Chapter 29. Small Islands

Coordinating Lead Authors
Leonard Nurse (Barbados), Roger McLean (Australia)

Lead Authors
John Agard (Trinidad and Tobago), Lino Pascal Briguglio (Malta), Rolph Payet (Seychelles), Netatua Pelesikoti (Samoa), Emma Tompkins (UK), Arthur Webb (Fiji)

Review Editors
Thomas Spencer (UK), Kazuya Yasuhara (Japan)

Volunteer Chapter Scientist
Veronique Morin (Canada)

Contents

Executive Summary

29.1. Introduction

29.2. Major Conclusions from Previous Assessments

29.3. Observed Impacts of Climate Change, including Detection and Attribution
- 29.3.1. Observed Impacts on Coastal and Marine Biophysical Systems
  - 29.3.1.1. Beaches and Coasts
  - 29.3.1.2. Coral Reefs and Reef Fishes
  - 29.3.1.3. Coastal Wetlands: Mangroves and Seagrasses
  - 29.3.1.4. Marine Turtles
- 29.3.2. Observed Impacts on Terrestrial Biophysical Systems
  - 29.3.2.1. Forests and Biodiversity
  - 29.3.2.2. Hydrology and Water Resources
- 29.3.3. Observed Impacts on Human Systems
  - 29.3.3.1. Settlements and Infrastructure
  - 29.3.3.2. Tourism and Recreation
  - 29.3.3.3. Human Health
  - 29.3.3.4. Migration

29.4. Projected Climate Change Impacts
- 29.4.1. Projected Impacts for Islands based on SRES Scenarios with Regional Variation by Scenario and Time Slice
- 29.4.2. Challenges, Needs, and Opportunities for Small Islands in the Context of Scenario Development
- 29.4.3. Projected Impacts based on SRES and RCPs
- 29.4.4. Multi-Sector Synthesis, Multiple Interacting Stresses, and Impacts in One Sector Affecting Multiple Sectors

29.5. Inter- and Intra-Regional Transboundary Impacts
- 29.5.1. Physical Events and Impacts
  - 29.5.1.1. Large Ocean Waves from Distant Sources
  - 29.5.1.2. Saharan Dust and its Impact
- 29.5.2. Movement and Impact of Introduced and Invasive Species across Boundaries
- 29.5.3. Spread of Aquatic Pathogens within Island Regions
- 29.5.4. Transboundary Movements and Human Health

29.6. Adaptation and Management of Risks
29.6.1. Adaptation and Risk
29.6.2. Experiences of Adaptation in Small Islands
29.6.2.1. Valuation of Impacts and Adaptation
29.6.2.2. Building Resilience
29.6.3. Barriers to Adaptation
29.6.3.1. Observed and Expected Barriers
29.6.3.2. Planned and Autonomous Adaptation
29.6.3.3. Mainstreaming and Integrating Climate Change into Development Plans and Policies
29.6.3.4. Overcoming Barriers to Adaptation

29.7. Adaptation and Mitigation Interactions
29.7.1. Assumptions / Uncertainties Associated with Adaptation and Mitigation Responses
29.7.2. Potential Synergies and Conflicts
29.7.2.1. Coastal Forestry
29.7.2.2. Energy Supply
29.7.2.3. Tourism
29.7.3. Facilitating Adaptation and Avoiding Maladaptation

29.8. Research and Data Gaps

References

Executive Summary

- This assessment confirms small islands have characteristics that make them especially vulnerable to the effects of climate change, sea-level rise and extreme weather- climate- and ocean-related events.
- The small island states and territories considered here are mainly located in the tropics in the central and western Pacific Ocean, central Indian Ocean, the Caribbean Sea, and the eastern Atlantic off the west coast of Africa, and the more temperate Mediterranean Sea.
- There has been a substantial increase in the literature relating to small islands since AR4, and the range of topics considered has expanded greatly. This range is exemplified in the present assessment and some of the gaps and research needs anticipated in the AR4 have now been filled and documented here.
- There are large differences in the physical, environmental, geographical, and socio- economic and cultural characteristics of small islands. This heterogeneity is beginning to be reflected in the different responses of small islands to climate change impact and adaptation issues.
- For most small islands climate change is seen as just one of a series of multiple stresses. In some islands it has been argued that priority in the short-term should be given to addressing immediate problems such as water supply, waste management, deteriorating ecosystems and food security, thereby increasing human and environmental resilience to the longer-term impacts of climate change. It is also evident that climate change impacts are likely to be greatest where local environments are already under stress as a result of human activities.
- The distinction between *observed impacts* of climate change and *projected impacts* is often not clear-cut in the literature on small islands. In fact many publications deal with both types of impact, often using a recent ‘observed’ impact relating to some extreme weather- climate- or ocean-related event as an analogy to what may happen in the future. Nevertheless, in this assessment we attempt to separate ‘observed’ and ‘projected’ impacts.
- Observed impacts on small islands cover a number of causative weather, climate and ocean processes that impact a range of bio-physical, socio-economic and human systems.
- Coastal and terrestrial physical and ecological systems are of great importance on most small islands because of the goods and services they provide. Climate change impacts on coastal systems are discussed for: beaches and

coasts, coral reefs and reef fishes, coastal wetlands (mangroves and sea grasses) and marine turtles. Observed impacts on terrestrial bio-physical systems include: forests and biodiversity and hydrology and water resources.

- Since the AR4 there has been a large increase in the small islands literature on contemporary impacts of weather- climate- and ocean-related events, and especially extreme events. The section on impacts on human systems covers a number of sectors including: settlements and infrastructure, tourism and recreation, human health, migration and security, the last two topics dealing with the displacement of people from small islands as a result of climate change
- Much of the literature on projected (future) climate change impacts on small islands is not specific about the scenario (s) used in impact studies, partly because of the difficulty in moving from global-scale scenarios and models to the scale of small islands. Downscaling has been a perennial problem for impact studies of small islands. In- roads are now being made into this situation and examples are given of the use of downscaled SRES scenarios for impact analysis of Cocos (Keeling) and Christmas Island in the Indian Ocean, as well as for 22 Pacific island countries where a comprehensive assessment of the vulnerability of the fisheries and aquaculture sectors to climate change has been undertaken. Examples of downscaling from the Caribbean are also reported.
- Many impacts on small islands are generated from well beyond the borders of an individual nation or island. These trans-boundary impacts may originate from within the region or from another region including continental countries. Most trans-boundary processes have negative impacts. These include: large ocean swell from high and mid-latitude sources, and dust from the Sahara reaching distant small islands down-drift from the desert source. Other trans-boundary impacts result from invasive plant and animal species that reach small islands and the spread of aquatic pathogens that may have implications for human health.
- Since AR4 adaptation to climate change has been a major theme, and small islands have shared in that emphasis. Whilst our assessment confirms that small islands generally have limited adaptive capacity, some reviews have challenged that view based on case studies of particular small islands.
- Several topics are considered in the section on adaptation and risk management including case studies of the experience of small islands with adaptation, valuation estimates and the importance of incorporating traditional knowledge about adaptation to assist in building resilience. The importance of community-based adaptation actions are seen as being critical to successful adaptation in small islands.
- Major constraints to adaptation on small islands include: lack of technology and human resource capacity, financial limitations, lack of cultural and social acceptability and uncertain political and legal frameworks. These and other barriers to adaptation are discussed in the small island context and how these barriers can be overcome. Whilst mainstreaming and integrating climate change into development plans is seen as a goal, several case studies document the difficulties in achieving that goal.
- There is now a convergence of views that adaptation and mitigation are not trade-offs, but must be regarded as complementary components of any meaningful global response for managing the risks associated with global climate change. Whilst greenhouse gas emissions from small islands are negligible in relation to global emissions, small islands, are likely to bear the brunt of climate change impacts. This paradox, and its moral and ethical overtones, are reviewed in a number of reports since AR4 and discussed in this assessment.
- The inter-linkages between adaptation and mitigation on small islands and the potential synergies, conflicts, trade-offs and risks are considered. Specifically three key areas for adaptation-mitigation inter-linkages in small islands are identified: coastal forestry, energy supply and tourism.
- Adaptation is locally delivered, context specific and generates private benefits whereas mitigation actions deliver global public goods. The interactions between adaptation and mitigation are therefore multi-scale and multi-dimensional, and the extraction of co-benefits from adaptation and mitigation action must be grounded in this reality. The challenge for small islands is to evaluate the benefits of aligning sectors for potential emissions reductions, with adaptation needs, and other co-benefits.

29.1. Introduction

It has long been recognized that greenhouse gas emissions from small islands are negligible in relation to global emissions, but that the threats of climate change and sea-level rise to small islands are very real. Indeed, it has been suggested that the very existence of some atoll nations are threatened by rising sea levels associated with global warming. Whilst such extreme scenarios are not applicable to all small island nations, there is no doubt that on the whole the impacts of climate change on small islands will have serious negative effects especially on socio-economic conditions and bio-physical resources. Some impacts have already been observed.

The small islands considered in this chapter are principally sovereign states and territories located within the tropics of the southern and western Pacific Ocean, central Indian Ocean, the Caribbean Sea, and the eastern Atlantic off the coast of west Africa, as well as in the more temperate Mediterranean Sea.

Although these small islands nations are by means homogenous politically, socially, or culturally, or in terms of physical size and character or economic development, there has been a tendency to lump all small islands together and to generalise about the potential impacts and their adaptive capacity. In this chapter we attempt to strike a balance between identifying the differences between small islands as well as recognising that small islands tend to share a number of common characteristics that have distinguished them as a particular group in international affairs. Also in this chapter we reiterate some of the frequently voiced and key concerns relating to climate change impacts, vulnerability and adaptation whilst emphasising a number of additional themes that have emerged in the literature on small islands since the IPCC's Fourth Assessment. These include situating climate change within the context of multiple stresses; the relationships between climate change policy, activities and development issues; externally generated trans-boundary impacts; and the implications of risk in relation to adaptation and the adaptive capacity of small island nations

29.2. Major Conclusions from Previous Assessments

Small islands were not given a separate chapter in the IPCC's First Assessment (FAR) in1990 though they were discussed in the chapter on 'World Oceans and Coastal Zones' (Tsyban *et al*., 1990). Two points were highlighted. First, that a 30-50 cm sea-level rise projected by 2050 would threaten low islands, and that a 1 m rise by 2100 'would render some island countries uninhabitable' (Tegart *et al*., 1990: 4). Second, the costs of protection works to combat sea-level rise would be extremely high for small island nations. Indeed, as a per cent of GDP the Maldives, Kiribati, Tuvalu, Tokelau, Anguilla, Turks and Caicos, Marshall Islands and Seychelles were ranked among the ten nations with the highest protection costs in relation to GDP (Tsyban *et al*., 1990: 6. 4). Interestingly, over twenty years later these two points continue to be emphasized. For instance, although small islands bear only a tiny share of the total global damage projected for a sea-level rise of 1.0 m in 2100 for the A1 scenario, 'at the same time these damage costs for the small island states are enormous in relation to the size of their economy' (Anthoff *et al*., 2010: 328) with several small island nations (Nauru, Marshall Islands, Palau, Federated States of Micronesia) being included in the group of ten countries with the highest relative impact in 2100 (Anthoff *et al*., 2010: 330).

The Second Assessment (SAR) in 1995 confirmed the vulnerable state of small islands, now included in a specific chapter titled 'Coastal Zones and Small Islands' (Bijlsma, *et al*., 1995). However, importantly the SAR recognized that both vulnerability and impacts would be highly variable between small islands and that impacts were 'likely to be greatest where local environments are already under stress as a result of human activities' (Bijlsma, *et al*., 1995: 290-291). That conclusion still holds up today. The report also summarized results from the application of a common methodology for vulnerability and adaptation analysis that gave new insights into the socio-economic implications of sea-level rise for small islands including:

- Negative impacts on virtually all sectors including tourism, freshwater supply and quality, fisheries and agriculture, human settlements, financial services and human health;
- Protection is likely to be very costly; and,
- Adaptation would involve a series of trade offs.

It also noted that major constraints to adaptation on small islands included: lack of technology and human resource capacity, serious financial limitations, lack of cultural and social acceptability and uncertain political and legal frameworks. Integrated coastal and island management was seen as a way of overcoming some of these constraints.

The Third Assessment (TAR) in 2001 included a specific chapter on 'Small Island States'. In confirming previously identified concerns of small island states two important factors were highlighted, the first relating to sustainability noting that 'with limited resources and low adaptive capacity, these islands face the considerable challenge of meeting the social and economic needs of their populations in a manner that is sustainable' (Nurse *et al*., 2001: 845). And the second, that there were other issues faced by small island states concluding that 'for most small islands the reality of climate change is just one of many serious challenges with which they are confronted' (Nurse *et al*., 2001: 846). Both of these themes are further developed in the present assessment.

Until the Fourth Assessment (AR4) in 2007, sea-level rise had dominated vulnerability and impact studies of small island states. Whilst a broader range of climate change drivers and geographical spread of islands was included in the 'Small islands' chapter, Mimura *et al*. (2007) prefaced their assessment by noting that the number of 'independent scientific studies on climate change and small islands since the TAR' had been quite limited and in their view 'the volume of literature in refereed international journals relating to small islands and climate change since publication of the TAR is rather less than that between the SAR in 1995 and TAR in 2001' (Mimura *et al*., 2007: 690). This is no longer the case.

Since AR4 the literature on small islands and climate change has blossomed. A number of features distinguish the literature we review here from that included in earlier assessments. First, the literature appears more sophisticated and does not shirk from dealing with the complexity of small island vulnerability, impacts and adaptation or the differences between island states. Second, and related to the first, the literature is less one-dimensional, and deals with climate change in a multidimensional manner as just one of several stressors on small island nations. Third, there has also been a tendency to critique some aspects of climate change policy, notably in relation to development and security, and to suggest that adaptations for the future are being placed above critical needs of the present. As a result, it is argued, there is a reduction in resilience that will have serious ramifications for small island adaptation in the future.

The present chapter builds on these earlier assessments. Inevitably there is some repetition of the key impacts, vulnerability and adaptation to climate change and sea level rise of small islands. Such themes continue in this assessment, though rather than repeating or summarizing these (though still acknowledging them) our assessment raises both some additional concerns as well as some hopeful signs.

29.3. Observed Impacts of Climate Change, including Detection and Attribution

The distinction between observed impacts of climate change and projected impacts is often not clear-cut in the literature on small islands. In fact many publications deal with both types of impact, often using a recent 'observed' impact relating to some extreme weather- climate- or ocean-related event as an analogy to what may happen in the future. Similarly, the question of detection and/or attribution is rarely covered in more than a simple statement that is often rather ambiguous or left implicit in a case study. Moreover, many island studies provide suggestions as to how negative impacts can be reduced.

The key climate and ocean drivers of change that impact small islands include variations in air and sea temperatures, rainfall, wind strength and direction, ocean-levels and wave climate, and especially the extremes such as tropical storms and cyclones, drought, king tides and deep ocean swell events. These have varying impacts, dependent on the magnitude and frequency and temporal and spatial extent, as well as on the nature of the island environments and their social, economic and political settings. Observed impacts covered in the following sections deal with impacts on bio-physical and human systems. In many cases the specific examples from small islands deal with the interactions between both biophysical and human systems and potential responses to impacts (i.e. adaptation).

