad challenges.

While increased temperatures will undoubtedly impact the nature of (subsistence and commercial) agriculture in the Pacific Islands, it is probably possible to maintain present levels of output by substituting food crops that are intolerant of higher temperatures and saline groundwater with those less so. One good example is the giant swamp taro (*Cyrtosperma chamissonis*) that is more tolerant of saline groundwater than other species of taro and, indeed, most traditional root crops in the Pacific Islands. There is clearly potential for introducing salt-tolerant species of other crops that are being developed and introduced elsewhere in the Asia-Pacific region (Molina et al., 2008).

Rather it is precipitation that is the major concern for Pacific Island agriculture and the level of uncertainty implicit in the figures in Table 3.1 is unhelpful for planning purposes. The conclusion of that Table, that extreme warm (and to a lesser extent, wet) seasons will increase in frequency during the 21st century, has an important message for agriculture planners. There should be more efficient use of water, increased planting of shade trees and more use of agroforestry: all solutions that earlier generations of Pacific Islanders utilized and deserve to become more widely known (Clarke and Thaman, 1993).

In the same vein, the response of Vutia villagers (section 2.9) to groundwater salinization was to construct raised-field systems, as their ancestors had done, which is a solution worthy of wider dissemination. The other major effect of sea-level rise on terrestrial food production in the region is the loss of (often highly productive) land. In some countries, entire coastal plains may be rendered unusable for agriculture within a few decades, underscoring the need to start planning now for alternative food-production systems. These might include fishponds – to counter losses of marine foods from nearshore ecosystems (see below) – and the spread of both subsistence and commercial agriculture to higher land where this exists.

The productivity of marine ecosystems on which modern Pacific Island peoples depend for food will be severely impacted in the next few decades. The imperative is then to try and re-create such ecosystems elsewhere – perhaps in well-managed shallow lagoons or, more feasibly, in artificial ponds on land either linked to the ocean or not (Bell et al., 2009). For many Pacific Islanders, sea food has traditionally provided the protein components of diets, so that such ponds could be managed to provide protein foods such as fish and crustacea.

The combined effects of coral bleaching and increased rates of $CaCO_3$ dissolution on ocean food productivity are likely to be profound for most of the Pacific Islands region, especially its warmer parts (Hoegh-Guldberg et al., 2007). Several analyses are in broad agreement in that most coral reefs in Solomon Islands and Vanuatu will be pushed beyond their normal environmental limits for the foreseeable future by 2030 (Coles, 2008) The impacts on ocean-food resources, not just for subsistence dwellers on Pacific Islands, have been thoroughly discussed (Phinney et al., 2006) and calls made for urgent restorative actions, especially for coral reefs (Dodge et al., 2008).

The issue for food productivity is not around coral reefs *per se* but, arguably more importantly, around the associated ecosystems, particularly reef-bordered lagoons, that supply most of the subsistence foods that Pacific Island people obtain from marine sources. While it is difficult to isolate the effects of climate change on ecosystems that are already being unsustainably managed in many parts of the region (Aalbersberg et al., 2005; Novaczek et al., 2005), it is clear that climate change will impact both the numbers and the diversity of marine organisms present in these ecosystems (Cheung et al., 2009).

Mangrove ecosystems may be severely impacted by rapid 21st-century sea-level rise although there are studies, empirical and theoretical, that imply otherwise (Nunn, 2000; Alongi, 2008; Ellison, 2010). It is possible that some existing mangrove fringes, particularly around the mouths of large rivers (where sediment supply to the littoral continues), will be able to move inland as sea level rises, maintaining their important role in food production for coastal dwellers. Pacific Island governments should recognize this possibility and re-double their efforts to conserve mangroves and re-plant viable communities along appropriate parts of island shorelines.

3.3. Effects of climate change on economic development in the Pacific Islands region

It is likely that over the next few decades, Pacific Island nations will be forced to invest heavily in a variety of climate-change adaptation strategies, including those relating to food production (see above) and those necessitated by re-location of people, infrastructure and other activities from areas (to be) rendered uninhabitable by sea-level rise (see next section). It is unrealistic to suppose that richer countries, which over the next few decades will be grappling increasingly with the rising costs of domestic climate-change adaptation, will be as able (or as willing) as they are presently to provide assistance. For this reason, it makes sense for Pacific Island governments to invest heavily now in anticipatory adaptation. This might involve relocating communities and activities and infrastructure now that might otherwise be underwater by mid-century, and examining present development trajectories critically to see how they might be adapted in future. For example, in countries where commercial agriculture is an important revenue generator, it is worth trying to extend such agriculture to higher ground rather than concentrating almost solely on lowland areas. This move might involve governments developing infrastructure in the often sparsely-populated and developed inland parts of islands in countries like Fiji and Samoa to encourage people to commence farming in these areas.

In such higher-island countries, the prospect of massive re-location of (near-) coastal dwellers to higher ground inland is something that will not only be very costly but also very disruptive to economic development if it is carried out at the last possible moment. Far better in terms of economic impact if Pacific Island governments develop strategies for staggered retreat, moving so many people and activities every few years, so that costs are spread more evenly over the next few decades. This is a process that must involve governments, sometimes even the entire region, because of the nature of land tenure in Pacific Island countries (Crocombe, 1987). Communities cannot simply move from the coast to a site inland that they do not own. Most such communities, being only partly within the cash economy, would be unable to afford to lease such land, so the only option is for governments to negotiate such arrangements country-wide. It will undoubtedly require investment, perhaps even compulsory purchase of large tracts of land that are currently in private hands (Duncan, 2008).

The situation for low-island countries in the Pacific region is quite different. Whereas their prospects looked grim under a 21st-century sea-level rise of 59 cm (IPCC AR4, 2007), these look far worse under a sea-level rise of 1-2 metres within the same period (see section 3.1.a). It is very difficult to see how any atoll island that rises no more than 2 metres above sea level today could remain habitable with a sea level 1-2 metres higher: a situation anticipated for Tuvalu by Dickinson (2009) and quantified in Table 3.2. Difficult as it may be, the inhabitants of atoll islands in the Pacific – which include most inhabitants of Kiribati, Marshall Islands, Tokelau and Tuvalu – need to understand the inevitability of re-location from their present locations, perhaps 20-30 years hence. They also need to understand that the economic costs involved (as well as the potential losses of sovereignty and culture) can be minimized with early anticipatory action, especially at a time when the global community has established a multi-billion dollar Adaptation Fund that such countries can access.

Sovereignty of countries that expect the "loss" of entire islands could be assured by "freezing" current baselines: in other words, allowing for future sovereignty to be based on existing national boundaries (Yamamoto and Esteban, 2010). Cultural conservation is potentially easier to achieve once it is accepted that culture is neither space-specific nor historically unchanging (Duncan, 2008; Lilley, 2008). Many expatriate Pacific Islander communities flourish in other Pacific Island nations and in metropolitan Pacific Rim countries.

Economic development in most Pacific Island countries is projected in the basis of increased revenue generation. While there are clearly limited opportunities for future extractive industry, production industries that meet niche needs in richer countries, as does Fiji Water (Connell, 2006a; Reddy and Singh, 2010), might be developed by Pacific Island governments. In many Pacific Island nations, manufacturing and other industries have been deliberately located in industrial parks, typically located in low-lying (sometimes reclaimed) areas; clearly in the absence of effective shoreline protection, these areas will be under threat from future sea-level rise. Increased remittances could help the economic prospects of Pacific island countries and could be achieved by facilitating increased (temporary and permanent) migration to metropolitan Pacific-Rim countries (Opeskin and MacDermott, 2009).

Tourism is a major (potential) income earner for many Pacific Island countries but clearly in a warmer world, long-term plans for tourism development should try and shift the emphasis away from on-coast tourism to over-water tourism or higher-ground tourism. Resorts would do well to invest in their own sustainable water supplies and ensure that emergency procedures for tropical cyclones are well rehearsed. With the expected loss of coral-reef biodiversity, emphasis might shift away from dive-tourism in some parts of the region (Becken and Hay, 2007).

Many Pacific Island countries depend on ocean fisheries for foreign revenue and there is huge demand for Pacific Ocean fish. A recent study looking specifically at the vulnerability of national economies to the effects of climate change on ocean fisheries concluded that the Pacific Island nations sampled (Fiji, French Polynesia and New Caledonia) were, like other Small Island Developing States (SIDS) included in the analysis, highly vulnerable (Thresher et al., 2007; Allison et al., 2009). This study intimated that the same result would have been obtained for other Pacific Island countries had adequate baseline data been available. What this means is that ocean fisheries in Pacific Island nations are under threat, first because they are currently being managed unsustainably and, second, because future climate change will re-organize ocean fish stocks in ways that may see far fewer ocean fish available in Pacific Island waters.