29.3.1. Observed Impacts on Coastal and Marine Biophysical Systems

The coastal and marine bio-physical systems of small islands, and the functions they perform, are sensitive to climate and ocean variability and extremes and to the rate and magnitude of incremental changes in climate and sea level. These systems provide a great range of services: they provide food, medicine, and energy; they process and store carbon and other nutrients; they provide protection from extreme events; and they supply opportunities for recreation and tourism.

Island coastal systems, whether they comprise steep limestone, volcanic or granitic rocky shores, black sand or carbonate beaches, coral reefs or low mangrove fringed muddy coasts, are all dynamic systems that undergo morphodynamic changes in response to weather, climate and ocean processes that operate at a range of different time and spatial scales. Whilst many island beaches and coasts adjust to these processes within a recognizable band-width of variation, gradual trends in sea-level rise and extremes in the last century or so have resulted in shoreline retreat, inundation and salt-water intrusion into island groundwater tables. Human activity has exerted additional pressures that may in fact result in more substantial changes than natural processes alone.

Surprisingly, there are very few investigations of changes to island beaches and coasts that have been attributed to climate change and/or sea-level rise during the past century. Island beaches affected by short-term erosion through storms, or longer term oscillations (such as ENSO) often return to their pre-event morphology. Such natural variability means it is difficult to identify the impacts of climate change separately from other processes including those associated with human impacts.

29.3.1.1. Beaches and Coasts

There is considerable evidence to support the view that the real and potential threat of beach and coastal land-loss on many islands will be exacerbated by the effects of various processes associated with climate change, including sea-level rise, ocean acidification and coral reef bleaching. Recognising the inertia associated with global climate change and various anthropogenic stressors on coastal areas, Defeo *et al*. (2009) suggest that there are no viable management interventions likely to reduce these stressors in the short term, and that the best solution is avoidance of development of areas prone to shoreline retreat. They also propose that commonly used ecosystem-based strategies such as zoning and application of setbacks, along with incentives for the sharing of responsibilities with coastal stakeholders, can provide an effective governance framework for beach management (Defeo *et al*., 2009). This view is largely supported by Schlacher *et al*. (2007; 2008), who consider the combination of anthropogenic and climate change-related impacts constitutes an ‘unprecedented’ threat to the management of sandy beaches. They further argue that in the face of climate risks and uncertainty, management interventions must not only focus on engineering solutions that seek to maintain the physical properties of sandy shores, but should also include ecological dimensions that can protect the unique biodiversity of beaches.

These findings are supported by Cambers (2009) who attributes the average beach erosion rate of 0.5 m yr^{-1} in eight Caribbean islands over the period 1985-2000 to anthropogenic factors, climate variability and climate change. Using case studies from Anguilla and Nevis (coastal planning) and Puerto Rico (rehabilitation of coastal forest), she suggests that against this background beach management strategies should be ‘nonexclusive’, and should include a mix of physical planning, ecological and structural options.

Island coastal systems are a reflection of ambient atmospheric and ocean climate and it follows that any changes in these conditions will influence shoreline processes. In the case of tropical reef mediated shorelines long-term changes in reef productivity, structure and composition are expected to influence shoreline stability, though the linkage between reef productivity, sediment provision and transport to adjacent beaches remains virtually unknown. The incidence of coral bleaching has risen over the last century (Veron *et al.,* 2009) and where reef health and structure has been compromised by frequent bleaching events the supply of reef debris for shoreline maintenance may be altered. But, whether this will result in an increase or decrease of sediment available for beach building is not known. Calcification rates of corals in the Great Barrier Reef (GBR) has declined over 14 per cent since 1990 (De’ath *et al*., 2009) and *in situ* cores of *Porites* in the GBR also show that pH has increased consistently since the 1940’s. These changes are due to a combination of more frequent bleaching events as well as ocean acidification. A number of calcifying species have been shown to be sensitive to increased CO_2 concentration which is of importance to coral islands where reef cementing species such as coralline algae contribute to the structural integrity of adjacent reefs (Anthony *et al.,* 2008). However, the potential impact of ocean acidification and increased coral bleaching on sediment production for islands has not been investigated.

Whilst incremental sea-level rise is inferred to cause widespread coastal erosion the attribution of any particular erosion event or trend to present rates of sea-level rise and other climate change stresses in tropical shores is inconclusive. Studies of historical shoreline position change in 27 central Pacific atoll islands over the last 20 – 60 years show that net island-wide loss of land area is not the predominate pattern, in fact 86 per cent of the islands studied showed stability or growth in land area over this time period (Webb and Kench, 2010). Likewise, Dawson and Smithers (2010) found that despite widespread fears of chronic erosion on the uninhabited Raine Island in the Great Barrier Reef that over all, both island area and volume increased 6 per cent and 4 per cent, respectively between 1967 and 2007. The authors suggest that seasonal erosion and accretion processes predominate over any long-term trend in morphological change. Kench and Brander (2006) and Kench *et al*. (2009) have come to similar conclusions regarding the response of reef island shorelines to seasonal climate conditions in South Maalhosmadulu atoll, Maldives.

Despite these historical studies of shoreline response, the rates of sea-level rise and other factors such as coral bleaching and reduced rates of calcification due to acidification are all increasing. Thus the historical resilience inferred in these studies cannot necessarily be projected onto future response. It is also important to recognize that patterns of human population growth, settlement and direct interference with shoreline processes through engineering, shoreline mining and near shore degradation of water quality also present sobering and immediate challenges in populated shoreline and coastal zones (Yamano *et al*., 2007; Storey and Hunter, 2010; Novelo-Casanova and Suarez, 2010).

29.3.1.2. Coral Reefs and Reef Fishes

Coral reefs are one of the most important resources of small islands in the tropics. They provide a number of valuable services including supplying sand to beaches and playing a critical role in the formation and maintenance of reef islands and atoll *motu*. Indeed they are the source of the material that makes up the low-lying atoll islands on which the inhabitants of the Maldives, Marshall Islands, Tuvalu, Tokelau and Kiribati live. For high islands, coral reefs function as protective barriers for island beaches, ports and infrastructure by reducing incident wave energy. Reefs provide habitats for a host of marine communities and reef fish that in many islands, particularly in the Pacific, provide an important component of subsistence food. Elsewhere, and especially in the Caribbean and Indian Ocean reefs and reef fish, are significant contributors to the economic resource base of many small island nations for the tourism and recreation assets they provide.

Whilst it appears that healthy reefs may be able to keep pace with sea-level rise, those that are not so healthy may ‘give-up’. However, a combination of higher sea temperatures and increasing acidity of the oceans may affect the viability of reefs in the future, especially those that are under stress from human activities. For instance in the Mesoamerican (mainly Belize) reefs, Carilli *et al*. (2010) have suggested that coral bleaching is on the increase and that it is typically associated with abnormally high water temperatures and solar irradiance. They produced chronologies of growth rates in the dominant reef builder, massive *Montastraea faveolata* corals, over the past 75–150 years from Belize, which showed that the mass bleaching event in 1998 was unprecedented in the past century. This event appeared to stem from reduced thermal tolerance of *M. faveolata* resulting from the interactive effects of human populations and thermal stress, and not just sea temperature alone. Similarly, the Grand Recif of Tulear, Madagascar was studied over a 40 year period (1960’s – 2008) with severe degradation evident during this time. However, despite an average 1^0C increase in temperature over this period damage was mostly ascribed to direct anthropogenic disturbance of the near shore marine environment (Harris *et al*., 2009).

Although water quality declines associated with human populations may result in chronic damage to reefs, and while reef recovery following temperature-related bleaching is improved in the absence of other human disturbances, bleaching events, some catastrophic, have also occurred in recent times in extremely isolated uninhabited mid Pacific Ocean atolls. Surveys by Alling *et al*. (2007) in 2004 of the remote Phoenix Group, Kiribati found that there had been near 100 per cent coral mortality in the lagoon environment and 62 per cent mortality on the outer leeward slopes of the otherwise pristine reefs of Kanton Atoll during 2002 / 2003. Four other atolls in this group were also visited and similar patterns of mortality were found. Likewise, temperature-induced coral bleaching has been recorded in remote and unpopulated Palmyra Atoll including during the 2009 ENSO event (Williams *et al*., 2010).

Elsewhere the incidence and implications of temperature-related coral bleaching is well documented and the synergistic implications of increasing ocean acidification is likewise considered a major threat to the long term survival of today's coral reef ecosystems (De'ath, *et al*., 2009; Veron *et al*., 2009). Also decreasing aragonite saturation levels caused by increasing CO_2 concentration in surface marine waters have been measured in the greater Caribbean including in the Turks Caicos, Lesser Antilles and Jamaica (Gledhill *et al*., 2008) with negative implications for the coral reef ecosystems and calcifying organisms in this region.

In addition to coral reefs, increasing ocean temperatures are predicted to have negative effects on coral reef fishes. Around Rangiroa Atoll (French Polynesia) Lo-Yat *et al*. (2011) compared sea surface temperature (SST) anomalies, surface current flow and chlorophyll-a concentrations with monthly patterns in larval supply of coral reef fishes in near shore waters from January 1996 to March 2000. That period included an intense El Nino event between two La Nina's. During the warm El Nino there was an increase in SST anomaly up to 3^0C above mean values, and although conditions improved during the subsequent La Nina, there was a lag in larval supply suggesting that productivity may be affecting both the production of larvae by adults and larval survival. As a result of this study Lo-Yat *et al*. (2011) conclude that warming temperatures in the world's oceans will have negative effects on the reproduction of reef fishes and survival of their larvae ultimately impacting on the replenishment of benthic populations, with serious implications for island populations.

29.3.1.3. Coastal Wetlands: Mangroves and Seagrasses

The importance of mangroves and seagrasses in island environments is not always appreciated either by islanders or visitors, though the ecosystem goods and services they provide is well documented, at least at the global scale by Polidoro *et al*. (2010) and Waycott *et al*. (2008) for mangroves and sea grasses respectively. Whilst species diversity and the extent of mangroves and sea grasses in small islands is generally low compared with the extensive forests and meadows elsewhere, they still have a host of commercial and subsistence uses in addition to providing natural coastal protection from erosion and storm events. In the Pacific islands mangroves are used as wood for construction, firewood and handicrafts and gathering of shellfish and crabs for food, whilst seagrasses are used in the manufacture of baskets, burning for salt, bedding, roof thatch, packing material and garden fertilizer (Ellison, 2009). There are however major threats to mangrove and seagrass habitats, both of which are declining globally (e.g., Polidoro, *et al*., 2010; Duarte *et al*., 2008) and in the islands (e.g., Ellison, 2009). Wetlands in small islands are largely vulnerable because of their small size, poor state of protection, destruction from increasing human population and development pressures. With reference to the Pacific islands, Ellison (2009: 199) argues: 'Climate change, sea-level rise and cyclone damage all increase vulnerability' and that the key to future survival of mangroves and seagrasses 'is engagement of local communities in their subsistence management, with accessible technical support from the scientific community, particularly in baseline assessment of the resource, monitoring and rehabilitation where required'.

Support for the widely held view that sea-level rise is a significant climate change threat to the survival of mangroves is a common theme, especially where there is 'net lowering in sediment elevation' and 'limited area for landward migration (Gilman *et al*., 2008). It is further posited that effective coastal planning should seek to accommodate mangrove migration under conditions of sea-level rise, the reduction of human-induced pressures and 'functionally linked ecosystems through representation, replication and refugia' (Gilman *et al*., 2008). Similar observations have been reported for the French Caribbean island of Martinique, where sea-level rise combined with 'coastal squeeze' is reducing the resilience of the island's coastal wetlands (Schleuper, 2008).

Sea-level rise is likely to have a less significant impact on seagrass meadows than an increase in sea temperature. Recent rapid warming of the Mediterranean Sea provides a regional example of the stress that threatens seagrasess. A 6-year monitoring of seawater temperature and shoot demography of *Posidonia oceanica* in the Balearic Islands (Western Mediterranean) allowed Marbá and Duarte (2010) to determine if warming influenced shoot mortality and recruitment rates of seagrasses growing in relative pristine environments. During higher temperature years shoot mortality exceeded recruitment rates and *P. oceanica* meadows experienced a steep decline in shoot abundance. Marbá and Duarte, (2010: 2374) concluded: 'Our results demonstrate that climate change poses a significant threat to seagrasses, which are important habitats already impacted by proximate stresses in many coastal areas'.

There are additional implications of sea temperature change to seagrasses. For instance the flowering season of *P. oceanica* is also linked to seasonal temperature change (Diaz-Almela *et al*., 2007) and thus changes in ambient temperature regimes may disturb the reproductive cycles of some species. A further factor is light availability, incident light levels over seagrass meadows decrease as water column depth increases indicating that sea-level rise and light reduction may be a limiting factor to seagrass growth (Ralph *et al.,* 2007). Additionally, recent study by Ogston and Field (2010) predict from observations of wave orbital velocity in Molokai, Hawaii, that a 20 cm of sea-level rise may double suspended sediment loads in the water column of the island's fringing reef, elevating turbidity and reducing light availability especially for benthic photosynthetic species such as seagrass, corals and algae.

Conversely, seagrass response to increased CO_2 concentrations may initially be positive with an increase in growth rate, productivity and biomass. For instance Connolly's (2009) review of climate change impacts on seagrasses suggests increasing atmospheric CO_2 concentrations are expected to result not only in an increase in dissolved CO_2 but also an increase in the relative proportion of dissolved CO_2 to HCO_3 the effect of which is likely to increase productivity and biomass of seagrass meadows. Thus, responses in seagrass are likely to be complex, regionally variable and potentially manifest in quite different ways even in the same location over foreseeable temporal time frames.

29.3.1.4. Marine Turtles

The potential impact of climate change and climate variability on marine turtles in island and tropical environments is well documented. Impacts range from changes in species distribution, alteration of the sex ratio of hatchlings, change in timing of nesting seasons, to the threat of habitat loss from sea level rise and coastal land loss (Houghton *et al*., 2006; Pike *et al*., 2006; Baker *et al*., 2006; Hawkes *et al*., 2007; Hays, 2008). More recently, Fuentes *et al*. (2009) have shown that nest temperature not only influences sea turtle sex ratios, but may also be a determinant of hatchling mortality. They demonstrate that sand temperature (a proxy for nest temperature) can be used to guide local-scale management interventions to reduce the effects of warming on turtle populations. Chaloupka *et al*. (2008) have shown an inverse correlation between nesting abundance of the Pacific loggerhead sea turtle and mean annual sea surface temperature (SST) in the year prior to the summer nesting season. They conclude that warming will likely lead to reduced foraging supplies, nesting and recruitment 'unless Pacific loggerheads adapt by shifting their foraging habitat to cooler regions' (Chaloupka *et al*., 2008). Similarly, Mazaris *et al*. (2008) found that with increasing SST in spring, the Mediterranean loggerhead marine turtle, *Caretta caretta*, is nesting earlier and clutch size is smaller although no significant correlation has been observed between SST, nesting season and hatchling production.

Research from different localities continue to corroborate and expand on these conclusions, underlining the need for enhanced ongoing conservation efforts, if the endangered turtles are to escape extinction. Robinson *et al*. (2009) note that while migratory fauna may be able to adapt in the short term, adaptive capacity would be constrained by such factors as damage, loss and fragmentation of habitat, as well as over-exploitation. This further highlights the importance of maintaining 'large, genetically diverse populations' in order to increase the likelihood of species survival (Robinson *et al*., 2009).

Fish *et al*. (2008) make a compelling case for the application of stringent setback limits for construction along sandy beaches, as a management strategy for protecting sea turtle nesting sites threatened by sea-level rise. Using sea level projections for 11 critical turtle nesting beaches on Barbados, they demonstrate that under all sea-level rise scenarios, all nesting sites would be negatively impacted; some loss would occur with setbacks of 50 m, one site would be affected with a setback of 70 m and no sites would be impacted where a setback of 90 m was applied. Evidently, these findings would appear to have useful application along sandy beaches on other small islands, where marine turtle nesting sites are threatened by physical development, climate change and sea level rise. Similar findings in relation to sea flooding of green turtle nesting beaches under various sea-level rise scenarios have been reported for eight important rookeries in Australia, where it is projected that as much as 38 per cent of the nesting area would be flooded, and egg mortality would increase (Fuentes *et al*., 2010).

29.3.2. Observed Impacts on Terrestrial Biophysical Systems

29.3.2.1. Forests and Biodiversity

Climate change is one of several factors considered in a comprehensive synthesis of plant conservation issues across oceanic archipelagos undertaken by Caujap-Castells *et al*. (2010). They summarize the pattern of endangerment for several small islands, and the Seychelles and Cape Verde islands are identified as two of nine ‘focal archipelagoes’ with full details. They also suggest that the impacts of climate change on island plant diversity are likely to be substantial. While changes in precipitation patterns are difficult to predict, Giambelluca *et al*. (2008) have suggested an overall trend towards less rainfall for tropical and subtropical oceanic islands. This together with an increasing incidence of extreme events, such as hurricanes and droughts, can be expected to promote enhanced habitat disturbance, which could lead to increased mortality of native species or facilitate invasion by non-native species (Caujap-Castells, *et al*., 2010). Increased dry periods may also increase the risk of fires. With changing climate oceanic island plants have fewer options than mainland plants to migrate to suitable habitat. On high islands some altitudinal movement may be possible but on small and low-lying islands it may not be possible. Also some island plants are more vulnerable to shifts in environmental conditions. While woody plants allow longer generation times when climatic conditions are stable, woodiness could represent a hindrance to survival in a changing environment. Both Seychelles (76 per cent) and Cape Verde (63 per cent) have a high percentage of woody endemics with respect to the total endemic flora (Caujap-Castells, *et al*., 2010).

In the islands of the south and central Pacific biodiversity is also likely to be much affected by climate change. While, Woinaski (2010) suggests the fragmented islands of Polynesia, Melanesia and Micronesia have a relatively small proportion of the world's tropical forests, those forests support an unusual richness of narrowly endemic species. In common with tropical forests across most of the world, tropical forests in the Pacific islands are declining due to increasing human populations, economic drivers and more intensive exploitation. In some islands, particularly in Melanesia, the forests are predisposed to disturbance, given a history of natural processes (particularly cyclones and drought), and of smaller-scale slash-and-burn agriculture or landscape-scale burning. But, in most islands, the current intensity, scale and/or rate of forest modification far surpass their precedents, and biodiversity is consequently diminishing. This together with invasions of introduced plants, animals and diseases has simplified the remaining native forest making it more susceptible to the impact of climate change. In light of this Woinaski (2010) suggests the future hope for biodiversity conservation in tropical forests in the islands of Polynesia, Melanesia and Micronesia lies in the renewed application of traditional management constraints, the appropriate delivery of international support (such as may be available through carbon markets), improved quarantine processes, and through some protection naturally offered by the remote scattering of these islands in the Pacific Ocean. Recovery from hurricane disturbance is also an issue in the dry forests of the Caribbean (Imbert and Portecop, 2008).

Legra et al. (2010) argue that currently most climate change studies on biodiversity focus on direct climate effects and little attention is paid to the effects of sea-level rise. They explore two scenarios of sea-level rise (1 m and 6 m) and the implications for biodiversity around the whole of New Guinea. Marine intrusion with a 1 m of sea-level rise would be geographically widespread and affect large sectors of New Guinea, leading to extensive loss of land, the formation of many small islands (through inundation) and altering the lower reaches of rivers and estuaries. Projected loss to habitats include mangrove loss (76 per cent) and southern New Guinea freshwater swamp and low rainforest loss (32 and 17 per cent respectively). Legra et al. (2010: 197) conclude ‘that sea-level rise will be a non-trivial agent of biodiversity loss in coming decades in New Guinea’.

29.3.2.2. Hydrology and Water Resources

Freshwater supply in small island environments has always presented challenges and has been an issue raised in all previous IPCC reports on small islands. On high volcanic and granitic islands small and steep river catchments respond rapidly to rainfall events and watersheds generally have restricted storage capacity. On porous limestone and low atoll islands surface runoff is minimal and water rapidly passes through the substrate into the ground water lens. With increasing population growth, urbanization, development and tourism greater demand is placed on these limited freshwater reserves in both high and low islands (Cashman *et al*., 2010; White *et al*., 2007).

In atoll situations White and Falkland (2010) and White *et al*. (2007) confirm that atoll fresh ground water supplies are extremely vulnerable to disturbance from existing urban demand and management practices, and there remains an urgent need to balance the preservation of safe and adequate groundwater supplies in urban atolls with competing forces of unmanaged demand, poor delivery infrastructure, unplanned settlement patterns and contamination through solid and liquid waste. Sea-level rise is also seen as a major issue. Much of what is understood of impacts of island ground water lens response to sea-level rise is derived from modeling studies that indicate fresh groundwater lenses do not necessarily suffer a net reduction in volume or quality due to sea-level rise alone, providing that adequate accommodation space is available above the present water table, and if there is adequate rainfall recharge.

Clear statistical trends of rainfall reduction in small islands is frequently inconclusive and the results of such analysis are made more difficult due to the generally poor spatial coverage and shortness of records, particularly of ground water. Likewise, evidence of saline intrusion into fresh groundwater reserves on atoll islands is generally only cited in scientific literature as a result of unusual wave over-topping, drought or over pumping rather than resulting from incremental sea-level rise. For example, in the Cook Islands storm surge over-wash on Pukapuka atoll in February 2005 caused the fresh water lens to become brackish and took some 11 months to recover to tolerable conductivity levels (Terry and Falkland, 2009). These observations highlight the fragility of atoll groundwater systems to wave incursion and the resultant vulnerability of remote communities with little else as fall back supply.

Given fresh groundwater lenses float above marine waters within the matrix of the island, incremental sea-level rise will gradually increase the height of the fresh groundwater table, assuming recharge rates remain stable. In the case of many atolls, central areas midway between the ocean and lagoon shores are very low-lying and as groundwater tables rise, they may eventually be expressed above the surface of the ground as flooding. This phenomena already occurs in very low-lying central areas of Fongafale Island, Tuvalu, and during 'king' tides large areas of the inner part of the island become inundated with marine waters (Yamano *et al*., 2007) a situation that is likely to become more frequent and manifest in more atoll locations as sea level increases.

In contrast to atoll islands in the Pacific and Indian oceans, the Caribbean islands include considerable variation in the types of freshwater supplies utilized, including groundwater, surface flow, rainwater harvest and desalinization Nevertheless, concern over the status of freshwater availability have been expressed for at least the past 30 years particularly in the eastern Caribbean islands (Cashman *et al*., 2010). Cashman *et al*. (2010) suggest that future freshwater availability will be vulnerable to extremes of climate and increasing demand. They also highlight the implications of climate change projections, under a range of scenarios, which suggest increasing average temperature, longer dry seasons and an increasing frequency of drought periods overlain on existing issues of water supply inadequacy will result in serious water shortages.

29.3.3. Observed Impacts on Human Systems

29.3.3.1. Settlements and Infrastructure

Traditional patterns of settlement and the more recent interest in tourism have resulted in the greater majority of infrastructure and development being located in the coastal fringe of small islands. In the case of atoll islands, land area is seldom more than 1 km wide from lagoon to ocean coasts and frequently far less. As such, all development and settlement on atolls is essentially coastal. It follows that populations, infrastructure, agricultural areas and fresh groundwater supplies are all vulnerable to extreme tides, wave and surge events and sea level rise. Population drift from outer islands or from inland on high islands, together rapid population growth in main centers, further exacerbates these problems and the lack accommodation space drives growing populations into ever more vulnerable locations. Additionally, without adequate resources and planning, engineering solutions such as shoreline reclamation also frequently place communities and infrastructure in positions of increased risk (Schleupner, 2008; Yamano *et al*., 2007).

Many of the environmental stresses that have been attributed to Tuvalu, the Marshall Islands and Maldives are in fact appropriate only to the major center and its surrounds, that is Funafuti, Majuro and Male respectively. As an example the 'Kiribati' problem is generally restricted to the southern half of Tarawa atoll. In Storey and Hunter's (2010), review of environmental problems in South Tarawa they acknowledge the 'real and alarming threats' climate change poses to atoll islands. However, they highlight preexisting issues of severe overcrowding, proliferation of informal housing and unplanned settlement, inadequate water supply, poor sanitation and solid waste disposal, pollution and conflict over land ownership as issues of immediate importance if the vulnerability of this community to climate change is to be managed effectively.

Similar, issues arise in other locations. In the Caribbean high island of Martinique rapid coastal development in a limited coastal zone area combined with population growth and tourism have placed great stress on coastal systems and has resulted in dense aggregations of infrastructure and people in potentially vulnerable conditions (Schleupner, 2008). Rapid unplanned urban development patterns on Majuro Atoll also highlight the unavoidable abandonment of traditional settlement patterns where the original settings for villages coincided with the least vulnerable locations on the island (Spennemann, 1996). Likewise, geophysical studies of Fongafale Island, the capital of Tuvalu, show that engineering works during World War II, and rapid development and population growth since independence, has lead to the settlement of inappropriate shoreline and swampland areas leaving communities in heightened conditions of vulnerability (e.g., Yamano *et al*., 2007). Ascribing direct climate change impacts in such disturbed environments is problematic due to the existing multiple lines of stress on the island's biophysical and social systems. However, it is clear that such pre-existing conditions of vulnerability add to the threat of climate change in such locations reducing environmental and human resilience.

29.3.3.2. Tourism and Recreation

Linkages between weather, climate and tourism in small islands have been assessed on several occasions, including in IPCC assessments. Weather conditions affect decisions by tourists to visit certain destinations and not others, particularly when seasonal variations are pronounced, as in the case of island destinations located in the temperate zone. There is a perception that some of these islands will become 'too hot' for comfort as a tourist attraction and the IPCC AR4 chapter on Europe predicted that higher summer temperatures may discourage tourism in the Mediterranean (Alcamo et al., 2007). This assertion has been reassessed by Rutty and Scott (2010), who found that by early this century under the warmest available climate change scenario, no additional beach or urban destination will became unacceptably hot, but by mid-century, thermal conditions for the island of Cyprus will become 'too hot' during the peak summer months. One conclusion that can be drawn from this study is that in the late-century scenario, most Mediterranean island destinations would become 'unacceptably hot' in the summer months. An important contrasting point is that at the same time there is a larger decrease in the number of months that are considered 'unacceptably cool' in the Mediterranean, perhaps leading to an increase in months that become 'ideal'.

In another study of Mediterranean tourism Moreno (2010) confirms the importance of climate as a destination attribute, but he argues that 'heat waves' may be considered as 'not too negative' by tourists, and such conditions may not have adverse impacts on the tourism trade. 'Ideal weather' for beach tourism is associated with temperatures of approximately 28°C, light breezes and a blue sky. If these conditions were to be found more temperate countries as a result of climate change, it would have only a moderate effect on destination choice. This assertion is to an extent supported by Gossling *et al*. (2006) with regard to tourism on the island of Zanzibar. They suggest that climate change affects tourism performance, not only because of actual impacts, but also because of perceptions of tourists regarding other climate variables, such as more rain, storms, and high humidity. These are more likely to negatively influence travel decisions than higher temperatures alone, the latter not necessarily perceived as negative.

As Moore (2010) notes climate change can either positively or negatively impact on the attractiveness of a tourist destination. Combining studies of future climatic conditions using the four SRES scenarios as well as empirical tourism demand models, Moore (2010) obtained anticipated scenarios of the direct effect of climate change on tourist arrivals to the Caribbean region for 2071 and 2100. His results suggest that under the A1 and A2 scenarios a slight increase in regional demand would be seen, whilst the B1 and B2 scenarios suggest a contraction in demand.

Country specific results are also presented, and the impact of climate change is likely to be fairly heterogeneous. Some countries such as Dominica, St Kitts-Nevis and the Dominican Republic-Haiti are projected to experience some increase in tourism demand under all four scenarios, while arrivals to St Lucia are likely to decline marginally under the four scenarios (Moore, 2010). The sustainability of tourism is also an issue in Mauritius, where tourism 'development can only be sustainable if it is based on and grown out of cultural and social identity' (Nunkoo and Ramkissoon, 2010).

29.3.3.3. Human Health

Many small island states currently suffer from climate-sensitive health outcomes, including morbidity and mortality from extreme weather events, certain vector-and food- and water-borne diseases (Ebi, *et al*., 2006). Extreme weather and climate events such as tropical cyclones, storm surges, flooding, and drought can have both short-and long-term effects on human health, including drowning, injuries, increased disease transmission, and health problems associated with deterioration of water quality and quantity. Most small island nations are in tropical areas with weather conducive to the transmission of diseases such as malaria, dengue, filariasis, and schistosomiasis. The rates of many of these diseases are increasing in the islands for a number of reasons, including poor public health practices, inadequate infrastructure, poor waste management practices, increasing global travel, and changing climatic conditions (Ebi, *et al*., 2006).

It is expected that these problems will increase as a consequence of climate change with increases in ambient temperature and changes in precipitation, vegetation and water availability (Russell, 2009). In the Pacific islands where the rates of diseases such as malaria and dengue fever are increasing, especially endemic dengue in Samoa, Tonga and Kiribati, other health threats as a consequence of climate change are expected to include outbreaks of cholera and ciguatera (Russell, 2009). In the Caribbean, the occurrence of autochthonous malaria in non-endemic island countries in the last ten years, suggests that all of the essential malaria transmission conditions now exist, and Rawlins *et al*. (2008) call for enhanced surveillance, recognizing the possible impact of climate change on the spread of anopheles and malaria transmission.

In a recent review of health governance and the impact of climate change on islands of the Pacific, Lovell (2011: 50) indicates that 'food security and access to fresh drinking water are already recognized as primary threats to the public health of many Pacific nations as saline intrusions into ground water tables is brought about by rising sea levels and increases in extreme weather events'. She also notes that many of the anticipated health effects of climate change in the Pacific are anticipated to be indirect, connected to the increased stress and declining well-being that comes with property damage, loss of economic livelihood and threatened communities and she suggests that 'human health in the Pacific is being shaped by processes of global environmental change that extend beyond climate change' and asks 'whether the current funding on surveillance is intended to distinguish between the effects of human induced climate change from other sources of environmental change in order to determine international obligations' (Lovell, 2011: 55).