3.4. Climate-forced migration and re-settlement

Given the recent upgrading of projections of future sea-level rise (section 3.1.d), it is now almost certain that large numbers of people (and infrastructure and activities) will need to move from the vulnerable locations they currently occupy to others that are less vulnerable. This will involve a lot of expense and, in a world where land is often at a premium and communally owned, a lot of negotiation. But if re-location is carried out in advance, much of the expense and the inconvenience can be reduced (Nunn, 2009b, 2010).

The projections in Table 3.2 suggest that Pacific atoll islands have at least 40 years before they are rendered completely uninhabitable. But it is likely that they will become so long before that time, as a result of increased groundwater salinization (similar to that described in Kiribati – section 2.5) and shrinkage of the freshwater lens on which most atoll islanders depend.

A recent prognosis suggests that as many as two million people might be displaced from their present locations in the Pacific Islands region during the 21^{st} century if no effective protection is put in place for a 2 metre sea-level rise (Nicholls et al., 2011).

In April 2009, Pacific church leaders issued a statement on resettlement (re-location) as a direct consequence of climate change; this was the Moana Declaration. This statement was farsighted in that it was the first statement by any Pacific leaders to focus on re-location and the associated practicalities. Among its elements were the following.

1. **Undertake** immediate measures to identify available land and other appropriate resources for the purposes of relocating and resettling all forced climate migrants, both those displaced internally as well as those likely to seek resettlement in other countries;
2. **Carry out** intensive public consultations with Pacific communities affected and will be affected by rising sea levels or other consequences of climate change, with a view to developing viable and practical plans to protect the rights of forced climate migrants, in particular their housing, land and property and related rights;

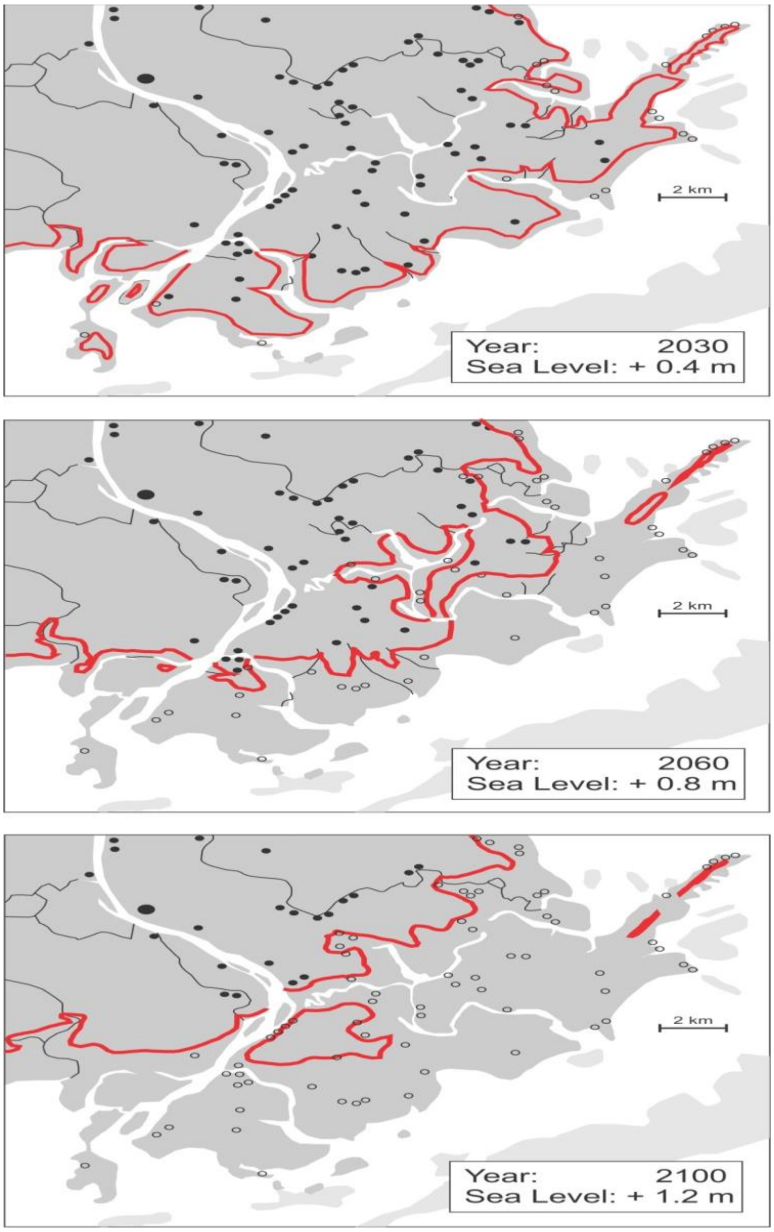
These two calls capture the main secular issues around re-location in the Pacific Islands region and are worth examining in slightly more detail here.

With reference to (1), the call is for individual countries to identify land and resources for climate migrants to be resettled. This will involve governments at all levels working with landowners to, first, identify vulnerable communities and, second, to identify places to which they might be re-located within their own country. That this process might also involve other countries is quite possible; resettlement of people between countries in the Pacific Islands region has many precedents and the experiences of these migrants might be sought in order to understand how best to manage the process in future. Yet this call also implies that some migrants (also known as environmental refugees) may have to be resettled outside their Pacific Islands region, which will require negotiations with appropriate countries.

With reference to (2), this acknowledges that the people who will be forced to re-locate are the victims of a process beyond their control and that, in consequence, their property and their human rights must be protected. Again this is something for governments and regional agencies to develop, but (2) also talks about public consultations. These are critically important to remove much of the anxiety that currently exists around climate-change forced migration, the rights and expectations of migrants. It is essential that such consultations are carried out in culturally-appropriate ways and vernacular languages so that the affected people are encouraged to buy-in to the process rather than view it as a foreign preoccupation that is being overstated (see section 2.6).

The inevitability of large-scale migration from affected areas is not yet widely accepted in the Pacific Islands region. It seems likely that an increase in the amount of scenario development, as in Table 3.2 and as shown for the Rewa Delta in Figure 3.1, may help bring the imperative of re-location to the wider community. Yet given the degree of scepticism and even outright denial that permeates the communities of the region, it will probably take a major incident (or a series of them) to bring the need for re-location of vulnerable communities to the front of the public psyche and government agendas.

Figure 3.1. Threats to the Rewa Delta (shown in Figure 2.8) from sea-level rise calculated on the basis of present-day topography



Source: Shoreline defined by mean low-water spring tide level (Fiji Datum), and realistic sea-level rise scenarios based on Vermeer and Rahmstorf (2009). Figure updated from Lata and Nunn (2011), full details in Lata (2010). Filled circles are settlements with more than 200 occupants at present, unfilled circles are settlements that are predicted to be below sea level at the times shown.

None of these comments are intended to trivialise the human traumas and the financial costs of re-location and resettlement, only to demonstrate their inevitability given our current understanding of how Pacific Island environments are likely to change in the future.

There is likely to be a need for some Pacific Island people, displaced from their present settlements, by rising sea level to re-locate to Pacific Rim countries like Australia and New Zealand. While this process is unlikely to be largely problem-free, the presence of sizeable

Pacific Islander communities in cities like Auckland and Sydney does mean that in-country support for migrants is likely to be adequate (Bedford et al., 2007).

3.5. Resettlement flashpoints

The major incidents alluded to at the end of the preceding section may take many forms. What is important is that public perceptions of these incidents will be sufficient to convince many people that climate change is really happening and that individual (and communal and national and regional) adaptation is unavoidable. It follows that the incidents will have to be (perceived as) without historical precedent and/or cause an unimagined degree of disruption to what are popularly perceived as "normal" activities at a particular location. There are of course many permutations of circumstance that may meet these requirements but such an incident would perhaps need to have the following attributes.

- It would not have to be a familiar occurrence, however extreme its effects. Thus it would probably not be the impact of a tropical cyclone, which are familiar if not annual occurrences in many western Pacific Island groups. Neither too could it be associated with a non-climate cause like tsunami or earthquake.
- It would have to have an unprecedented effect, either in terms of its impact or its duration. If impact, then it might involve the flooding of a well-known coastal (or delta) settlement to an unprecedented depth, causing unprecedented disruption to livelihoods of the affected people, possibly to the extent that they declare that can never re-create their livelihoods at that location. If duration, then it could be that such a coastal settlement (or even a large stretch of inhabited coastline) is flooded for a month rather than a week, with the result that its inhabitants also declare that they will never return.
- It would have to be widely noticed by people within the country (or countries) where the incident occurred, but also beyond. It would have to attract the attention of aid donors who might encourage the need for a long-term strategy like re-location. But the incident would have to receive enough publicity within the Pacific Islands region for many groups of people to re-examine their scepticism, even their denial, about climate change and its projected impacts.

Given that these are perhaps the main criteria for an incident to have a region-wide impact on people's perceptions of climate change and the attendant need for adaptation, it is worth examining where such an incident might occur and what its most attention-grabbing attributes might be.