29.3.3.4. Migration

Since the AR4 there has been a large increase in studies of potential displacement of people from several small island nations as a result of climate change. This is especially the case with the prospect of sea-level rise on low-lying islands and particularly the atoll nations of Kiribati, Marshall Islands, Maldives and Tuvalu which have been described as 'sinking nations' (Jarvis, 2010). In fact the last country, Tuvalu, has been the subject of many media reports most of which have suggested that rising sea levels will result in substantial land loss or indeed the disappearance of Tuvalu, though this has been seen as 'wishfull sinking ' by Farbotko (2010). On the other hand there is evidence for the robustness of atoll islands in the face of tsunami and tropical cyclones (e.g., Kench *et al.,* 2008), as well as examples of some atoll islands in the Maldives accumulating during rising sea level in the mid- to late-Holocene (Kench *et al*., 2005), and that several atoll islands in the central Pacific have 'grown' during the global sea level rise of the last 20 to 60 years (Webb and Kench, 2010).

Whether the movement of people from one location to another from climate change is an 'impact' or 'adaptation' is perhaps a theoretical matter. But in recent years a new literature has been spawned relating to climate change-migrants or 'refugees' from small islands. Such a consequence has frequently been seen as an equity or human rights issue or 'a moral imperative' (Amizadeh, 2007) that deals with the 'biopolitics of displaced bodies' (Bastos, 2008) and the need to provide 'new homes for climate change exiles' (Byravan and Rajan, 2006). It is also an issue that has important 'security implications' that relate not just to out-migration but to the impact on 'recipient' countries (Podesta and Ogden, 2007). In fact, Podesta and Ogden (2007) referring to the Caribbean islands, argue that climate change outward migration could cause de-stabilizing effects and political tensions in the host country, in this case probably the USA, which may induce negative attitudes toward Caribbean migrants generally.

However Mortreux and Barnett (2009), in a study on Funafuti (Tuvalu) challenge the widely held assumption that climate change is, will, or should result in large-scale migration from Tuvalu. They show that for most people climate change is not a reason for concern, let alone a reason to migrate, and that would-be migrants do not prioritize climate change as a reason to leave the country. Indeed many small islands have a long history of temporary or permanent out-migration, and some countries, for example Cape Verde, have some resilience in that tradition (Akesson, 2008).

A related argument, put forward by Rasmussen *et al*. (2009) with regard to Polynesian outlier islands in Melanesia (Solomon Islands) is that migration occurs due to various factors, and climate change factors are difficult to disentangle from other reasons. Populations from outlying islands constantly move to the larger islands and centers, for a host of reasons including the breakdown of the traditional population control mechanisms, the search for jobs and health care. Whether climate change can be identified to be an independent factor in such movements is doubtful.

29.4. Projected Climate Change Impacts

Much of the literature on small islands is not specific about the scenario (s) used in impact, vulnerability and adaptation studies. Nor are the time-scales particularly precise. Instead scenarios and times are often taken from IPCC assessments, such as those associated with sea-level rise, though rigorous adherence to a particular scenario is rarely maintained. Nevertheless, there are several studies of the potential impacts of climate change and sea-level rise in the literature on small islands with most firmly anchored in recent experiences of climate and sea level variability and extremes.

29.4.1. Projected Impacts for Islands based on SRES Scenarios with Regional Variation by Scenario and Time Slice

Projected changes in climate for the Caribbean, Pacific, Indian Ocean and Mediterranean Islands, generally apply to the regions as a whole and not specific countries. This is because the grid squares in the Global Circulation Models used in the SRES scenarios used over the last decade, were between 200 and 600 km^2, which provides inadequate resolution over the land areas of virtually all small islands. The broad synthesis in the AR4 (Mimura *et al*., 2007), of projected impacts on small island regions remains valid, however most socio-economic decisions are taken at smaller scales, and as a result a few regional and local studies have been undertaken that are based on downscaled data generated by statistical interpolation or using one GCM. In the five main regions in which most tropical or sub-tropical small island developing states are located, there are only one or two independent peer reviewed scientific publications providing downscaled climate data projections, and virtually none illustrating the experience gained from their use for policy making. Most reports appear to be consultancies for governments or international donor agencies.

One illustrative example is the climate downscaling projections for Australia's two Indian Ocean territories. Projections for the Cocos (Keeling) Islands and Christmas Island are presented using the CSIRO Mark 3.0 climate model with the SRES A2 scenario which implies a reduction of the greenhouse gases emissions in a more economic and regional world (Maunsell Australia, 2009). Future climate change projections for the two islands for 2030 and

2070 include quantitative estimates of air and sea temperature increases and sea-level rise as well as estimates of the intensity, frequency and distribution of tropical cyclones and storms.

Similarly, downscaling climate projections to 25 km^2 have been generated by the Caribbean Community Climate Change Centre for some Caribbean islands using the Hadley Centre PRECIS GCM (Taylor et al., 2007, Chen et al., 2008). Downscaling results are also sometimes used as advocacy pieces to sell the case for the vulnerability of small islands (e.g. Simpson et al., 2010). Of greater scientific value are global scale modelling studies in which the vulnerability of small islands to future climate projections can be objectively shown to be greater in comparison to other geographic areas. Such a study is the use of the FUND model to assess the economic impact of substantial sea-level rise in a range of socio-economic scenarios downscaled to the national level, including the four SRES storylines (Anthoff *et al.*, 2010). Although this study shows that in magnitude, a few regions experience most of the costs of sea-level rise by 2100, especially East Asia, North America, Europe and South Asia, these same results when expressed as percent of GDP show that most of the top ten and four of the top five most impacted are small islands from the Pacific and Caribbean (Anthoff *et al.*, 2010).

A comprehensive assessment of the vulnerability of the fisheries and aquaculture sectors to climate change in 22 Pacific island countries and territories has recently been completed, and the results are due to be published in a peer-reviewed book in October 2011 (Bell *et al.*, in press). An information paper provides a summary of the methodology and results (SPC, 2011). The assessment focussed on two future time-frames (2030 and 2100) and two SRES emissions scenarios, B1 (low emissions) and A2 (high emissions) and was designed to identify:

- The observed and projected changes to surface climate and the ocean in the tropical Pacific;
- The effects of these changes on the habitats that support fisheries and aquaculture including mangroves, seagrasses and coral reefs; and,
- The impacts on oceanic fisheries and coastal fisheries as well as the implications for economic development, government revenue, food security and livelihoods in the island of the region.

Projected changes to selected features of tropical Pacific surface climate and oceans are summarised in Table 29-1.

[INSERT TABLE 29-1 HERE
Table 29-1: Projected changes to selected key features of Pacific surface climate and ocean relative to 1980-1999 values (after SPC, 2011: Tables 1 and 2).]

Estimates of changes in habitat area (mangroves, seagrasses, freshwater fish) coral reef cover and demersal fish production for the two scenarios and time-slices are given in Table 29-2, while preliminary projected percentage changes in tuna catches and estimated changes to government revenue resulting from change in skipjack tuna catch in 2030 and 2100 are summarized in Table 29- 3. Substantial differences between the two emission scenarios and time-slices are evident as well as between the eastern and western Pacific for the commercial tuna catch, with implications for government revenue and island food security (SPC, 2011).

[INSERT TABLE 29-2 HERE
Table 29-2: Projected estimated percentage or percentage change in habitat area, reef cover, coastal (demersal) fish production (after SPC, 2011, Tables 4, 5, 6 and 8).]

[INSERT TABLE 29-3 HERE
Table 29-3: Preliminary projected percentage changes in tuna catches relative to the 20 year average (1980-2000) and estimated percentage change in government revenue resulting from projected changes in the catch of skipjack tuna in 2030 and 2100 (after SPC, 2011: Tables 7, 11 and 12).]

29.4.2. Challenges, Needs, and Opportunities for Small Islands in the Context of Scenario Development

Small Islands face many challenges in using climate change projections for policy development and decision-making. Primary among these is the absence of credible regional socio-economic scenarios relevant at the scale at which most decisions are taken. Scenarios are an important tool to help decision makers disaggregate vulnerability to the direct physical impacts of the climate signal from the vulnerability associated with socio-economic conditions and governance. Such a determination of effective policy for adaptation and mitigation under a range of socio-economic scenarios would better guide decision-makers in developing more effective adaptation and mitigation strategies.

Before building socio-economic scenarios to aid decision making, there has to be scientifically credible simulation of future small island climates. In this regard, there is a serious problem in generating climate scenarios at the scale of small islands since they are generally much smaller than the resolution of the models. The scale problem has been usually addressed by the implementation of statistical downscaling models that relate the GCM output to the historical climate of a local small island data point. The limitation of this approach is the need for daily observed data for at least 1960–1999 for a number of points on the island in order to establish the statistical relationships between the GCM data and the observations. In most small islands long term quality controlled climate data is generally sparse so that resort is made to global online databases containing inappropriate downscaling of GCM's to fine scales such as 1 km^2 even where the appropriate local historical island data is unavailable. A potentially better approach requiring less data and computation demand is to use a dynamic downscaling technique which responds to the guidance of the GCMs within the local domain only (see Nurse and Charlery, 2011).

29.4.3. Projected Impacts based on SRES and RCPs

The IPCC has catalyzed the scientific community to produce and make available four new global Representative Concentration Pathways (RCPs) in order to explore a range of global climate signals up to the year 2300 (e.g., Moss *et al.,* 2010; van Vuuren *et al*., 2010). Within the global framework of the IPCC, four socio-scenarios are being developed, but scientists have recognized and strongly cautioned against the specification of detailed sub-global conditions and trends (regional/local) based on these coarser global datasets and models. They are thus calling for the generation of regional and locally-relevant data and models which would be nested within the global scenarios, and which could create conversations between the local and global scales by providing local and regional texture to the global scenarios. The proposed scenarios framework explores the interaction of the two components (that is biophysical and social) of climate vulnerability. Proximal vulnerabilities commonly appearing in the literature include sensitivity, coping and adaptive capacities, hazard, and exposure, all of which processes occur at multiple scales with cross-scale interactions (Preston and Stafford-Smith, 2009). Pending the development of new scenarios for small island regions within the context of the global RCP based scenarios, the proposed scenarios framework compartments will be populated with examples from the existing SRES projections for small island regions in an attempt to delineate any pattern in projected impacts that will make a start to looking at how mitigation and adaptation choices at different scales.

29.4.4. Multi-Sector Synthesis, Multiple Interacting Stresses, and Impacts in One Sector Affecting Multiple Sectors

Studies such as those envisaged in the framework outlined in the previous section disaggregating the climate signal from the socio-economic vulnerability, do not yet exist. However, looking at how islands fare in the global study by Anthoff *et al*. (2010) on the economic impact of substantial sea-level rise provides some clues. According to that study, on a global basis the damage costs of sea-level rise in 2100 as percent of GDP for a 1 m sea-level rise in 2100 for scenario A1 with protection, is highest for the Federated States of Micronesia, followed by Palau and the Bahamas. The different socio-economic status of these three small island states is likely to affect their response to coastal protection. The model also shows that without protection 'the Maldives are estimated to be completely inundated in 2085 for the 1 m rise scenario' such that after 2085 the value of its dry land is zero. That is the Maldives does not exist. Clearly this is not a satisfactory valuation from an economic point of view (Anthoff *et al*., 2010). Nor is it realistic. The authors also point out that even though it is economically rational to protect, in some cases such as islands and deltas, the diversion of investment from other uses could overwhelm the capacity of these societies to protect.

29.5. Inter- and Intra-Regional Transboundary Impacts

Many impacts on small islands are generated from well beyond the borders of an individual nation or island. These trans-boundary impacts may originate from within the region or from another region including continental countries. Some trans-boundary processes may have positive effects on the receiving small island or nation, though most that are reported have negative impacts. However, deciphering a climate change signal in inter- and intra-regional trans-boundary impacts on small islands is often not easy and usually involves a chain of linkages tracing back from island-impact to a climate or climate-related bio-physical or human process.

Below we discuss a number of observed trans-boundary impacts with examples encompassing physical, biological and human mechanisms and their direct or indirect effects.

29.5.1. Physical Events and Impacts

29.5.1.1. Large Ocean Waves from Distant Sources

Unusually large deep ocean swells, generated from far distant sources in the mid- and high-latitudes cause considerable damage on the coasts of small islands thousands of kilometers away in the tropics. Impacts include sea-flooding and inundation of settlements, infrastructure and tourism facilities as well as severe erosion of beaches. Examples from small islands in the Pacific and Caribbean are common though perhaps the most significant instance, in terms of a harbinger of climate change and sea-level rise, occurred in the Maldives in April 1987 when long period swells originating from the southern Indian Ocean some 6000 km away caused major flooding, damage to property, destruction of sea defences and erosion of reclaimed land and islands. This event, described by Harangozo (1992) and another in 1988 stimulated President Gayoom to convene the first Small Island States Conference on Sea-Level Rise, held in Male in November, 1989. The Maldives have been subject to comparable ocean swell events more recently, most notably in May 2007 (Department of Meteorology, 2007)

In the Caribbean northerly swells affecting the coasts of islands have been recognized as a significant coastal hazard ever since the 1950s (Donn and McGuinness, 1959). They cause considerable seasonal damage to beaches, marine ecosystems and coastal infrastructure (Cambers, 2009; Bush *et al*., 2009). These high-energy events manifest themselves as long period, high-amplitude waves generated by extra-tropical cyclones (mid-latitude depressions) originating thousands of kilometers away in the Atlantic. They occur during the Northern Hemisphere winter, are typically confined to the period November – March and often impact the normally sheltered, low-energy leeward coasts of these islands (Bush *et al.,* 2009; Cambers, 2009). They differ from the 'normal' wave climate conditions experienced by these islands, particularly with respect to direction of wave approach, wave height and periodicity. Based on statistical analysis of wave data from voluntary observer ships (VOS), Gulev and Grigorieva (2006) suggest that significant wave heights have increased by between 10 – 40 cm/decade in both the North Atlantic and North Pacific, during the period 1958-2002.

Swells of similar origin and characteristics are also known to occur in the North Pacific. This is exemplified by the case of Oahu Island, Hawaii, where there is documented evidence of damage to coral growth by northerly swell, especially during years with a strong El Nino signal (Fletcher *et al*., 2008). Whereas the origin of the long period ocean swells that impact small islands in the tropical regions come from the mid-and high-latitudes in the Pacific, Indian and Atlantic oceans, there are also instances of unusually large waves generated from tropical cyclones that spread into the mid- and high- latitudes. One example occurred during 1999 when tide gauges at Ascension and St. Helena Islands in the central south Atlantic recorded unusually large deep-ocean swell generated from distant Hurricane Irene (Vassie *et al*., (2004). All of these instances 'serves to remind us of the potential importance of swells to communities on distant, low-lying coasts, particularly if the climatology of swells is modified under future climate change' (Vassie *et al*., 2004: 1095).

29.5.1.2. Saharan Dust and its Impact

The transport of Saharan dust across the Atlantic and into the Caribbean has engaged the attention of researchers for some time. The resulting dust clouds are known to transport pollen, microbes, insects, bacteria, fungal spores and various chemicals (Prospero *et al*., 2005; Griffin, 2007; Middleton *et al*., 2008; Monteil, 2008). During major events, dust concentrations can exceed 100 $\mu g\ m^{-3}$ (Prospero, 2006; Griffin, 2007). Various independent studies using different methodologies have all found a strong negative correlation between dust levels in the Caribbean and periods of higher rainfall in the Sahara, while concentrations show a marked increase during periods of drought. Consequently, it is argued that higher dust emissions due to increasing aridity in the Sahel and other arid areas could have enhanced climate effects over large areas, including the Eastern Caribbean and the Mediterranean (Prospero and Lamb, 2003; Santese *et al*., 2009). Similar findings have been reported at Cape Verde where dust emission levels were found to be a factor of nine lower during the decade of the 1950s when rainfall was at or above normal, when compared to the 1980s, a period of intense drought in the Sahel region (Nicoll *et al*., 2011). Emissions from Sahara dust events have also long been known to occur in the Mediterranean (e.g., Santese *et al*., 2009).

There is evidence that the trans-boundary movement of Saharan dust into the island regions of the Caribbean, Pacific and Mediterranean is associated with various human health diseases including asthma admissions in the Caribbean (Monteil, 2008; Monteil and Antoine, 2009; Prospero *et al*., 2008), cardiovascular morbidity in Cyprus in the Mediterranean (Middleton *et al.,* 2008) and is found to be a risk factor in respiratory and obstructive pulmonary disease in the Cape Verde islands (Martins *et al*., 2009). While these findings may not all be fully conclusive, they underscore the need for further research into the link between climate change, airborne aerosols and human health in situ, and in localities far distant from the source of the particulates.

29.5.2. Movement and Impact of Introduced and Invasive Species across Boundaries

Invasive species are colonizer species that establish populations outside their normal distribution ranges and spread into natural or local areas. The spread of invasive alien species is regarded as a significant trans-boundary threat to the health of biodiversity and ecosystems, and has emerged as a major factor in species decline, extinction and loss of biodiversity goods and services worldwide. This is particularly true of islands, where both endemicity and vulnerability to introduced species tend to be high (Kenis *et al*., 2008; Reaser *et al*., 2007; Westphal *et al*., 2008; Rocha *et al*., 2009; Kueffer *et al*., 2010). The extent to which alien invasive species successfully establish themselves at new locations in a changing climate will be dependent on many variables, but non-climate factors such as ease of access to migration pathways, suitability of the destination, ability to compete and adapt to new environments, and susceptibility to invasion of host ecosystems are deemed to be critical. This is borne out for example by Le Roux *et al*., (2008) who studied the effect of the invasive weed *Miconia calvescens* in New Caledonia, Society Islands and Marquesas islands, by Gillespie and Pau (2008) in an analysis of the spread of *Leucaena leucocephala*, *Miconia calvescens*, *Psidium sp*. and *Schinus terebinthifolius* in the Hawaiia islands, and by Christenhusz and Toivonen (2008) whose work shows the potential for rapid spread and establishment of the oriental vessel fern, *Angiopteris evecta*, from the South Pacific throughout the tropics. Mutualism between an invasive ant and locally honeydew-producing insects has been strongly associated with damage to the native and functionally important tree species, *Pisonia grandis* on Cousine island, Seychelles (Gaigher, *et.al*., 2010).

Whilst invasive alien species constitute a major threat to biodiversity in small islands, the removal of such species can result in recovery of that condition. This has been demonstrated in Mauritius where some forested areas were weeded of alien plants and after a decade species richness and abundance of seedlings was higher compared to the adjacent non-weeded native forest. Baider *et al*. (2011) also found that several species that were presumed extinct or critically threatened had recovered dramatically as a result of the removal of the alien invaders. They concluded, given the severity of alien plant invasion in Mauritius, that their example can 'be seen as a relevant model for a whole swath of other island nations and territories around the world particularly in the Pacific and Indian Oceans' (Baider, *et al*., 2011).

The movement of aquatic and terrestrial invasive fauna within and across regions will almost certainly exacerbate the threat posed by climate change in island regions, and could impose significant environmental, economic and social costs. Englund (2008) has documented the negative effects of invasive species on native aquatic insects on Hawai'i and French Polynesia, and their potential role in the extirpation of native aquatic invertebrate in the Pacific. Similarly, there is evidence that on the island of Oahu introduced slugs appear to be 'skewing species abundance in favour of certain non-native and native plants', by altering the 'rank order of seedling survival rates', thereby undermining the ability of preferred species (e.g. the endangered *C. Superba*) to compete effectively (Joe and Daehler., 2008: 11).

29.5.3. Spread of Aquatic Pathogens within Island Regions

The mass mortality of the black sea urchin, *Diademe antillarum*, in the Caribbean Basin during the early 1980s demonstrates the ease with which ecological threats in one part of a region can be disseminated to other jurisdictions thousands of kilometres away. The die-off was first observed in the waters off Panama around January 1983, and within 13 months the disease epidemic had spread rapidly through the Caribbean Sea affecting practically all island reefs, as far away as Tobago some 2000 km to the south and Bermuda, some 4000 km to the east. The diadema population in the wider Caribbean declined between 90-95 per cent as a consequence of this single episode (Lessios, 1988, 1995; Lessios and Robertson, 1984; Rotjan, 2008; Alvarez-Filip *et al.*, 2009; Croquer and Weil, 2009). As *D. antillarum* is one of the principal grazers that removes macroalgae from reefs and thus promotes juvenile coral recruitment, the collateral damage was severe, as the region's corals suffered from high morbidity and mortality for decades thereafter (Carpenter and Edmunds, 2006; Myhre and Acevelo-Grutierrez, 2007; Idjadi *et al.*, 2010). There are other climate-sensitive diseases such as yellow, white and black band, white plague and white pox that travel across national boundaries and infect coral reefs directly. This is variously supported by examples from the Indo-Pacific relating to the role of bacterial infections in white syndrome and yellow band disease (Piskorska *et al.*, 2007; Cervino *et al.*, 2008), the impact of microbial pathogens as stressors on benthic communities in the Mediterranean associated with warming seawater (Ainsworth *et al.*, 2007; Danovaro *et al.*, 2009; Rosenberg *et al.*, 2009), and an increasing evidence of white, yellow and black band disease associated with Caribbean and Atlantic reefs (Rosenberg *et al.*, 2009; Cervino *et al.*, 2008; Brandt and McManus, 2009; Croquer et al, 2009; Miller *et al.*, 2009; Weil and Croquer, 2009; McClanahan *et al*,, 2009; Weil and Rogers, 2011).

29.5.4. Transboundary Movements and Human Health

Island communities should also be concerned about the trans-boundary implications of existing and future human health challenges that are projected to increase in a changing climate. For instance, the aggressive spread of the invasive giant African snail, *Achatina fulica*, throughout the Caribbean, Indo-Pacific islands and Hawaii is not only assessed to be a severe threat to native snails and other fauna (e.g. native gastropods), flora and crop agriculture, but is also identified as a vector for certain human diseases such as meningitis (Reaser *et al.*, 2007; Meyer *et al.*, 2008; Thiengo *et al.*, 2010).

Like other aquatic pathogens ciguatoxins, which cause ciguatera fish poisoning, may be readily dispersed by currents across and within boundaries in tropical and sub-tropical waters. Ciguatoxins are known to be highly temperature-sensitive and may flourish when certain sea water temperature thresholds are reached, as has been noted in the South Pacific (Llewellyn, 2010), Cook Islands (Rongo and van Woesik, 2010), Kiribati (Chan *et al.*, 2011), the Caribbean and Atlantic (Morrison *et al.*, 2008; Otero *et al.*, 2010; Tester *et al.*, 2010) and Mediterranean (Aligizaki and Nikolaidis, 2008). Similar concerns relating to the relationship between outbreaks of ciguatera fish poisoning and El Niño events in the Pacific have previously been raised in IPCC Assessments.

29.6. Adaptation and Management of Risks

29.6.1. Adaptation and Risk

There is now a convergence of views that adaptation and mitigation are not trade-offs, but must be regarded as complementary components of any meaningful global response for managing the risks associated with global climate change. While the statement is true for most countries, it is postulated that in the case of poorer countries and small islands, 'stringent mitigation is necessary to keep risks at manageable levels' (van Vuuren, *et al*., 2010). Similar views have been expressed by other authors, including Fussel (2009) and Nicholls *et al*. (2011).

That small islands tend to be highly prone to natural hazards, including cyclones, tsunamis and earthquakes, is well documented. Mills (2009) argues that projects that simultaneously reduce greenhouse-gas emissions while bolstering disaster resilience would be attractive to insurance companies. The same author opines that insurers will be very wary to avoid being involved in 'green-washing' projects. Mills (2009) also argues that economic conditions affect the perceptions of risks associated with climate change, and suggests, for example, that the recent financial turmoil may have blunted the need for insurers to decisively prepare for climate change.

29.6.2. Experiences of Adaptation in Small Islands

The importance of taking into account local interests and traditional knowledge in adaptation in small islands is emphasized by Kelman and West (2009). The authors argue that placing climate change into appropriate contexts is also important for filling in prominent knowledge gaps among different Small Island developing States (SIDS). To date Pacific and Caribbean SIDS dominate climate change work, indicating a need for more detailed studies on African and Indian Ocean small island states, for example.

29.6.2.1. Valuation of Impacts and Adaptation

Valuation techniques for environmental assets vary and there exists a fairly large body of literature on the subject (Stage, 2010; Markantonis and Bithas, 2009). A widely used technique involves the conducting of surveys that seek to determine how much stakeholders and others are willing to pay or to receive, for the goods or services provided by environmental assets. This approach can also be applied to the loss of biodiversity that can arise from climate change, in order to justify cost outlays on adaptation projects. Kenter *et al*. (2011) show that the value that people in the Solomon Islands place on ecosystem services from tropical forests in some cases amounted to 30 per cent of household income. Following deliberative intervention exercises, key ecosystem services effectively became price less as participants were unwilling to trade them off in the choice experiment scenarios, regardless of financial cost. The use of a group-based participatory approach, instead of a conventional individual survey, helped to overcome many of the practical difficulties associated with valuation in developing countries. Such a methodology raises questions about how valuation can deal with unwillingness to trade-off key ecosystem services, which results in the breakdown of monetary valuation methods. This would seem to suggest that adaptation costs relating to ecosystems services, once clearly understood by stakeholders, could be justified and rationally determined by people directly affected.

29.6.2.2. Building Resilience

Briguglio (2010) proposed a methodological framework for assessing the risk of being harmed by climate change. His main argument is that vulnerability should be considered as an inherent and permanent feature, such as the case of low-lying islands' exposure to sea-level rise. Briguglio argued that resilience (meaning the ability to bounce back or recover) as a result of adaptation, should be associated with policy-induced action so that the risk of a territory being harmed by climate change will be a combination of natural factors (vulnerability) and nurtured factors (adaptation), to such an extent that proper adaptation can lead to resilience which could totally or partially offset the natural disadvantages, whereas mal-adaptation may even exacerbate them. In the case of small islands, this methodological approach could be useful, as islands will permanently remain vulnerable to the adverse effects of climate change, but they may be able to do something about it. This may depend on appropriate international mechanisms for effective greenhouse gas emissions reduction and if adequate support systems for adaptation are implemented in a timely manner.

Resilience building through applying traditional knowledge has been suggested as an adaptation to climate change. As Lefale (2010: 318) notes: 'Recently, there has been growing recognition that for small islands of the Pacific, adaptation to natural climate variability, in particular, weather and climate extremes, not only promises to reduce their vulnerability in the immediate term, but also provides insights and experiences that could provide valuable in enhancing their resilience to long term human induced climate change.' Lefale (2010) examined traditional knowledge of weather and climate in Samoa. Samoans have there own seasonal calendar based on observations of local environmental changes, which are in turn influenced by weather and climate. Their ability and knowledge to forecast the onset of extreme weather and climate events relying predominantly on local environmental changes are tools that should be incorporated in the formulation of human induced climate change adaptation strategies (Lefale, 2010: 317).

29.6.3. Barriers to Adaptation

Ever since publication of the IPCC SAR in 1996, significant barriers to the implementation of various climate change response strategies in island settings have been discussed in considerable detail. The impediments include inadequate access to financial, technology and human resources, issues related to cultural and social acceptability of measures, and constraints imposed by the existing political and legal framework. Owing to their nature and complexity, these constraints will not be easily eliminated in the short term and will require ongoing attention if their impact is to be minimized incrementally over time. While lack of access to adequate financial, technology and human resources is often cited as the most critical constraint, experience has shown that endogenous factors such as culture, ethics, knowledge and attitudes to risk are equally important considerations in making adaptation choices. They can function either as barriers or facilitating factors, depending on the local circumstances. The lack of local support for the development of new infiltration galleries as an efficacious option for augmenting freshwater supply on Tarawa atoll, Kiribati, highlights the importance of social acceptability as a factor in adaptation choices. Although water scarcity is severe, there is much resistance to the use of this simple technology, because it will necessitate encroachment on traditional lands (Moglia *et al*., 2008). Such considerations have led to the conclusion that there is still much to be learned about the drivers of past adaptation and how 'mainstreaming' into national programmes and policies, widely acclaimed to be a virtually indispensable strategy, can practically be achieved (Mercer *et al*., 2007; Adger *et al*., 2009; Mertz *et al*., 2009).

Many islands are also confronted by the reality that small physical size is also proving to be an impediment to accessing some sources of adaptation funds. For example, it is difficult to see how funding and technology resources from projects under the Clean Development Mechanism (CDM) would accrue to small islands in any substantial way, owing to the limited certified emission reduction credits (CERs), and high transaction costs which these initiatives would generate (Winkelman and Moore, 2011). In the circumstances, most small islands are unlikely to be regarded by potential developed country partners as attractive locations for CDM investment opportunities. The continuing lobby among SIDS and LDCs for reform of the CDM and other Kyoto financing mechanisms, as well the various adaptation funds under the United Nations Framework Convention on Climate Change, is a response to the perceived inequality of access to these resources (Bakker *et al*., 2011). Similarly, while some SIDS with substantial forest cover (e.g. Guyana, Belize, Papua New Guinea, Fiji) may be able to access resources through the 'Reducing Emissions from Deforestation and Forest Degradation mechanism (REDD+), very small islands and atolls, including those with a high percentage of forest cover, are unlikely to benefit from the initiative. Although it has been argued by some analysts that the challenges identified above may partially be offset by 'bundling' of many small projects in a single country or region, the logistics of doing so still constitute a significant impediment to accessing resources from these mechanisms.

Notwithstanding the ongoing global debate and the extensive and ever-growing body of literature on the subject, there is still a relatively low level of awareness and understanding at the local, community level on many islands about the nature of the threat posed by climate change (Nunn, 2009). Lack of awareness, knowledge and understanding can function as an effective barrier to the implementation and ultimate success of efficacious adaptation programmes. This is borne out by the earlier referenced example from Tarawa atoll, Kiribati, where there was much resistance to the use of infiltration galleries, as an adaptation measure in the water resources sector (refer to section 29.6.3). Although widely acknowledged to be critical in small island states, few initiatives pay little more than perfunctory attention to the importance of awareness, knowledge and understanding in climate change adaptation planning. Hence, the renewed call for adaptation initiatives to include and focus directly on these elements on an ongoing basis (e.g., Crump, 2008; Kelman and West, 2009; Kelman, 2010; Kuruppu and Liverman, 2011; Gero *et al*., 2011) is timely, if these barriers are to be eventually removed.