It is likely that within the next ten years or so, a tropical Pacific atoll island will be impacted so severely by a storm that the island itself will be rendered uninhabitable and the people will have to be moved elsewhere permanently. But atolls are globally perceived as unusually vulnerable and there is a tendency among the peoples of higher Pacific Island groups to regard themselves as far less vulnerable – even though this view is somewhat fallacious (Nunn and Mimura, 1997).

It seems likely that the incident may be a storm impact, not associated with a tropical cyclone *sensu stricto* but perhaps rather a slow-moving tropical depression, that affects a major low-lying urban centre, such as Nadi in Fiji (see section 2.7), Nuku'alofa in Tonga, Apia in Samoa, or even Suva (Fiji), the largest city in the independent Pacific Islands. The associated flooding might necessitate the closure of the urban centre for more than two weeks.

3.6. Effective communication – bridging the divide between science and society

The failure of many initiatives over the past 25 years intended to develop and sustain effective adaptation to climate change can be attributed in large part to the misapprehension of the pathways of environmental decision-making as well as a naivete about how to communicate scientific imperatives around climate change effectively to Pacific Island people (see section 2.4). For the future, it is essential that such errors are not repeated for the imperative of effectively communicating climate change issues to people in this region is becoming daily more pressing.

To encourage ownership of climate change (especially adaptation agendas) by Pacific Island people, at national and community levels, it is necessary to translate information about the science and impacts of climate change into appropriate vernacular languages. Translation in this context does not simply mean translating words but also ensuring that the concepts are effectively communicated; for example, the phrase "climate-change adaptation" is one that many second-language speakers struggle to comprehend, yet it is something that Pacific Island people have been doing (without giving it such a label) for generations. In addition to translation, appropriate cultural avenues of communication must be utilized for discussions of climate change. These include appropriate cultural settings as well as other strategies to encourage buy-in, especially at community level.

One of these strategies, tried and tested in a Pacific Island context by Veitayaki et al. (2003) and Aalbersberg et al. (2005), is participatory community risk assessment (van Aalst et al., 2008). A similar approach is Participatory Learning and Action (PLA), which has also been successfully trialled in a rural Pacific Islands situation (Terry and Khatri, 2009). The basic approach of both is to engage communities who are experiencing problems with environmental management, perhaps manifested as diminishing food resources or faecal pollution of water sources, and facilitate the identification of solutions by key members of those communities. Scientific information is offered to the communities to help inform their decision about which of several possible solutions is to be adopted, but since the purpose of such methods is to ensure sustained community buy-in of a particular solution, it is critical that outsider knowledge is not imposed on community decision-making, at least without umprompted invitation.

The gender dimensions of climate change in the Pacific Islands have only recently been acknowledged as important (Lane and McNaught, 2009). Surveys reported in this work find that gender awareness of particular aspects of ecosystem fragility are widespread in the Pacific Islands. Clearly, if such awareness is factored in to adaptation strategies, then they are likely to be more effective and sustainable than they might otherwise be. Yet the awareness of gender roles and the desire to increase gender sensitivity among Pacific Island communities must be done within culturally-appropriate ways if it is to be successful and not run the risk of generating a backlash from communities.

It is clear that there also needs to be increased communication between climate scientists and social scientists for the Pacific islands region. Few climate scientists, aware of the nature of future climate projections and their impacts on physical environments, are communicating effectively with social scientists, who understand better the likely effects of these projections on people in this region. Improved communication between the two types of scientist would be a first step to more effective engagement of key stakeholders in the region, both in governments and as representatives of civil society.

4. Production, Exchange and Consumption: a broad outline

To understand the range of adaptation options and strategies available to human societies in and around the Pacific Islands region, Table 4.1 identifies and weights the principal sources of production, exchange and consumption.

Table 4.1. Principal components of production, exchange and consumption in the Pacific Islands region

PRODUCTION	**Weighting**
Commercial agriculture and fisheries	Medium to High
Forestry	High
Manufacturing	High
Mining	High
Subsistence agriculture and fisheries	Low to Medium
Tourism	High
EXCHANGE (across region)	
Cross-Pacific transport (by air and sea)	High
CONSUMPTION	
Food imports	High
Other imports	High
Power consumption	Medium to High

Each of these three components is discussed further in the following subsections.

4.1. Understanding production in the Pacific Islands

For the purposes of this discussion, production is defined as the use of resources to generate goods and services.

Commercial agriculture and fisheries usually requires the products generated to be taken far away from the places where they were sourced at disproportionately high cost. Given that most such resources are not processed (or processed only slightly) within the region also loses value for the region. There are some exceptions, such as the crushing of sugar cane in Fiji (which would otherwise make sugar export uneconomical). Yet given the abundance of fresh produce (fruit and vegetables) grown in the region, it is unfortunate that there are so few region-based enterprises that add value to these before they are exported. Much the same is true for commercial fisheries, which are generally in deepwater and operated by foreign fishing fleets that pay host countries only nominal licence fees (Hannesson, 2008). In a few countries, notably Fiji and American Samoa, there are fish processing facilities that produce end products like canned tuna but these are few compared to the numbers of fish caught. There is a burgeoning market for the export by air of rapidly frozen fish species, especially to Japan, something that illustrates well the ways in which production is undervalued in the Pacific Islands (Swartz et al., 2010). There is good evidence that deepwater fishing activities in parts of the Pacific Islands region are unsustainable and will inevitably lead to a reduction in future fish production (Bell et al., 2009). One component of commercial agriculture and fisheries that is important to note is the trend for small-scale farmers and artisanal fishers, particularly in peri-urban areas, to produce surpluses for sale to urban dwellers. This aspect of this sector is poorly understood but is likely to be implicated in the increasing decline in the production potential of such places and their increasing vulnerability to weather-driven changes and price fluctuations (McGregor et al., 2009).

Forestry is an activity that continues be a way in which production in the Pacific Islands region benefits Pacific Rim countries (to which wood is exported) far more than those where it is produced. The rampant deforestation of many islands and island groups has caused widespread concern (Hviding and Bayliss-Smith, 2000). Replanting of logged forests occurs in a few places, while initiatives like REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) hold out hope that fewer forests will disappear in the future in this region. Loss of forests not only exposes the land often leading to rapid degradation but also removes a whole range of ecosystem services for local subsistence dwellers, who commonly gain little from their logging (Lomo, 2001).

In efforts to boost Pacific Island economies, some countries have developed small manufacturing sectors that usually import primary products (such as cloth) from elsewhere and add value to them (by making garments) before exporting them. The success of such activities is usually contingent on favourable trade agreements with destination countries, something that can be withdrawn at will (Gani, 2010).

Mining is perhaps the best example of high-cost production in the Pacific islands region since almost all the products of mining in the islands are exported with often no or minimal in-region processing. Examples range from the phosphate mining on Nauru and Banaba islands (Cox, 2009), which has left most of the landscapes unable to be utilized for any other purpose, through nickel mining on New Caledonia to gold mining throughout the region (Connell, 2010). Future prospects of increased offshore mining throughout the region are unlikely to prove any more beneficial to Pacific Island nations.

The least wasteful production sector in Table 4.1 is subsistence agriculture and fisheries which, by definition, have low environmental impacts and short distances to consumers. This is not to say that this sector does not have stresses associated particularly with unsustainable demands on particular systems or their inadvertent degradation (Thaman, 1982; Popkin and Horton, 2001; FAO, 2008).

Tourism is a growing sector in some countries of the region but is in many ways a mixed blessing because much of the value of the production (sun, sand and sea) is exported. This is not only because most of the largest and most profitable tourism enterprises have offshore owners but also because most of the material used to enhance the tourism experience (from deckchairs to food) is also imported to the region (Singh, 2008; Narayan et al., 2010).

Opportunities for reducing the loss of production from the Pacific Islands region are comparatively few and require the agreement of multiple countries, both within and outside the region, which seems unlikely. Perhaps the best opportunities lie in adding more value to exports so that they receive a higher price in their destination countries, but the cost of infrastructure associated with this value-add is prohibitive for many countries.

With this in mind, the more helpful strategy for the future, especially with the threats from climate change increasing, is to conserve natural production systems to ensure that they continue to help sustain the peoples of the Pacific islands for the foreseeable future (Connell, 2010; Barnett, 2011).

4.2. Understanding trans-ocean exchange in the Pacific Islands

The Pacific Ocean is the largest in the world. As the largest carbon sink on the planet, there is global interest in keeping it healthy. Yet inevitably the Pacific Ocean is crossed regularly by numerous ship and air traffic that both uses energy and, through pollution, contributes to the depletion of the health of this vast ocean. This is something that is insidious and little discussed, yet is clearly important to this region's future. Examples include the transport of airborne pollutants across the region from continental source areas (Wang et al., 2009) and the transport of waterborne viruses in ships' ballast tanks (Leichsenring and Lawrence, 2011).

4.3. Understanding consumption in the Pacific Islands

Most people in the Pacific Islands region depend in part on the consumption of imported foods every day (FAO, 2008. The trend away from locally-produced foods is one that has been noted for some time (Thaman, 1982; Barnett, 2007; McGregor et al., 2009). In addition, increased food insecurity has resulted from the loss of traditional knowledge among communities in many parts of the region about food preservation and storage techniques that were likely to have been developed as ways of withstanding prolonged food shortages (Mercer et al., 2007; Nunn, 2009b; Barnett and Campbell, 2010).

Besides food, many other items are imported into Pacific Island countries simply in order to sustain life and livelihoods. The disproportionately high costs of importing such goods and the general lack of government revenue to pay for them often means that most capital projects are aid-funded. This in turn creates a condition of involuntary dependency for many island countries to which there is no alternative if they are to remain supplied with hospitals and highways, besides many other things (Duncan, 2008).

Power is a conspicuous example of consumption that has generally high costs in all Pacific island countries (Mishra et al., 2009), despite the continuing promise of renewable energy development using sun, wind, waves, water or locally-manufactured biofuels (Mala et al., 2009; Cloin, 2007).

Future consumption is unlike to improve across sectors with concerted regional consensus for change and considerable sustained support from traditional donor countries.

5. Recommendations for Reducing Impacts of Future Climate Change

Given the lessons of the recent past, it is possible to issue several recommendations (in bold throughout this chapter) that are thought likely to bring about effective and sustainable adaptation to projected climate change in the Pacific Islands region. It is worth dwelling for a moment on what is intended by "effective" and "sustainable" adaptation.

Adaptation must be effective in the sense that it is the right solution for the particular aspects of climate change that a nation or community wishes to adapt to. For example, it is neither simply enough to uncritically transpose adaptive solutions from a continental to an island country nor from a "developed" to a "developing" country. Such adaptive solutions must be tailored to the particular environment. They must also be designed in such a way that local stakeholders buy-in to their implementation and understand how they are expected to solve particular problems.

Adaptation must also be sustainable in the sense that Pacific Island governments and local communities must be able to sustain adaptive solutions for the foreseeable future. This requires that such people comprehend these solutions and that they have the resources (financial/material and human) to sustain them indefinitely. For example, artificial shoreline structures may be unduly expensive for a (largely) subsistence community to maintain whereas a replanted mangrove forest along the coastal fringe would not be.

This chapter is organized by the key stakeholders in climate-change adaptation in the Pacific Islands, namely international partners (section 5.1), regional agencies and national governments (section 5.2), communities (section 5.3), non-government organizations (section 5.4), and individuals (section 5.5).

5.1. International partners: effective interventions and assistance

There is no doubt that international assistance (aid) will continue to flow into the Pacific Islands over the next few decades to help underwrite the costs of climate-change adaptation. Some of this aid will be bilateral, flowing from one country to another. Some will be for the region as a whole, directed largely through regional agencies or international bodies (such as the GEF). The latter aid will include many traditional flows but also far larger sums through initiatives like the Global Adaptation Fund for developing countries that was established post-COP-15 in 2010.

As the problems posed by climate change become more serious and widespread in the next 20-30 years, so international partners will likely become more concerned about making a difference than they appear to have been up to this point. To this end,

Recommendation 1: It is recommended that international partners of Pacific Island nations make far greater efforts to ensure the effectiveness of their assistance for climate-change adaptation.

This would involve understanding the pathways of environmental decision-making in the Pacific Islands region and intervening where this can be most effective. At this point in time, this might seem to involve less assistance directly to regional agencies and to national governments, which generally have a poor track record of delivering effective and sustainable adaptation, and more directly to communities where almost all environmental decision-making in this region is currently carried out. There might be less emphasis on capacity-building through formal qualifications and more emphasis on empowering community leaders to make sensible and far-sighted decisions about the environments they control for the benefit of the people who live there.

Most of the communication for empowerment should be in vernacular languages, use familiar concepts, and acknowledge cultural mores. There should be less emphasis on financing and more emphasis on action assistance. International partner countries might consider training cohorts of appropriately-educated people to go and live for prolonged periods in vulnerable communities and guide their thinking about effective and sustainable adaptation.

International partners might also be able to intervene strategically. One example is around re-location of vulnerable communities. In many situations, neither governments nor community leaders are seriously considering re-location because of the prohibitively high costs involved. Were an international donor able to underwrite the costs of identifying and developing the site for such a community to move to, it might encourage the government to adopt re-location as a long-term adaptive strategy and, more pragmatically, for the community in question to start to re-locate. Once other communities had witnessed this occurrence and comprehended its long-term benefits, it might encourage them to follow suit.

5.2. Regional and national (government) action

With a trend towards increased regionalism in the Pacific Islands, the time is ripe for regional agencies to be invested with a greater power of self-determination, allowing them to develop proactive agendas, particularly around climate change. External (ODA) funding of their core budgets would allow them to assume a stewardship role for the environments of the Pacific island nations and become independent (to some extent) from a focus on short-term goals. As long as these regional agencies remain subordinate to member governments, they will continue to be largely reactive and ineffectual in developing and implementing long-term and sustainable adaptive strategies.

For the purposes of environmental management in the face to climate change, regional agencies should be encouraged to think beyond political boundaries more than they do. There are many commonalities among island types and environments within the region that transcend political borders. For example, the problems faced by atoll islands in Kiribati are much the same as those in Tuvalu. Regional agencies should also be at the forefront of new approaches to embedding effective and sustainable adaptation to climate change.

National governments must themselves ponder their roles in climate-change adaptation for their constituents. These governments must be encouraged to think long-term and their citizens must be effectively engaged so that they understand why governments may have to pursue policies that appear anti-development.

In larger and archipelagic Pacific Island countries, governments should be prepared to relinquish some of their aspirations about mainstreaming effective and sustainable climate-change adaptation throughout their countries, and should support the efforts of their international partners to reach out directly to communities. In such countries, national governments still have important roles in helping their citizens understand and buy-in to adaptation.

Recommendation 2: Regional agencies and governments should realistically examine the effectiveness of their present aspirations around climate-change adaptation, and re-define their roles accordingly.

5.3. Community-level action

For most of the Pacific Islands region, the only road to effective and sustainable adaptation for climate change during the 21st century is for local-area communities (and civil society more generally) to be given the information they need to make informed decisions about their preferred long-term interactions with the environments they occupy. There seems no chance that in most island countries, national or sub-national top-down governance will ever become strong enough to ensure this kind of adaptation.

Given the hierarchical nature of most Pacific Island societies, it is sensible to target "persons of influence" (such as community leaders like "chiefs", religious leaders, school teachers, as well as private sector leaders) within particular communities and instruct these persons in appropriate ways about what is happening and what is likely to happen to their environments. Emphasis should be placed on community participation in decision-making yet the instruction must also include scientific knowledge about future climate change.

Recommendation 3: Persons of influence in Pacific Island communities should be empowered to make informed and sustainable decisions about the environments they occupy.

In this context, it is also important to harness the natural inbuilt resilience of Pacific Island societies (discussed in section 1.4) ensuring, for example, that there is encouragement for maintaining traditional support networks based on kinship. Tradition can also be called upon to develop strategies, perhaps informally or through traditional forms of legislation, for giving land to family groups who lose their (useful) land as a result of sea-level rise, for example.

5.4. Role of non-government organizations (NGOs)

Many of the needs of the region for climate-change adaptation may not be readily accomplished because they lie outside the normal areas in which governments, regional agencies, and their international partners operate. While it is hoped that this may change in the next few decades, NGOs have a potentially significant role to play at least in the interim. This role could involve the translation and communication of information about climate change to stakeholders utilising appropriate media, especially radio. The most effective communication in Pacific Island societies remains face-to-face and NGOs (including religious organizations) are well placed to undertake this.

International partners might well help underwrite the costs of particular NGOs undertaking this kind of work, which would in turn require the NGOs to jettison some of the more partisan parts of their agendas around climate change and work more closely with regional agencies to ensure that everyone is delivering a similar message.

5.5. Individual understanding and action

Most people in the Pacific Islands presently have an imperfect understanding of climate change and its potential to adversely affect their livelihoods over the next few decades. For optimal adaptation to occur, this situation needs to change: awareness needs to be raised. There are several ways of accomplishing this.

All groups discussed in sections 5.1-5.4 have the capacity and the ability to help raise awareness among Pacific Island people about climate change; there is potential for targeting females and youth. There is also a role for formal inculcation in school and university syllabi. There is also a need for printed material in appropriate vernaculars, as well as material utilizing other audiovisual media.

The public media have a huge role in raising awareness about climate change in the Pacific Islands region, a role to which they appear to have been largely indifferent. These media should become better-informed, less subordinated to their foreign counterparts, and less sympathetic to marginal (fringe) interpretations of climate-change futures.