29.6.3.1. Observed and Expected Barriers

Empirical observations from Kiribati demonstrate that the manner in which communities 'cognitively perceive' adaptation can prove to be a significant barrier to adaptation in the future (Kuruppu and Liverman, 2010). In a study of adaptation to water stress on the island, it was found that individuals' belief in their own ability to cope with water scarcity, largely based on past experience, appeared to be a key driver in their attitude to and choice of adaptation strategy. The study concluded that in Kiribati the approach to dealing with water stress will be conditioned more by past experience, than by any detailed understanding of climate change impacts. This may lead to over-confidence in their capacity to cope with water scarcity and impede the implementation of more efficacious strategies (Kuruppu and Liverman, 2011).

29.6.3.2. Planned and Autonomous Adaptation

While some traditional adaptation technologies and skills are being lost on many islands, some others have persisted with good effect, as shown by the following examples from the Solomon Islands. Elevated concrete floors have traditionally been used on Ontong Java to keep floors dry during heavy rainfall events, while islanders build 'low, aerodynamic houses and sago palm leaves as roofing material on Tikopia in order to avoid hazards from flying debris such as metal roofs' during the passage of tropical cyclones (Rasmussen *et a*., 2009: 10). Contrastingly, on Bellona, an atoll also in the Solomon Islands archipelago, houses that adopt 'more modern' construction materials and practices '..are easily destroyed in cyclones' (Rasmussen *et al*., 2009: 10).

Analogues can provide some insight into the way highly vulnerable island communities populations may respond in the face of extreme events (Jarvis, 2010; McLeman and Hunter, 2010). One example is the case of internal migration within Papua New Guinea, as a response to inundation during the 2009 king tide season. So severe was the threat that the inhabitants of the Carteret Islands loaded their personal effects into fishing nets and secured them at elevation between palm trees, before seeking refuge on neighbouring Bougainville island (Jarvis, 2010). It should not however be assumed that migration would be a viable option in all such circumstances, as it is unlikely that such movement of people could have been so easily accomplished if the receiving island was not part of the same country. Neither would such internal migration be possible within states with all low-lying islands. While the example cited cannot be described as evidence of climate change adaptation *per se*, it suggests that under some scenarios entire island communities may need to be relocated in the future, whether within the same jurisdiction, or externally. In the latter case, the international community could find itself confronted with other critical issues such as 'the legal and political continuity of a state, even though its territory might vanish' (Cournil and Gemenne, 2010).

In the context of increases in the frequency and severity of extreme events caused by climate change, Rasmussen *et al*. (2009) argue that, in the case of the three Polynesian outliers in the Solomon Islands referenced above (Ontong Java, Bellona and Tikopia), traditional social organization leads to adaptive capacity. But they posit that it is methodologically complex to distinguish between adaptive actions and strategies directly related to climate change on the one hand, and general livelihood strategies, which take into account climatic variability and the risks of extreme weather events on the other, since livelihoods have always been extremely climate and weather dependent. It is also acknowledged that while many practices may be considered as spontaneous adaptation strategies addressing climate and weather, it cannot be concluded with certainty that these are particularly related to climate change, or that similar actions will be effective in the future.

29.6.3.3. Mainstreaming and Integrating Climate Change into Development Plans and Policies

There is a growing body of literature that discusses the benefits and possibilities of mainstreaming or integrating climate change policies in development policies, and various mechanisms through which development agencies as well as donor and recipient countries can seek to capitalize on the opportunities for so doing are beginning to emerge (see for example Klein *et al*., 2007; Mertz *et al*., 2009). This view finds support in the work of Agarwala and van Aalst (2008) who, based on examples from various countries including Fiji, have shown that climate change can affectively be linked to development objectives due to the various synergies and trade-offs involved in integrating adaptation to climate change in development cooperation activities. Yet, Boyd *et al*. (2009) hold the view that 'both the threats and the opportunities that climate change poses for the development agenda are still underappreciated' and further suggest that the 'policy response that is required needs to be better, quicker and more coherent than anything that has been seen so far' (Boyd *et al*., 2009: 659).

However, it is generally agreed that there are differences between policies associated with climate change and those associated with development in general. Swart and Raes (2007) contend that adaptation and mitigation usually operate at different temporal and spatial scales and are mostly relevant for different economic sectors, so that costs and benefits are distributed differently. Although there are synergies and benefits to be derived from the integration of climate change and development policies, Schipper and Pelling (2010) caution that conflicts in policy responses to address these issues separately can give rise to conflict and an intellectual divide, which may be attributed primarily to a lack of institutional overlap and also to differences in language, method and political relevance. Overall however, there appears to be an emerging consensus around the views expressed by Swart and Raes (2007) that climate change and development strategies should be considered as complementary, and that some elements such as land and water management and urban planning provide important adaptation and mitigation opportunities.

29.6.3.4. Overcoming Barriers to Adaptation

Previous IPCC assessments have identified some generic approaches aimed at minimizing the impediments to adaptation, however, these strategies require further elaboration and specificity to be effectively operationalized. In the literature more attention is now being focused on the relevance and application of community-based adaptation (CBA) principles to island communities, as a facilitating factor in adaptation planning and implementation (Warrick, 2009; Kellman *et al*., 2011). Warrick's work in Vanuatu focuses on empowerment, that is 'helping people to help themselves', while addressing local priorities and building on local knowledge and capacity. This approach to adaptation is unequivocally being promoted as an appropriate strategy for small states, since it is something done 'with' rather than 'to' communities" (Warrick, 2009). Dumaru (2010), has also documented the outcomes of a pilot community-based adaptation project implemented on Druadrua Island, north-eastern Fiji: more effective management of local water resources through capacity building, enhanced knowledge of climate change, and the establishment of mechanisms to facilitate greater access to technical and financial resources from outside the community. Similarly, review of an adaptation project in coastal Samoa reveals that 'intensive participatory village consultation' and capacity building which take into account traditional practices, can be vital to the success of adaptation initiatives in island communities (Daly, 2010). Case studies from Fiji and Samoa in which multi-stakeholder and multi-sectoral participatory approaches were used to help enhance resilience of local residents to the adverse impacts of disasters and climate change (Gero *et al*., 2010), further support this view.

As in previous IPCC Assessments, there is continuing strong support for the incorporation of indigenous knowledge into adaptation strategies. In fact, the point is underscored by one analyst, who suggests that the vulnerability of indigenous groups in small islands cannot be effectively tackled unless indigenous and Western knowledge are combined in. 'a culturally compatible and sustainable manner' (Mercer *et al*., 2007: 245). This view converges with that of Gamble *et al*. (2010), who in a study involving sixty farmers in St. Elizabeth Parish, Jamaica, report a high level of agreement between the farmers' perception of increasing drought incidence and statistical analysis of precipitation and vegetation data for the area. In this case the farmers perceptions clearly validated the observational data and vice versa.

29.7. Adaptation and Mitigation Interactions

Greenhouse gas emissions from small islands are negligible in relation to global emissions, yet small islands, along with the 'poorest of the poor' are likely to bear the brunt of climate change impacts (Srinivasan 2010). As small islands' populations have not caused anthropogenic climate change there is little moral imperative for them to reduce greenhouse gas emissions, though most have chosen to do so because of the potential co-benefits and synergies. Malta and Cyprus are obliged to do so in line with EU climate and energy policies. This section considers some of the inter-linkages between adaptation and mitigation on small islands and considers the potential synergies, conflicts, trade-offs and risks. Unfortunately there is relatively little research on the emissions reduction potential of small islands, and far less on the inter-linkages between climate change adaptation and emissions reduction in small islands. Therefore in this section a number of assumptions are made about how and where adaptation and mitigation actions interact.

29.7.1. Assumptions / Uncertainties Associated with Adaptation and Mitigation Responses

Small islands are not homogeneous, they have diverse geo-physical characteristics (e.g. remote, low-lying, mountainous) and economic structures. Following Nunn (2009) we assume that the combination of island geography and economic types informs the extent to which adaptation and mitigation actions might interact. Island geography and location influences sensitivity to hydro-meteorological and related hazards such as cyclones, floods, droughts, invasive alien species, vector borne disease, and landslides (although the capacity of island residents to cope is more informed by income levels, access to capital assets and resources, technology and knowledge). Island economies can be grouped into four broad 'types', i.e. those that depend on: i) remittances from migrant workers overseas; ii) natural resource extraction and export; iii) earnings from services (mostly tourism); and iv) diversified economies with manufacturing – mostly larger economies (UNCTAD, 1997) These economic types appear to inform the potential for greenhouse gas emissions reduction, as not all of these have the key 'mitigation' sectors: that is energy, transport, industry, built environment, agriculture, forestry, or waste management sectors (Metz et al., 2007). For example, aid dependent small island economies, often do not have extensive industrial development, extensive commercial buildings, or large transport sectors. Hence the opportunities for emissions reductions in these cases are very limited. Far more mitigation opportunities are likely to exist in larger island economies that rely on services, natural resource exports, or manufacturing. Table 29-4 presents a speculative assessment of potential areas for mitigation activity on small islands by island economy type.

[INSERT TABLE 29-4 HERE
Table 29-4: Economic structure of small islands and areas of potential emissions reduction.]

For many small islands, small domestic markets and high costs of transporting goods to international markets act as significant barriers to industrial development (Armstrong and Read, 2002) potentially limiting the options for industrial emissions reductions. Limited land area means that forestry and agriculture sectors are often small scale, or subsistence. Energy supply is often delivered through state-supported monopolies, or imported, due to limited economies of scale, and the small domestic market (Read, 2010). In short, the geography and economies of islands limits economic diversity, and by extension, the potential for adaptation and mitigation, however there remains scope for both synergies and conflicts between adaptation and mitigation on islands.

Many authors refer to the high relative costs of the impacts of, and adaptation to, climate change in small islands. Bueno (2008) examines the potential costs to the island nations of the Caribbean if greenhouse gas emissions continue unchecked and found that for just three categories—increased hurricane damages, loss of tourism revenue, and infrastructure damages—the Caribbean's annual cost of inaction is projected to total $22 billion annually by 2050 and $46 billion by 2100. These costs represent 10 per cent and 22 per cent, respectively, of the current Caribbean economy.

29.7.2. Potential Synergies and Conflicts

Metz *et al*. (2007) suggest that adaptation and mitigation interactions occur in one of four main ways: adaptations that reduce greenhouse emissions, mitigation that supports ability to adapt, policy decisions that affect adaptation and mitigation, and trade-offs and synergies between adaptation and mitigation. Each of these elements is now considered, for key areas of adaptation-mitigation inter-linkages, i.e. coastal forestry, energy supply, and tourism.

29.7.2.1. Coastal Forestry

Small islands have relatively large coastal zones (in comparison to land area), therefore coastal adaptation is of critical importance in small islands. Coastal ecosystems (coral reefs, sea grasses and mangroves) can play an important role in protecting coastal communities from wave erosion, tropical cyclones and storm surges, although notably not necessarily against tsunami (Cochard *et al*., 2008).Where mangrove 'bioshields' are created from exotic species, there can be a damaging impact on the native ecosystem (Feagin *et al*., 2010). Although in general healthy coastal ecosystems are seen as a positive contributor to reducing disaster risk from coastal hazards. Debates about the relative importance of developing country forests as carbon sinks are well developed (van der Werf *et al*., 2009). In the coastal zone, research has started to consider how much organic Carbon is stored in tropical wetland forests, initial estimates suggest that tropical wetlands may be among the largest terrestrial stores of Carbon (Donato *et al*., 2011). There are many reasons to conserve mangroves for developmental and adaptation benefits, however, it now seems that there may be additional mitigation co-benefits. Despite this knowledge researchers have found that current climate extremes, landslides, and agricultural pressures have made the expansion of forest carbon stocks more challenging (Fox *et al*., 2010). Gilman *et al*. (2008) reassert this, noting that many human activities within tropical wetlands can reduce the buffering capacity of mangrove systems.

29.7.2.2. Energy Supply

There is some work that considers the potential for renewable energy supplies in islands, although there are few empirical examples. Stuart (2006) speculates that the lack of uptake of renewable technologies to date might be due to historical commitments to conventional fossil fuel based infrastructure, and a lack of resources to spend on costly research and development. Those islands that have introduced renewable energy technologies have often done so with support from international development assistance (Dornan, 2011). Despite highly subsidized (or sometimes free) provision, there remain significant barriers to the wider institutionalization of renewable technologies in small islands. Research in Europe and the United States has shown the mitigation and cost savings benefits of Energy Service Companies (ESCOs). ESCOs are companies that enter into medium-to-long term performance-based contracts with energy users, invest in energy efficiency measures in buildings and firms, and profit from the ensuing energy savings measures for the premises, see for example (Steinberger *et al.,* 2009). Potential benefits exist in creating the opportunity for ESCOs to operate in small islands. Preliminary evidence from Fiji suggests that if the incentive mechanisms can be resolved, and information asymmetries between service providers and users can be aligned, ESCOs could provide an opportunity to expand renewable technologies (Dornan, 2009).

The transition towards renewable energy sources (such as the shift to hydro-power in Fiji), away from fossil fuel dependence has been partly driven by economic reasons, notably to avoid oil price volatility and its impact (Dornan, 2009). The cost effectiveness of renewable technologies is critical. Yet studies investigating the potential for expansion of renewable energy technology in small islands have shown mixed findings. Cost-benefit analyses have shown that in southeast Mediterranean islands photovoltaic generation and storage systems may be more cost-effective than existing thermal power stations (Kaldellis, 2008; Kaldellis *et al*., 2009). Studies on tourist islands in the Maldives showed that solar power could produce about only 10 per cent of energy demand (van Alphen et al., 2007), or 44.7 per cent (Georgei *et al.,* 2010). With such a disparity in these estimates it is difficult to accurately assess the cost-effectiveness of such technologies.

29.7.2.3.Tourism

Many small islands rely heavily on the foreign exchange that the tourism sector brings in. Yet globally the tourism sector contributes around 5 per cent of total greenhouse gas emissions (UNWTO *et al*., 2008). When ecosystem services, on which the tourism sector relies (e.g. sewage treatment by coastal ecosystems, or greenhouse gas emissions from electricity production), are costed, there are clear reasons to reduce the burden on ecosystems and to engage in more sustainable tourism planning (Thomas-Hope and Jardine-Comrie, 2007). In Jamaica, Thomas-Hope and Jardine-Comrie suggest that sustainable tourism planning should include activities undertaken by the industry, that is tertiary treatment of waste, and re-use of water, as well as composting organic material and investing in renewable energy. In contrast, Gossling and Schumacher (2010) suggest that tourists themselves could play a role in becoming carbon neutral, through voluntary offsetting. In their analysis of tourism in the Seychelles they recommend first undertaking a detailed assessment of emissions, and following this with a review of the options for becoming carbon neutral.

29.7.3. Facilitating Adaptation and Avoiding Maladaptation

Adaptation is locally delivered, context specific and generates private benefits (Tompkins *et al*., 2010) whereas mitigation actions deliver global public goods. The interactions between adaptation and mitigation are therefore multi-scale and multi-dimensional, and the extraction of co-benefits from adaptation and mitigation action must be grounded in this reality. The challenge for small islands is to evaluate the benefits of aligning sectors for potential emissions reductions, with adaptation needs, and other co-benefits.

In the case of the energy sector, and transition to renewable energy – one of the key challenges is in the area of energy storage. To avoid mal-adaptation, advanced energy planning is needed to consider the range of energy supply and storage issues (Martins *et al*., 2009

Sectoral studies include a variety of new paradigms. In the area of conservation, instead of traditional conservation approaches, under climate change, Hansen et al. (2010) suggest: using protected areas to protect climate refugia, reducing non-climate stressors on ecosystems, adopting adaptive management approaches and reducing greenhouse gas emissions wherever possible. In the area of energy supply, potential benefits may be found in creating the opportunity for ESCOs to operate in small islands (Kaldellis *et al*., 2009). Within the tourism sector, particularly multi-national hotel chains, long term performance contracts could be offered where the risks of energy savings could be spread across many premises. Alternatively large energy supply monopolies offer significant scope for emissions reductions through similar initiatives. A further option may be to reduce the energy use by tourists by focusing on increasing tourism yields, as in Norfolk Island, rather than total numbers (Lenzen, 2008).

Moreno and Becken (2009) in their study on the Manamuca islands (Fiji) argue that a methodology that explicitly integrates stakeholders into the process through each step in vulnerability assessments, will facilitate such assessments in a range of coastal destinations, allow comparison to be made of vulnerabilities across different situations, provide a basis for more research into specific adaptation measures and assist destinations to put in place appropriate adaptation measures. The reason for this is that adaptation measures are often subjective in nature and the stakeholder involvement will reflect the priorities and expectations that these stakeholders attach to the sector being protected.

Caution is needed to ensure that donors are not driving the adaptation and mitigation agenda in small islands, as there is a risk that donor-driven adaptation or mitigation will not address the salient challenges on small islands, and may lead to inadequate adaptation or a waste of scarce resources (Barnett, 2010; Nunn, 2009). Even in low-lying atoll states, such as Kiribati, where the threats of climate change are very real, other environmental challenges, notably pollution, sewerage and solid waste management should not be sidelined. Indeed all of these stressors need to be considered when developing adaptation and mitigation strategies (Storey and Hunter, 2010).

29.8. Research and Data Gaps

It should be evident from the foregoing assessment that significant advances in our understanding of the effects of climate change on small islands have been made since the AR4. These advances cover a range of themes including: dynamic downscaling of scenarios appropriate for small islands; impacts of trans-boundary processes generated well beyond the borders of an individual nation or island; barriers to adaptation in small islands and how they may be overcome; the relationships between climate change adaptation and disaster risk reduction; and, the relationships between climate change adaptation and sustainable development.

It is also evident that there are some important information gaps and uncertainties that still exist. These include:

- Lack of climate change and socio-economic scenarios and data at the required scale. For example, projected changes in climate for the Caribbean, Pacific, Indian Ocean and Mediterranean islands, generally apply to the regions as a whole and not specific countries. However, most socio-economic decisions are taken at smaller scales and as a result a few regional and local studies have been undertaken that are based on downscaled climate or socio-economic data. There is need for further credible simulations of future small island climates and socio-economic conditions.
- Uncertainty about the potential impacts of climate change. In several small islands adaptation is being progressed without adequate understanding of impacts or vulnerability. Whilst assessment of impacts is hampered because of uncertainty in climate projections at the local island level, alternative scenarios could be used for impact and sensitivity studies.
- Need for a range of climate change-related projections beyond temperature and sea-level. Generally climate-model projections of temperature and sea-level have been satisfactory, but there are strong requirements for projections for other variables that are of critical importance to small islands. These include rainfall and drought, wind direction and strength, tropical storms and wave climate, and recognition that trans-boundary processes are also significant in a small island context.
- Need to acknowledge the heterogeneity and complexity of small island states and territories. Although small islands have several characteristics in common, neither the heterogeneity or complexity of small islands is sufficiently appreciated. Thus, transferring data and practices from a continental situation, or from one small island state to another, needs to be done with caution.
- A typology that classifies small island states into a few groupings based on social, cultural, physical, ecological, etc., characteristics of relevance to climate change impacts and vulnerability is an elusive, though required task. Similarly for adaptation and adaptive capacity, recognizing that some small island states are single islands and others highly fragmented multiple islands.
- Within country/territory differences need to be understood. Many of the environmental and human impacts we have reported have been attributed to the whole country, when in fact they refer only to the major centre or town or region. There is need for more work on rural areas, outer islands and secondary communities and not just in the urban areas where it has hitherto been concentrated.

The foregoing list is a sample of the gaps, needs and research agenda appropriate for small island states. If those gaps are filled, needs satisfied and research achieved, we feel that the general view that small islands are highly vulnerable to climate change, and, that they have low adaptive capacity, may well be challenged by some nations as well as in some sectors and/or regions within small island states.

References

Adger, W., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. Nelson, L. Naess, J. Wolf, and A. Wreford, 2009: Are there social limits to adaptation to climate change? *Climatic Change,* **93(3)**, 335-354.

Agrawala, S. and M. van Aalst, 2008: Adapting development cooperation to adapt to climate change. *Climate Policy,* **8(2)**, 183-193.

Ainsworth, T.D., M. Fine, G. Roff, and O. Hoegh-Guldberg, 2007: Bacteria are not the primary cause of bleaching in the Mediterranean coral *oculina patagonica*. *ISME J,* **2(1)**, 67-73.

Akesson, L., 2008: The resilience of the Cape Verdean migration tradition. In: *Transnational archipelago. perspectives on cape verdean migration and the diaspora*. [Batalha, L.C.,J. (ed.)]. Amsterdam University Press, Amsterdam, pp. 269-293.
Alcamo, J., J. Moreno, B. Novsky, M.Bindi, R. Corobov, R. Devoy, M.L. Parry, O.F. Canziani, J. Palutikof, P. van der Linden, and C. Hanson, 2007: Europe. In: *Climate change 2007: Impacts, adaptation and vulnerability. contributions of working group II to the fourth assessment report to the intergovernmental panel on climate change*. Cambridge University Press, Cambridge, pp. 541-580.
Aligizaki, K. and G. Nikolaidis, 2008: Morphological identification of two tropical dinoflagellates of the genera *Gambierdiscus* and *Sinophysis* in the Mediterranean Sea. *Journal of Biological Research-Thessaloniki,* **9**, 75-82.
Alling, A., O.A. Doherty, H. Logan, L. Feldman, and P. Dustan, 2007: Catastrophic coral mortality in the remote central Pacific Ocean: Kiribati Phoenix islands. *Atoll Research Bulletin,* **(551)**, 1-21.
Alvarez-Filip, L., N.K. Dulvy, J.A. Gill, I.M. Cote, and A.R. Watkinson, 2009: Flattening of Caribbean coral reefs: Region-wide declines in architectural complexity. *Proceedings of the Royal Society B-Biological Sciences,* **276(1669)**, 3019-3025.
Aminzadeh, S.C., 2007: A moral imperative: The human rights of climate change. *Hastings International Comparative Law Review,* **30(2)**, 231-265.
Anthoff, D., R. Nicholls, and R. Tol, 2010: The economic impact of substantial sea-level rise. *Mitigation and Adaptation Strategies for Global Change,* **15(4)**, 321-335.
Anthony, K.R.N., D.I. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg, 2008: Ocean acidification causes bleaching and productivity loss in coral reef builders. *Proceedings of the National Academy of Sciences of the United States of America,* **105(45)**, 17442-17446.
Armstrong, H.W. and R. Read, 2002: The phantom of liberty?: Economic growth and the vulnerability of small states. *Journal of International Development,* **14(4)**, 435-458.
Baider, C. and F.B.V. Florens, 2011: Control of invasive alien weeds averts imminent plant extinction. *Biological Invasions,* 1-6.
Baker, J.D., C.L. Littnan, and D.W. Johnston, 2006: Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the northwestern Hawaiian Islands. *Endangered Species Research,* **4**, 1-10.
Bakker, S., C. Haug, H. Van Asselt, J. Gupta, and R. Saïdi, 2011: The future of the CDM: Same same, but differentiated? *Climate Policy,* **11(1)**, 752-767.
Barnett, J. and J. Campbell, 2010: *Climate change and small islands states: Power, knowledge and the south pacific*. Earthscan, London and Washington D.C., pp. 218.
Bastos, C., 2008: Migrants, settlers and colonists: The biopolitics of displaced bodies. *International Migration,* **46(5)**, 27-54.
Beaumont, L.J., A. Pitman, S. Perkins, N.E. Zimmermann, N.G. Yoccoz, and W. Thuiller, 2011: Impacts of climate change on the world's most exceptional ecoregions. *Proceedings of the National Academy of Sciences,* **108(6)**, 2306-2311.
Bienfang, P.K., S.V. DeFelice, E.A. Laws, L.E. Brand, R.R. Bidigare, S. Christensen, H. Trapido-Rosenthal, T.K. Hemscheidt, D.J. McGillicuddy, D.M. Anderson, H.M. Solo-Gabriele, A.B. Boehm, and L.C. Backer, 2011: Prominent human health impacts from several marine microbes: History, ecology, and public health implications. *International Journal of Microbiology,* **2011**, 1-15.
Bijlsma, L., C.N. Ehler, R.J.T. Klein, S.M. Kulshrestha, R.F. McLean, N. Mimura, R.J. Nicholls, L.A. Nurse, H. Perez Nieto, E.Z. Stakhiv, R.K. Turner, and R.A. Warrick, 1996: Coastal zones and small islands. In: *Climate change 1995: Impacts,adaptations and mitigation of climate change: Scientific - technical analyses. contribution of working group II to the second assessment report of the intergovernmental panel on climate change*. [Watson, R.T., M.C. Zinyowera, and R.H. Moss(eds.)]. Cambridge University Press, Cambridge, UK and New York, USA, pp. 289-324.
Boyd, E., N. Grist, S. Juhola, and V. Nelson, 2009: Exploring development futures in a changing climate: Frontiers for development policy and practice. *Development Policy Review,* **27(6)**, 659-674.
Brandt, M.E. and J.W. McManus, 2009: Disease incidence is related to bleaching extent in reef-building corals. *Ecology,* **90(10)**, 2859-2867.
Briguglio, L.P., 2010: Defining and assessing the risk of being harmed by climate change. *International Journal of Climate Change Strategies and Management,* **2(1)**, 23-34.

Bueno, R., C. Herzfeld, E. Stanton, and F. Ackerman, 2008: The Caribbean and Climate Change: The Costs of Inaction, Stockholm Environment Institute and US Center of Global Development and Environment Institute, Tufts University, 37 pp.
Bush, D.M., W.J. Neal, and C.W. Jackson, 2009: Summary of Puerto Rico's vulnerability to coastal hazards: Risk, mitigation, and management with examples. *Geological Society of America Special Papers,* **460**, 149-165.
Byravan, S. and S.C. Rajan, 2006: Providing new homes for climate change exiles. *Climate Policy,* **6(2)**, 247-252.
Cambers, G., 2009: Caribbean beach changes and climate change adaptation. *Aquatic Ecosystem Health and Management,* **12(2)**, 168-176.
Carilli, J.E., R.D. Norris, B. Black, S.M. Walsh, and M. McField, 2010: Century-scale records of coral growth rates indicate that local stressors reduce coral thermal tolerance threshold. *Global Change Biology,* **16(4)**, 1247-1257.
Carpenter, R.C. and P.J. Edmunds, 2006: Local and regional scale recovery of Diadema promotes recruitment of scleractinian corals. *Ecology Letters,* **9(3)**, 268-277.
Cashman, A., L. Nurse, and J. Charlery, 2010: Climate change in the Caribbean:The water management implications. *Journal of Environment and Development,* **19(1)**, 42-67.
Caujape-Castella, J., A. Tye, D.j. Crawford, A. Santos-Guerra, A. Sakai, K. Beaver, W. Lobin, F.B.W. Florens, M. Moura, R. Jardim, I. Gomes, and C. Kueffer, 2010: Conservation of oceanic floras: Present and future global challenges. *Perspectives in Plant Ecology, Evolution and Systematics,* **12(2)**, 107-129.
Cervino, J.M., F.L. Thompson, B. Gomez-Gil, E.A. Lorence, T.J. Goreau, R.L. Hayes, K.B. Winiarski-Cervino, G.W. Smith, K. Hughen, and E. Bartels, 2008: The vibrio core group induces yellow band disease in Caribbean and Indo-Pacific reef-building corals. *Journal of Applied Microbiology,* **105(5)**, 1658-1671.
Chaloupka, M., N. Kamezaki, and C. Limpus, 2008: Is climate change affecting the population dynamics of the endangered pacific loggerhead sea turtle? *Journal of Experimental Marine Biology and Ecology,* **356(1-2)**, 136-143.
Chan, W.H., Y.L. Mak, J.J. Wu, L. Jin, W.H. Sit, J.C.W. Lam, Y. Sadovy de Mitcheson, L.L. Chan, P.K.S. Lam, and M.B. Murphy, 2011: Spatial distribution of ciguateric fish in the Republic of Kiribati. *Chemosphere,* **84(1)**, 117-123.
Christenhusz, M.J.M. and T.K. Toivonen, 2008: Giants invading the tropics: The oriental vessel fern, Angiopteris evecta (marattiaceae). *Biological Invasions,* **10(8)**, 1215-1228.
Cochard, R., S.L. Ranamukhaarachchi, G.P. Shivakoti, O.V. Shipin, P.J. Edwards, and K.T. Seeland, 2008: The 2004 tsunami in Aceh and southern Thailand: A review on coastal ecosystems, wave hazards and vulnerability. *Perspectives in Plant Ecology Evolution and Systematics,* **10(1)**, 3-40.
Connolly, R.M., 2009: Seagrass. In: *A marine climate change impacts and adaptation report card for Australia 2009* [Poloczanska, E.S., A.J. Hobday, and A.J. Richardson(eds.)]. NCCARF Publication 05/09, ISBN 978-1-921609-03-9.
Cournil, C. and F. Gemenne, 2010: Les populations insulaires face aux changements climatique: Des migrations a anticiper. *Vertigo,* **10(3)**, doi : 10.4000/vertigo.10482.
Croquer, A. and E. Weil, 2009: Spatial variability in distribution and prevalence of Caribbean scleractinian coral and octocoral diseases. II. genera-level analysis. *Diseases of Aquatic Organisms,* **83(3)**, 209-222.
Daly, M., N. Poutasi, F. Nelson, and J. Kohlhase, 2010: Reducing the climate vulnerability of coastal communities in Samoa. *Journal of International Development,* **22(2)**, 265-281.
Danovaro, R., S.F. Umani, and A. Pusceddu, 2009: Climate change and the potential spreading of marine mucilage and microbial pathogens in the Mediterranean Sea. *Plos One,* **4(9)**, e7006.
Dawson, J.L. and S.G. Smithers, 2010: Shoreline and beach volume change between 1967 and 2007 at Raine Island, Great Rarrier Reef, Australia. *Global and Planetary Change,* **72(3)**, 141-154.
De'ath, G., J.M. Lough, and K.C. Fabricius, 2009: Declining coral calcification on the Great Barrier Reef. *Science,* **323(5910)**, 116-119.
Defeo, O., A. McLachlan, D.S. Schoeman, T.A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini, 2009: Threats to sandy beach ecosystems: A review. *Estuarine Coastal and Shelf Science,* **81(1)**, 1-12.
Department of Meteorology (Maldives), 2007: The Unusually Strong Tidal Waves Hit Maldives, 15-18 May, 12 pp.
Diaz-Almela, E., N. Marba, and C.M. Duarte, 2007: Consequences of Mediterranean warming events in seagrass (Posidonia oceanica) flowering records. *Global Change Biology,* **13(1)**, 224-235.
Donn, W.L. and W.T. McGuinness, 1959: Barbados storm swell. *Journal of Geophysical Research,* **64(12)**, 2341-2349.