Many organizations can work together to give Pacific Island people an improved understanding of the vulnerable environments they occupy and how these might change in the future.

Bibliography

Aalbersberg, W., Tawake, A. and Parras, T. 2005. Village by village: recovering Fiji's coastal fisheries. *World Resources 2005:The Wealth of the Poor: Managing Ecosystems to Fight Poverty*. World Resources Institute, Washington DC. 144-152.

Allen, B. and Bourke, R.M. 2008. People, land and environment. In: Bourke, R.M. and Harwood, T.T. (eds). *Pipol, Kauai nab mania: Agriculture in Papua New Guinea*. Canberra: Australian National University Press, pp. 45-54.

Alley, R. 1999. The South Pacific's environmental policy tensions. *Public Administration and Development*, 19, 137-151.

Allison, E. H., Perry, A. L., Badjeck, M.-C., Neil Adger, W., Brown, K., Conway, D., Halls, A. S., Pilling, G. M., Reynolds, J. D., Andrew, N. L. and Dulvy, N. K. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10, 173–196.

Alongi, D.M. 2008. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science*, 76, 1-13.

Anderson, A., J. Chappell, M. Gagan and R. Grove. 2006. Prehistoric maritime migration in the Pacific islands: an hypothesis of ENSO forcing. *The Holocene* 16, 1-6.

Banner, S. 2007. *Possessing the Pacific: land, settlers, and indigenous people from Australia to Alaska*. Cambridge, Mass.: Harvard University Press.

Barnett, J. 2007. Food security and climate change in the South Pacific. *Pacific Ecologist*, 14, 32-36.

Barnett, J. 2008. The effect of aid on capacity to adapt to climate change: insights from Niue. *Political Science*, 60, 31-47.

Barnett, J. 2011. Dangerous climate change in the Pacific Islands: food production and food security. *Regional Environmental Change*, 11 (Supplement 1), S229-S237.

Barnett, J. and Adger, W.N. 2003. Climate dangers and atoll countries. *Climatic Change* 61, 321-337.

Barnett, J. and Campbell, J. 2010. *Climate Change and Small Island States: Power, Knowledge and the South Pacific.* London: Earthscan.

Bartlett, C.Y., Pakoa, K. and Manua, C. 2009. Marine reserve phenomenon in the Pacific Islands. *Marine Policy*, 33, 673-678.

Becken, S. and Hay, J.E. 2007. *Tourism and Climate Change: Risks and Opportunities.* Clevedon: Channel View Publications.

Bedford, R. and Ho, E. 2003. Labour force participation as a measure of progress amongst New Zealand's Pacific population: a cohort approach. In: Gao, J., Le Heron, R. and Logie, J. (eds) *Windows on a Changing World: Proceedings of the 22nd New Zealand Geographical Society Conference, Auckland, 6-11 July*. Auckland: New Zealand Geographical Society, 229-232.

Bedford, R., Ho, E., Krishnan, V. and Hong, B. 2007. The neighbourhood effect: the Pacific in Aotearoa and Australia. *Asian and Pacific Migration Journal*, 16, 251-269.

Bell, J.D., Kronen, M., Vunisea, A., Nash, W.J., Keeble, G., Demmke, A., Pontifex, S. and Andrefouet, S. 2009. Planning the use of fish for food security in the Pacific. *Marine Policy*, 33, 64-76.

Bridges, K.W. and McClatchey, W.C. 2009. Living on the margin: ethnoecological insights from Marshall Islanders at Rongelap atoll. *Global Environmental Change* 19:140-146.

Campbell, I.C. 2001. *Island Kingdom: Tonga ancient and modern*. Christchurch: Canterbury University Press.

Campbell, J. R. 2006. Traditional disaster reduction in Pacific Island communities, GNS Science Report 2006/38 46 p.

Cazenave, A., and Nerem, R. S. 2004. Present-day sea level change: observations and causes. *Review of Geophysics*, 42, RG3001, doi:10.1029/2003RG000139.

Cheung, W. W., Lam, V. W., Sarmiento, J. L., Kearney, K., Watson, R. and Pauly, D. 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries*, 10, 235–251.

Chowdhury, M.R., Chu, P.S., Schroeder, T.A. and Zhao, X. 2008. Variability and predictability of sea-level extremes in the Hawaiian and US-Trust Islands – a knowledge base for coastal hazards management. *Journal of Coastal Conservation*, 12, 93-104.

Chowdhury, M.R., Chu, P-S., Zhao, X., Schroeder, T.A. and Marra, J.J. 2010. Sea level extremes in the U.S.-affiliated Pacific Islands – a coastal hazard scenario to aid in decision analyses. *Journal of Coastal Conservation*, 14, 53-62.

Church, J.A., White, N.J. and Hunter, J.R. 2006. Sea-level rise at tropical Pacific and Indian Ocean islands. *Global and Planetary Change* 53,155-168.

Clarke, W.C. and Thaman, R.R. (eds.). 1993. *Pacific Island agroforestry: Systems for sustainability*. United Nations University Press, Tokyo. 297pp.

Cloin, J. (2007), Coconut oil as a fuel in the Pacific Islands. *Natural Resources Forum*, 31: 119–127.

Coles, S. 2008. *Potential climate change impacts on corals and coral reefs in Melanesia from bleaching events and ocean acidification*. Honolulu: BP Bishop Museum Technical Report 42.

Connell, J. 2003. Losing ground? Tuvalu, the greenhouse effect and the garbage can. *Asia Pacific Viewpoint*, 44, 89-107.

Connell, J. 2006a. 'The Taste of Paradise': selling Fiji and Fiji Water. *Asia Pacific Viewpoint*, 47, 342-350.

Connell, J. 2006b. Nauru: the first failed Pacific state? *The Round Table*, 95, 47-63.

Connell, J. 2010. Pacific islands in the global economy: Paradoxes of migration and culture. *Singapore Journal of Tropical Geography*, 31: 115–129.

Connell, J. and Lea, J. P. 2002. *Urbanisation in the Island Pacific: Towards Sustainable Development*. London: Routledge.

Constanza, R. 1999. The ecological, economic, and social importance of the oceans. *Ecological Economics* 31, 199-213.

Cox, J. 2009. The money pit: an analysis of Nauru's phosphate mining policy. *Pacific Economic Bulletin*, 24, 174-186.

Crocombe, R.G. 1987. *Land Tenure in the Pacific*. The University of the South Pacific, Suva, Fiji.

Crocombe, R. 2001. *The South Pacific*. Suva: Institute of Pacific Studies, The University of the South Pacific.

Denslow, J. S., Space, J. C. and Thomas, P. A. 2009. Invasive exotic plants in the tropical Pacific Islands: patterns of diversity. *Biotropica*, 41, 162–170.

Dickinson, W.R. 1999. Holocene sea-level record on Funafuti and potential impact of global warming on central Pacific atolls. *Quaternary Research*, 51, 124-132.

Dickinson, W.R. 2003. Impact of mid-Holocene hydro-isostatic highstand in regional sea level on habitability of islands in Pacific Oceania. *Journal of Coastal Research* 19, 489-502.

Dickinson, W.R. 2009. Pacific Atoll living: how long already and until when? *Geological Society of America, Today*, 19, 4-10.

Dodge, R.E., Birkeland, C., Hatziolos, M., Kleypas, J., Palumbi, S.R., Hoegh-Guldberg, O., Van Woesik, R., Ogden, J.C., Aronson, R.B., Causey, B.D. and Stuab, F. 2008. A call to action for coral reefs. *Science*, 322, 189-190.

Doney, S.C. 2006. The dangers of ocean acidification. *Scientific American*, 294, 58–65

Doney, S.C., Fabry, V.J., Feely, R.A. and Kleypas, J.A. 2009. Ocean acidification: the other CO_2 problem. *Annual Review of Marine Science*, 1, 169-192.

Donner, S.D., 2007. Domain of the Gods: an editorial essay. *Climatic Change*, 85, 231-236.

Douglas, B. 2002. Why religion, race, and gender matter in Pacific politics. *Development Bulletin*, 59, 8-14.

Duncan, R. 2008. Cultural and economic tensions in Pacific Islands' futures. *International Journal of Social Economics*, 35, 919-929.

Ellison, J.C. 2010. *Vulnerability of Fiji's mangroves and associated coral reefs to climate change*, World Wildlife Fund (2010) [Consultancy Report]

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, 436, 686-688.

FAO. 2008. *Climate Change and Food Security in Pacific Island Countries*. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy.

Farbotko, C. 2010. Wishful sinking: disappearing islands, climate refugees and cosmopolitan experimentation. *Asia Pacific Viewpoint*, 51, 47-60.

Farbotko, C. and McGregor, H.V. 2010. Copenhagen, climate science and the emotional geographies of climate change. *Australian Geographer*, 41, 159-166.

Feyrer, J and Sacerdote, B. 2009. Colonialism and modern income: islands as natural experiments. *The Review of Economics and Statistics*, 91, 245-262.

Gani, A. 2009. Governance and foreign aid in Pacific Island countries. *Journal of International Development*, 21, 112-125.

Gani, A. 2010, Some aspects of trade between Australia and Pacific Island Countries. *The World Economy*, 33: 89–106.

Glynn, P. W. 1993. Coral reef bleaching: ecological perspectives. *Coral Reefs* 12, 1–17.

Guinotte, J. M., Buddemeier, R. W. and Kleypas, J. A. 2003. Future coral reef habitat marginality: temporal and spatial effects of climate change in the Pacific basin. *Coral Reefs* 22, 551-558.

Halatuituia, S.N.K. 2006. *Tonga's contemporary land tenure system: reality and rhetoric*. Unpublished PhD thesis, University of Sydney.

Hales, S., Weinstein, P. and Woodward, A. 1999. Ciguatera (fish poisoning), El Niño, and sea surface temperatures. *Ecosystem Health*, 5, 5-20.

Hanich, Q. and Tsamenyi, M. 2008. Managing fisheries and corruption in the Pacific Islands region. *Marine Policy,* 33, 386-392.

Hannah, J. 2004. An updated analysis of long-term sea level change in New Zealand. *Geophysical Research Letters*, 31, L03307, doi:10.1029/2003GL019166.

Hannesson, R. 2008. The exclusive economic zone and economic development in the Pacific Island countries. *Marine Policy*, 32, 886-897.

Hassall, G. 2008. Good governance and political developments in the Pacific: can existing concepts and institutions deliver security? In: Kennedy, G. (ed), *Models of Regional Governance for Pacific Island States: The Future Architecture of Pacific Regionalism*. University of Canterbury Press, Christchurch, 161-188.

Hassall, G. and Kennedy, G. 2008. Conclusion. In: Kennedy, G. (ed), *Models of Regional Governance for Pacific Island States: The Future Architecture of Pacific Regionalism*. University of Canterbury Press, Christchurch, 211-216.

Hassall, G. and Tipu, F. 2008. Local government in the Pacific Islands. *Commonwealth Journal of Local Governance*, 1, 1-24.

Hau'ofa, E. 1993. *Our Sea of Islands*. Suva: School of Social and Economic Development, The University of the South Pacific.

Hay, J.E., Mimura, N., Campbell, J., Fifita, S., Koshy, K., McLean, R.F., Nakalevu, T., Nunn, P. and de Wet, N. 2003. *Climate Variability and Change and Sea-Level Rise in the Pacific Islands Region*. Apia, Samoa: South Pacific Regional Environment Programme.

Hoegh-Guldberg, O. 1999. Coral bleaching, climate change and the future of the world's coral reefs. *Review of Marine and Freshwater Research* 50, 839-866.

Hoegh-Guldberg, O., Mumby. P. J, Hooten, A. J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P.F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., and Hatziolos, M. E. 2007. Coral reefs under rapid climate change and ocean acidification. *Science* 318, 1737–1742

Holland, P. 2008. Disaster risk management in the Pacific: economic analysis and advocacy. Inaugural Pacific Regional Disaster Risk Management Meeting for Pacific CEOs of Finance/Planning and Disaster Management, 24-25 July 2008, Nadi, Fiji.

Hook, S. 2009. Institutional reform and state capacity in the South Pacific. *Pacific Economic Bulletin*, 24, 155-167.

Hunt, C. 1996. Property rights and environmental management on Pacific atolls. *International Journal of Social Economics*, 23, 221-234.

Hviding, E. and Bayliss-Smith, T.P. 2000. *Islands of Rainforest: agroforestry, logging and eco-tourism in Solomon Islands*. Aldershot: Ashgate.

Iati, I. 2008. The potential of civil society in climate change adaptation strategies. *Political Science*, 60, 19-30.

IPCC, AR4, 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning (eds.)].

Jayaraman, T. K. 2007. Regional Economic Integration in the Pacific Problems and Prospects. In: Kisanga, E. and Danchie, S. (eds). *Issues in Economic Development of Small Island Economies.* London: Commonwealth Secretariat, pp. 165-187.

Johannes, R.E., 2002. The renaissance of community-based marine resource management in Oceania. *Annual Review of Ecological Systems*, 33. 317-340.

Kallmeyer, N. 2008. Climate change hitting women harder? Medill Reports, Northwestern University.

Kaluwin, C. and Smith, A. 1997. Coastal vulnerability and integrated coastal zone management in the Pacific Island region. *Journal of Coastal Research, Special Issue* 24, 95-106.

Kingsford, R.T., Watson, J. E. M., Lundquist, C. J., Venter, O., Hughes, l., Johnston, E.L., Atherton, J., Gawel, M., Keith, D.A., Mackey, B.G., Morley, C., Possingham, H.P., Raynor, B., Recher, H.F. and Wilson, K.A. (2009), Major conservation policy issues for biodiversity in Oceania. *Conservation Biology,* 23: 834–840.

Kleypas, J.A., Buddemeier, R.W. Archer, D. Gattuso, J-P., Langdon, C. and Opdyke, B.N. 1999. Geochemical consequences of increased atmospheric CO_2 on coral reefs. *Science*, 284: 118-120.

Kleypas, J.A., Buddemeier, R.W. and Gattuso, J.-P., 2001. The future of coral reefs in an age of global change. *International Journal of Earth Science* 90, 426-437.

Knutson, T.R., McBride, J.L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J.P., Srivastava, A.K. and Sugi, M. 2010. Tropical cyclones and climate change. *Nature Geoscience*, 3, 157-163.

Kumar, R. 2007. Problems and prospects for islands at the margins: a case study of Moturiki Island, central Fiji. In: Moriwaki, H. and Kawai, K. (eds) *Global warming and Pacific Islands*. Kagoshima University Research Center for the Pacific Islands Occasional Paper 47, pp 41-50.

Lal, P.N., Kinch, J. and Wickham, F. 2009a. Review of economic and livelihood impact assessments of, and adaptation to, climate change in Melanesia. Unpublished report at www2.bishopmuseum.org/ccbm/Areas/Melanesia/Papers/EconomicImpactsMelanesia_Lal.pdf accessed in January 2010.

Lal, P.N., Rita, R. and Khatri, N. 2009b. *Economic Costs of the 2009 Floods in the Fiji Sugar Belt and Policy Implications*. Gland, Switzerland: IUCN.

Lane, R. and McNaught, R. 2009. Building gendered approaches to adaptation in the Pacific. *Gender and Development*, 17, 67-80.

Lata, S. 2010. Perceptions of future climate change in a vulnerable community and its implications for future adaptation: a case study of the Rewa Delta Fiji. Unpublished MSc thesis, The University of the South Pacific.

Lata, S. and Nunn, P.D. 2011. Misperceptions of climate-change risk as barriers to climate-change adaptation: a case study from the Rewa Delta, Fiji. *Climatic Change*, 110, 169-186.
Leichsenring, J. and Lawrence, J. 2011. Effect of mid-ocean ballast water exchange on virus-like particle abundance during two trans-Pacific voyages. *Marine Pollution Bulletin*, doi 10.1016/j.marpolbul.2011.01.034

Levitus, S., Antonov, J.I., Boyer, T.P. and Stephens, C. 2000. Warming of the world ocean. *Science*, 287, 2225-2229.

Lilley, I. 2008. Apocalypse now (and avoid the rush): human dimensions of climate change in the Indo-Pacific. *Archaeology in Oceania*, 43, 35-40.

Lobban, C.S. and Schefter, M. 1997. *Tropical Island Environments*. Mangilao, Guam: Tropical Island Books.

Locke, J.T. 2009. Climate change-induced migration in the Pacific Region: sudden crisis and long-term developments. *The Geographical Journal*, 175, 171-180.

Lomo, F.F. 2001. Commercial logging, subsistence livelihoods and rural development: a case study of Rufoki Village, Malaita Province, Solomon Islands. Unpublished MA thesis, Department of Geography, The University of the South Pacific.

Mala, K., Schläpfer, A. and Pryor, T. 2009. Better or worse? The role of solar photovoltaic (PV) systems in sustainable development: case studies of remote atoll communities in Kiribati. *Renewable Energy*, 34, 358-361.

Mataki, M., Koshy, K. and Nair, V., 2007a. Top-down, bottom-up: mainstreaming adaptation in Pacific Island townships. *Climate Change and Adaptation*. N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarini, R. Lasco (eds). Earthscan, London. 264-278.

Mataki, M., Koshy, K. and Lal, M. 2007b. Baseline climatology of Viti Levu, Fiji and current climatic trends. *Pacific Science*, 60, 49-68.

McGregor, A., Bourke, R.M., Manley, M., Tubuna, S. and Deo, R. 2009. Pacific island food security: situation, challenges and opportunities. *Pacific Economic Bulletin*, 24, 24-42.

McGregor, K. 2009. Barriers to CDM projects in Pacific Island countries: a focus on Fiji. *Pacific Economic Bulletin*, 24, 161-173.

McLeod, E., Salm, R., Green, A. and Almany, J. 2009. Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and the Environment*, 7, 362–370.

McNeill, J.R. 1999. Islands in the Rim: Ecology and History In and Around the Pacific, 1521-1996. In: Flynn, D.O., Frost, L. and Latham, A.J.H. (editors). *Pacific Centuries: Pacific and Pacific Rim History since the Sixteenth Century*. London: Routledge, pp. 70-84.

Mercer, J., Dominey-Howes, D., Kelman, I. and Lloyd, K. 2007. The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards*, 7, 245-256.

Merrifield, M.A., Merrifield, S.T. and Mitchum, G.T. 2009. An anomalous recent acceleration of global sea level rise. *Journal of Climate*, 22, 5772-5781.

Mertz, O., Halnæs, K., Olesen, J.E., and Rasmussen, K. 2009. Adaptation to climate change in developing countries. *Environmental Management*, 43, 743-752.

Miller, K.A. 2007. Climate variability and tropical tuna: management challenges for highly migratory fish stocks. *Marine Policy*, 31, 56-70.

Mimura, N. and Nunn, P.D. 1998. Trends of beach erosion and shoreline protection in rural Fiji. *Journal of Coastal Research*, 14, 37-46.

Mimura, N. and Pelesikoti, N., 1997. Vulnerability of Tonga to sea-level rise. *Journal of Coastal Research* 24 (special issue). 117-151.

Mimura, N., Nurse, L., McLean, R.F., Agard, J., Briguglio, L., Lefale, P., Payet, R. and Sem, G., 2007. Small islands. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Cambridge University Press, Cambridge. 687-716.

Mishra, V., Smyth, R. and Sharma, S. 2009. The energy-GDP nexus: evidence from a panel of Pacific Island countries. *Resource and Energy Economics*, 31, 210-220.

Molina, A.B., Baroña, M.L.J., Sinohin, V.G.O. and Generoso, J.D. (eds). 2008. Advancing banana and plantain R&D in Asia and the Pacific. Proceedings of the 6th BAPNET Steering Committee, Tiruchirapalli, Tamil Nadu, India, 22-25 October 2008. Biodiversity International – Asia Pacific, Los Banos, Laguna, Philippines. [online at musalit.inibap.org/pdf/IN090749_en.pdf].

Mortreux, C. and Barnett, J. 2009. Climate change, migration and adaptation in Funafuti, Tuvalu. *Global Environmental Change*, 19, 105-112.

Murray, W.E. 2001. The Second Wave of Globalisation and Agrarian Change in the Pacific Islands. *Journal of Rural Studies*, 17, 135-148.

Narayan, P.K., Narayan, S., Prasad, A. and Prasad, B.C. 2010. Tourism and economic growth: a panel analysis for Pacific Island countries. *Tourism Economics*, 16, 169-183.

NASA Goddard Institute for Space Studies. n.d. "GISS Surface Temperature Analysis (GISTEMP)". [http://data.giss.nasa.gov/gistemp/] Last accessed in November 2006.

NationMaster. n.d. 'Statistics'. [http://www.nationmaster.com/statistics]. Last accessed on 10 July 2012.

New, M., Liverman, D., Schroder, H. and Anderson, K. 2011. Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. *Philosophical Transactions of the Royal Society of London*, A 369, 6-19.

Nicholls, R.J., Marinova, N., Lowe, J.A., Brown, S., Vellinga, P., de Gusmão, D., Hinkel, J. and Tol R.S.J. 2011. Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century. *Philosophical Transactions of the Royal Society of London* A 369, 161-181.

NIWA (National Institute for Water and Atmospheric Research)
. [www.niwascience.co.nz/ncc/clivar/pastclimate] Last accessed on 31st October 2006).

NOAA (National Oceanic and Atmospheric Administration). 2011. "NOAA: 2010 Tied for warmest year on record". 12 January. [http://www.noaanews.noaa.gov/stories2011/20110112_globalstats.html]. Last accessed on 10 July 2012.

Novaczek, I., Mitchell, J. and Veitayaki, J. (eds). 2005. *Pacific Voices: equity and sustainability in Pacific Island fisheries*. Suva: Institute of Pacific Studies, The University of the South Pacific.

Nunn, P.D. 1990. Recent environmental changes on Pacific islands. *The Geographical Journal*, 156, 125-140.

Nunn, P.D. 1994. *Oceanic Islands.* Oxford, Blackwell.

Nunn, P.D. 1998. *Pacific Island Landscapes*. Suva, Fiji: Institute of Pacific Studies.

Nunn, P.D. 2000. Coastal changes over the past two hundred years around Ovalau and Moturiki Islands, Fiji: implications for coastal-zone management. *Australian Geographer*, 31, 21-39.

Nunn, P.D. 2007*a*. *Climate, Environment and Society in the Pacific during the Last Millennium*. Amsterdam: Elsevier.

Nunn, P.D. 2007b. Holocene sea-level change and human response in Pacific Islands. *Transactions of the Royal Society of Edinburgh: Earth and Environmental Sciences*, 98, 117-125.

Nunn, P.D. 2008 Understanding Environmental Decisionmaking in the Rural Pacific Islands. Final Report for APN CAPaBLE Project CBA2007-03NSY, 146 pages. [available online at www.apn-gcr.org/en/products/ project_reports/2007/CBA2007-03NSY-Nunn_Final%20Report.pdf]

Nunn, P.D. 2009a. *Vanished Islands and Hidden Continents of the Pacific*. Honolulu: University of Hawai'i Press.

Nunn, P.D. 2009b. Responding to the challenges of climate change in the Pacific Islands: management and technological imperatives. *Climate Research*, 40, 211-231.

Nunn, P.D. 2010. Bridging the gulf between Science and Society: imperatives for minimizing societal disruption from climate change in the Pacific In: Sumi, A., Fukushi, K. and Hiramatsu, A. (eds). *Adaptation and Mitigation Strategies for Climate Change*. Berlin, Springer, 233-248.

Nunn, P.D. 2012. Societal disruption in the Pacific Islands from rapid sea-level fall about AD 1300: new evidence from northern Viti Levu Island, Fiji. *Journal of Coastal Conservation*, 16 (2): 199-209.

Nunn, P.D. and Kumar, R. 2006. Coastal history in the Asia-Pacific region. In: Harvey, N. (ed.). *Global Change and Integrated Coastal Management: The Asia-Pacific Region*. Berlin: Springer, pp. 93-116.

Nunn, P.D. and Mimura, N. 1997. Vulnerability of South Pacific nations to sea-level rise and climate change. *Journal of Coastal Research*, Special Issue 24, 133-151.

Nunn, P.D., Hunter-Anderson, R., Carson, M.T., Thomas, F., Ulm, S. and Rowland, M. 2007. Times of plenty, times of less: chronologies of last-millennium societal disruption in the Pacific Basin. *Human Ecology: An Interdisciplinary Journal*, 35, 385-401.

Opeskin, B. and MacDermott, T. (2009), Resources, population and migration in the Pacific: Connecting islands and rim. *Asia Pacific Viewpoint*, 50: 353–373.

Overpeck, J.T. and Weiss, J.L., 2009. Projections of future sea level becoming more dire. *Proceedings of the National Academy of Science*, 106. 21461-21462.

Phinney, J.T., Hoegh-Guldberg, O., Kleypas, J., Skirving, W. and Strong, A. (eds). 2006. *Coral Reefs and Climate Change: Science and Management*. AGU Monograph Series, Coastal and Estuarine Studies, Am. Geophys. Union, Washington DC, vol 61.

Pollock, N.J. 1992. *These Roots Remain: Food Habits in Islands of the Central and Eastern Pacific since Western Contact*. Honolulu: University of Hawaii Press.

Popkin, B. and Horton, S.S.K. 2001. The nutrition transition and prevention of diet-related diseases in Asia and the Pacific. *Food and Nutrition Bulletin* 22 (Special Supplement).

United Nations University, Tokyo.

Prasad, B.C. 2008. Institutions, good governance and economic growth in the Pacific Island countries. *International Journal of Social Economics,* 35, 904 – 918.

Pugh, D.T. 2004. *Changing Sea Levels: effects of tides, weather and climate*. Cambridge: Cambridge University Press.

Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E. and Somerville, R.C.J. 2007. Recent climate observations compared to projections. *Science* 316, 709-709.

Rasmussen, K., May, W., Birk, T., Mataki, M., Mertz, O. and Yee, D. 2009. Climate change on three Polynesian outliers in the Solomon Islands: impacts, vulnerability and adaptation. *Geografisk Tidsskrift – Danish Journal of Geography*, 109, 1-13.

Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Shepherd, J., Turley, C. and Watson, A. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. Policy document 12/05. The Royal Society, London.

Reddy, M. and Singh, G. 2010. Branding of Fiji's bottled water: edging into sustainable consumption. *International Journal of Entrepreneurship and Small Business*, 9, 447-462.

Reenberg A, Birch-Thomsen T, Mertz O, Fog B, Christiansen S. 2008. Coupled human–environment timelines of SW Pacific small island societies: event driven adaptation of human coping strategies. *Human Ecology,* 36, 807–819.

Robb, K.R. and Nunn, P.D. 2012. Nature and chronology of prehistoric settlement on the Vatia Peninsula, northern Viti Levu Island, Fiji. *Journal of Island and Coastal Archaeology*, 7, 272-281. Seacrest, S., Kuzelka, R. and Leonard, R. 2000. Global climate change and public perception: the challenge of translation. *J Am Water Resour As* 36, 253-263.

Singh, D.R. 2008. Small Island Developing States (SIDS): tourism and economic development. *Tourism Analysis*, 13, 629-636.

Singh, R., Hales, S., de Wet, N., Raj, R., Hearnden, M. and Weinstein, P. 2001. The influence of climate variation and change on diarrheal disease in the Pacific Islands. *Environmental Health Perspectives*, 109, 155-159.

Siringan, F.P., Maeda, Y., Rodolfo, K.S. and Omura, A. 2000. Short-term and long-term changes of sea level in the Philippine Islands. In: Mimura, N. and Yokoki, H. (editors). *Global Change and Asia Pacific Coasts*. Kobe: Asia-Pacific Network for Global Change Research, pp. 143-149.

Smith, L.E. and Long, J.R. 2000. Literacy, writing systems, and development in the Pacific. *Studies in the Linguistic Sciences*, 30, 169-181.

SPC (Secretariat of the Pacific Community). n.d. *National Minimum Development Indicators – Statistics for Development Programme*. [http://www.spc.int/prism/] Last accessed on 10 July 2012

Swartz, W., Sumailia, U.R., Watson, R. and Pauly, D. 2010. Sourcing seafood for the three major markets: the EU, Japan and the USA. *Marine Policy*, 34, 1366-1373.

Syvitsky, J.P.M., Kettner, A.J., Overeem, I., Hutton, E.W.H., Hannon, M.T., Brakenridge, G.R., Day, J., Vörösmarty, C., Saito, Y., Giosan, L. and Nicholls, R.J. 2009. Sinking deltas due to human activities. *Nature Geoscience*, doi: 10.1038/ngeo629.

Takesy, A. 2004. Using the churches to spread the gospel: earth's stewards of the Pacific. *Islands Business* 30, 46.

Terry, J.P. and Falkland, A.C. 2009. Responses of atoll freshwater lenses to storm-surge overwash in the Northern Cook Islands. *Hydrogeology Journal*, 18: 749-759.

Terry, J.P. and Khatri, K. 2009. People, pigs and pollution – experiences with applying participatory learning and action (PLA) methodology to identify problems of pig-waste management at the village level in Fiji. *Journal of Cleaner Production*, 17, 1393-1400.

Terry, J.P., McGree, S. and Raj, R. 2004. The exceptional flooding on Vanua Levu Island, Fiji, during Tropical Cyclone Ami in January 2003. *Journal of Natural Disaster Science*, 26, 27-36.

Thaman, R. 1982. Deterioration of traditional food systems, increasing malnutrition and food dependency in the Pacific Islands. *Journal of Food and Nutrition*. 39:109-125.

Thaman, R.R. 2002. Threats to Pacific Island biodiversity and biodiversity conservation in the Pacific Islands. *Development Bulletin*, 58, 23-27.

Thaman, R.R. 2008. Atolls – the "biodiversity cool spots" vs hot spots: a critical new focus for research and conservation. *Micronesica*, 40, 33-61.

Thomas, F.R. 2002. Self-reliance in Kiribati: contrasting views of agricultural and fisheries production. *The Geographical Journal*, 168, 163-177.

Thresher, R.E., Koslow, J.A., Morison, A.K. and Smith, D.C. 2007. Depth-mediated reversal of the effects of climate change on long-term growth rates of exploited marine fish. *Proceedings of the National Academy of Sciences of the United States of America* 104, 7461-7465 .

Timmermann, A., McGregor, S. and Jin, F-F. 2010. Wind effects on past and future regional sea level trends in the southern Indo-Pacific. *Journal of Climate*, 23, 4429-4438.

Tisdell, C. 2008. Global warming and the future of Pacific Island countries. *International Journal of Social Economics*, 35, 889 – 903.

Turnbull, J. 2004. Explaining complexities of environmental management in developing countries: lessons from the Fiji Islands. *The Geographical Journal*, 170, 64-77.

Turner, R.A., Cakacaka, A., Graham, N.A.J., Polunin, N.V.C., Pratchett, M.S., Stead, S.M. and Wilson, S.K. 2007. Declining reliance on marine resources in remote South Pacific societies: ecological versus socio-economic drivers. *Coral Reefs*, 26, 997-1008.

UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific), ADB (Asian Development Bank) and UNDP (United Nations Development Programme).2007. *The Millennium Development Goals: Progress in Asia and the Pacific 2007.*Asia-Pacific Regional MDG Report. Bangkok: UNESCAP, ADB and UNDP.

Urban, F.E., Cole, J.E. and Overpeck, J.T. 2000. Influence of mean climate change on climate variability from a 155-year tropical Pacific coral record. *Nature*, 407, 989-993.

van Aalst, M.K., Cannon, T. and Burton, I. 2008. Community level adaptation to climate change: the potential role of participatory community risk assessment. *Global Environmental Change* 18,165-179.

Veitayaki, J., Tawake, A., Aalbersberg, B., Rupeni, E. and Tabunakawai, K. 2003. Mainstreaming resource conservation: the Fiji locally-managed marine area network and national policy development. In: Jaireth H, Smyth D (eds) *Innovative Governance, Indigenous People, Local Communities and Protected Areas*. Ane Books, New Delhi, 105-124.

Vermeer, M. and Rahmstorf, S. 2009. Global sea level linked to global temperature. *Proceedings of the National Academy of Science, USA*, 106, 21527-21532.

Wang, K., Y. Zhang, C. Jang, S. Phillips, and B. Wang. 2009. Modeling intercontinental air pollution transport over the trans-Pacific region in 2001 using the Community Multiscale Air Quality modeling system. *Journal of Geophysical Research*, 114, D04307, doi:10.1029/2008JD010807.

Ward, R.G. 1989. Earth's empty quarter? The Pacific islands in the Pacific century. *The Geographical Journal* 155: 235-246.

Webb, A. 2007. Assessment of salinity of groundwater in swamp taro (*Cyrtosperma* *chamissonis*) *puluka* pits in Tuvalu. EU EDF8-SOPAC Project Report, Suva, Fiji.

Webb, A.P. and Kench, P.S. 2010. The dynamic response of reef islands to sea-level rise: evidence from multi-decadal analysis of island change in the central Pacific. *Global and Planetary Change*, 72, 234-246.

Weber, E.U. 2006. Experience based and description based perceptions of long-term risk: why global warming does not scare us (yet). *Climatic Change* 77, 103-120.

Webster, P.J., Holland, G.J., Curry, J.A. and Chang, H.R. 2005. Changes in tropical cyclone number, duration and intensity in a warming environment. *Science*, 309, 1844-1846.

Weisler, M. I., 1999. The antiquity of aroid pit agriculture and significance of buried A-horizons on Pacific atolls. *Geoarchaeology* 14, 621–654.

Weisler, M. I., 2001. Precarious landscapes: Prehistoric settlement of the Marshall Islands. *Antiquity* 75:31–32.

White, I. and Falkland, T. 2010. Management of freshwater lenses on small Pacific Islands. *Hydrogeology Journal*, 18, 227-246.

White, I., Falkland, T., Metutera, T., Katatia, M., Abete-Reema, T., Overmars, M., Perez, P. and Dray, A. 2008. Safe water for people in low, small island Pacific nations: the rural-urban dilemma. *Development*, 51, 282-287.

Wong, P. 2003. Where have all the beaches gone? Coastal erosion in the tropics. *Singapore Journal of Tropical Geography*, 24: 111–132.

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

Yamamoto, L. and Esteban, M., 2010. Vanishing Island States and sovereignty, *Ocean & Coastal Management, vol. 53, pp 1-9.*

Yeh, S-W., Kang, S-K., Kirtman, B.P., Kim, J-H., Kwon, M-H. and Kim, C-H. 2010. Decadal change in relationship between western North Pacific tropical cyclone frequency and the tropical Pacific SST. *Meteorology and Atmospheric Physics* 106:3-4, 179-189.