Dornan, M., 2009: Methods for assessing the contribution of renewable technologies to energy security: The electricity sector of Fiji. *Pacific Economic Bulletin,* **24(3)**, 71-91.
Dornan, M., 2011: Solar-based rural electrification policy design: The renewable energy service company (RESCO) model in Fiji. *Renewable Energy,* **36(2)**, 797-803.
Duarte, C., W. Dennison, R. Orth, and T. Carruthers, 2008: The charisma of coastal ecosystems: Addressing the imbalance. *Estuaries and Coasts,* **31(2)**, 233-238.
Dumaru, P., 2010: Community-based adaptation: Enhancing community adaptive capacity in Druadrua Island, Fiji. *Climate Change,* **1(5)**, 751-763.
Ebi, K.L., N.D. Lewis, and C. Corvalan, 2006: Climate variability and change and their potential health effects in small island states: Information for adaptation planning in the health sector. *Environmental Health Perspectives,* **114(12)**, 1957-1963.
Ellison, J.C., 2009: Wetlands of the Pacific island region. *Wetlands Ecology and Management,* **17(3)**, 169-206.
Englund, R.A., 2008: Invasive species threats to native aquatic insect biodiversity and conservation measures in Hawai'i and French Polynesia. *Journal of Insect Conservation,* **12(3-4)**, 415-428.
Farbotko, C., 201: Wishfull sinking: Disappearing islands, climate refugees and cosmopolitan experimentation. *Asia Pacific Viewpoint,* **51**, 47-60.
Feagin, R.A., N. Mukherjee, K. Shanker, A.H. Baird, J. Cinner, A.M. Kerr, N. Koedam, A. Sridhar, R. Arthur, L.P. Jayatissa, D. Lo Seen, M. Menon, S. Rodriguez, M. Shamsuddoha, and F. Dahdouh-Guebas, 2010: Shelter from the storm? use and misuse of coastal vegetation bioshields for managing natural disasters. *Conservation Letters,* **3(1)**, 1-11.
Fish, M.R., I.M. Cote, J.A. Horrocks, B. Mulligan, A.R. Watkinson, and A.P. Jones, 2008: Construction setback regulations and sea-level rise: Mitigating sea turtle nesting beach loss. *Ocean & Coastal Management,* **51(4)**, 330-341.
Fletcher, C.H., C. Bochicchio, C. Conger, M. Engels, F. Feirstein, N. Frazer, C. Glenn, R.W. Grigg, E.E. Grossman, and J.N. Harvey, 2008: Geology of Hawaii reefs. In: *Coral Reefs of the USA* [Riegl, B. and R.E. Dodge (eds.)]. Springer, pp. 435-487.
Fox, J.C., C.K. Yosi, P. Nimiago, F. Oavika, J.N. Pokana, K. Lavong, and R.J. Keenan, 2010: Assessment of above ground carbon in primary and selectively harvested tropical forest in Papua New Guinea. *Biotropica,* **42(4)**, 410-419.
Fuentes, M., J.A. Maynard, M. Guinea, I.P. Bell, P.J. Werdell, and M. Hamann, 2009: Proxy indicators of sand temperature help project impacts of global warming on sea turtles in northern Australia. *Endangered Species Research,* **9(1)**, 33-40.
Füssel, H., 2009: An updated assessment of the risks from climate change based on research published since the IPCC fourth assessment report. *Climatic Change,* **97**, 469-482.
Gaigher, R., M. Samways, J. Henwood, and K. Jolliffe, 2011: Impact of a mutualism between an invasive ant and honeydew-producing insects on a functionally important tree on a tropical island. *Biological Invasions,* , 1-5.
Gamble, D.W., D. Campbell, T.L. Allen, D. Barker, S. Curtis, D. McGregor, and J. Popke, 2010: Climate change, drought, and Jamaican agriculture: Local knowledge and the climate record. *Annals of the Association of American Geographers,* **100(4)**, 880-893.
Garrabou, J., R. Coma, N. Bensoussan, M. Bally, P. Chevaldonne, M. Cigliano, D. Diaz, J.G. Harmelin, M.C. Gambi, D.K. Kersting, J.B. Ledoux, C. Lejeusne, C. Linares, C. Marschal, T. Perez, M. Ribes, J.C. Romano, E. Serrano, N. Teixido, O. Torrents, M. Zabala, F. Zuberer, and C. Cerrano, 2009: Mass mortality in northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. *Global Change Biology,* **15(5)**, 1090-1103.
Georgei, M., J. Krueger, and B. Henning, 2010: Concentrating solar power in sustainable tourism. In: *Management of natural resources, sustainable development and ecological hazards*. [Brebbia, C.A., N. Jovanovic, and E. Tiezzi(eds.)]. pp. 283-294.
Gero, A., K. Méheux, and D. Dominey-Howes, 2011: Integrating community based disaster risk reduction and climate change adaptation: Examples from the Pacific. *Natural Hazards and Earth System Sciences,* **11(1)**, 101-113.
Giambelluca, T.W., H.F. Diaz, and M.S.A. Luke, 2008: Secular temperature change in Hawaii. *Geophysical Research Letters,* **35**, L12792 doi.10.1029/2008GLO34377.
Gilman, E.L., J. Ellison, N.C. Duke, and C. Field, 2008: Threats to mangroves from climate change and adaptation options: A review. *Aquatic Botany,* **89(2)**, 237-250.

Gledhill, D.K., R. Wanninkhof, F.J. Millero, and M. Eakin, 2008: Ocean acidification of the greater Caribbean region. *Journal of Geophysical Research, Oceans,* **113** (C10031, doi:10.1029/2007JC004629).
Gossling, S. and K.P. Schumacher, 2010: Implementing carbon neutral destination policies: Issues from the Seychelles. *Journal of Sustainable Tourism,* **18(3)**, 377-391.
Gössling, S., M. Bredberg, A. Randow, E. Sandström, and P. Svensson, 2006: Tourist perceptions of climate change: A study of international tourists in Zanzibar. *Current Issues in Tourism,* **9(4)**, 419-435.
Griffin, D.W., 2007: Atmospheric movement of microorganisms in clouds of desert dust and implications for human health. *Clinical Microbiology Reviews,* **20(3)**, 459-477.
Gulev, S.K. and V. Grigorieva, 2006: Variability of the winter wind waves and swell in the North Atlantic and North Pacific as revealed by the voluntary observing ship data. *Journal of Climate,* **19(21)**, 5667-5685.
Hansen, L., J. Hoffman, C. Drews, and E. Mielbrecht, 2010: Designing climate-smart conservation: Guidance and case studies. *Conservation Biology,* **24(1)**, 63-69.
Harangoza, S.A., 1992: Flooding in the maldives and its implications for the global sea level rise debate. In: *Sea level changes: Determination and effects*. [Woodworth, P.L., D.T. Pugh, J.G. DeRonde, R.G. Warrick, and J. Hannah(eds.)]. International Union of Geodesy and Geophysics and the American Geophysical Union, pp. 95-99.
Harris, A., G. Manahira, A. Sheppard, C. Gough, and C. Sheppard, 2009: Demise of Madagascar's once great barrier reef-change in coral reef condition over 40 years. *Atoll Research Bulletin,* **(574)**.
Hawkes, L.A., A.C. Broderick, M.H. Godfrey, and B.J. Godley, 2007: Investigating the potential impacts of climate change on a marine turtle population. *Global Change Biology,* **13(5)**, 923-932.
Hays, G.C., 2008: Sea turtles: A review of some key recent discoveries and remaining questions. *Journal of Experimental Marine Biology and Ecology,* **356(1-2)**, 1-7.
Houghton, J.D.R., A.E. Myers, C. Lloyd, R.S. King, C. Isaacs, and G.C. Hays, 2007: Protracted rainfall decreases temperature within leatherback turtle (*dermochelys coriacea*) clutches in Grenada, West Indies: Ecological implications for a species displaying temperature dependent sex determination. *Journal of Experimental Marine Biology and Ecology,* **345(1)**, 71-77.
Idjadi, J.A., R.N. Haring, and W.F. Precht, 2010: Recovery of the sea urchin Diadema antillarum promotes scleractinian coral growth and survivorship on shallow Jamaican reefs. *Marine Ecology-Progress Series,* **403**, 91-100.
Imbert, D. and J. Portecop, 2008: Hurricane disturbance and forest resilience: Assessing structural vs. functional changes in a Caribbean dry forest. *Forest Ecology and Management,* **255(8-9)**, 3494-3501.
IPCC, 2007: *Climate change 2007: Impacts, adaptation and vulnerability. contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge, U.K., pp. 976.
Jarvis, R., 2010: Sinking nations and climate change adaptation strategies. *Seattle Journal of Social Justice,* **9(1)**, 447-486.
Joe, S.M. and C.C. Daehler, 2008: Invasive slugs as under-appreciated obstacles to rare plant restoration: Evidence from the Hawaiian islands. *Biological Invasions,* **10(2)**, 245-255.
Kaldellis, J.K., 2008: Integrated electrification solution for autonomous electrical networks on the basis of RES and energy storage configurations. *Energy Conversion and Management,* **49(12)**, 3708-3720.
Kaldellis, J.K., D. Zafirakis, E.L. Kaldelli, and K. Kavadias, 2009: Cost benefit analysis of a photovoltaic-energy storage electrification solution for remote islands. *Renewable Energy,* **34(5)**, 1299-1311.
Kelman, I., J. Lewis, J.C. Gaillard, and J. Mercer, 2011: Participatory action research for dealing with disasters on islands. *Island Studies Journal,* **6(1)**, 59-86.
Kelman, I. and J. West, 2009: Climate change and small island developing states: A critical review. *Ecological and Environmental Anthropology,* **5(1)**, 1-16.
Kelman, I., 2010: Introduction to climate, disasters and international development. *Journal of International Development,* **22(2)**, 208-217.
Kench, P.S. and R.W. Brander, 2006: Response of reef island shorelines to seasonal climate conditions: South Maalhosmadulu atoll, Maldives. *Journal of Geophysical Research,* **111** (doi:10.1029/2005JF000323).
Kench, P.S., R.W. Brander, K.P. Parnell, and J.M. O'Callaghan, 2009: Seasonal variations in wave characteristics around a coral reef island, South Maalhosmadulu atoll, Maldives. *Marine Geology,* **262(1-4)**, 116-129.
Kench, P.S., R.F. McLean, and S. Nichol, 2005: New model of reef-island evolution: Maldives, Indian Ocean. *Geology,* **33(2)**, 47-60.

Kench, P.S., S. Nichol, S. Smithers, R.F. McLean, and R. Brander, 2008: Tsunami as agents of geomorphic change in mid-ocean reef islands. *Geomorphology,* **95**, 361-383.

Kenis, M., M.A. Auger-Rozenberg, A. Roques, L. Timms, C. Pere, M. Cock, J. Settele, S. Augustin, and C. Lopez-Vaamonde, 2009: Ecological effects of invasive alien insects. *Biological Invasions,* **11(1)**, 21-45.

Kenter, J.O., T. Hyde, M. Christie, and I. Fazey, 2011: The importance of deliberation in valuing ecosystem services in developing countries--evidence from the Solomon Islands. *Global Environmental Change,* **21(2)**, 505-521.

Klein, R., S. Ericksen, L. Ness, A. Hammill, T. Tanner, C. Robledo, and K. O'Brien, 2007: Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. *Climatic Change,* **84(1)**, 23-44.

Kueffer, C., C.C. Daehler, C.W. Torres-Santana, C. Lavergne, J.Y. Meyer, R. Otto, and L. Silva, 2010: A global comparison of plant invasions on oceanic islands. *Perspectives in Plant Ecology Evolution and Systematics,* **12(2)**, 145-161.

Kuruppu, N. and D. Liverman, 2011: Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change,* **21(2)**, 657-669.

Le Roux, J.J., A.M. Wieczorek, and J.Y. Meyer, 2008: Genetic diversity and structure of the invasive tree Miconia calvescens in Pacific islands. *Diversity and Distributions,* **14(6)**, 935-948.

Lefale, P., 2010: *Ua afa le aso* stormy weather today: Traditional ecological knowledge of weather and climate. the Samoa experience. *Climatic Change,* **100(2)**, 317-335.

Legra, L., X. Li, and A.T. Peterson, 2008: Biodiversity consequences of sea level rise in New Guinea . *Pacific Conservation Biology,* **14**, 191-199.

Lenzen, M., 2008: Sustainable island businesses: A case study of Norfolk Island. *Journal of Cleaner Production,* **16(18)**, 2018-2035.

Lessios, H.A., 1988: Mass mortality of Diadema antillarum in the Caribbean: What have we learned? *Annual Review of Ecology and Systematics,* **19(1)**, 371-393.

Lessios, H.A., 1995: Diadema antillarum 10 years after mass mortality: Still rare, despite help from a competitor. *Proceedings of the Royal Society of London. Series B: Biological Sciences,* **259(1356)**, 331-337.

Lessios, H.A., D.R. Robertson, and J.D. Cubit, 1984: Spread of Diadema mass mortality through the Caribbean. *Science,* **226(4672)**, 335-337.

Llewellyn, L.E., 2010: Revisiting the association between sea surface temperature and the epidemiology of fish poisoning in the South Pacific: Reassessing the link between ciguatera and climate change. *Toxicon,* **56(5)**, 691-697.

Lo-Yat, A., S.D. Simpson, M. Meekan, D. Lecchini, E. Martinez, and R. Galzin, 2011: Extreme climatic events reduce ocean productivity and larval supply in a tropical reef ecosystem. *Global Change Biology,* **17(4)**, 1695-1702.

Marba, N. and C.M. Duarte, 2010: Mediterranean warming triggers seagrass (*Posidonia oceanica*) shoot mortality. *Global Change Biology,* **16(8)**, 2366-2375.

Markantonis, V. and K. Bithas, 2010: The application of the contingent valuation method in estimating the climate change mitigation and adaptation policies in Greece. an expert-based approach. *Environment, Development and Sustainability,* 12(5), 807-824.

Martins, P., J. Rosado-Pinto, M. Do Céu Teixeira, N. Neuparth, O. Silva, H. Tavares, J.L. Spencer, D. Mascarenhas, A.L. Papoila, N. Khaltaev, and I. Annesi-Maesano, 2009: Under-report and under-diagnosis of chronic respiratory diseases in an African country. *Allergy,* **64(7)**, 1061-1067.

Martins, R., G. Krajacic, L. Alves, N. Duic, T. Azevedo, and M.D. Carvalho, 2009: Energy storage in islands - modelling Porto Santo's hydrogen system. In: [Klemes, J. (ed.)]. Proceedings of 12th international conference on process integration, modelling and optimisation for energy saving and pollution reduction, Rome, Italy, pp. 367-372.

Mataki, M., K. Koshy, and V. Nair, 2006: Implementing Climate Change Adaptation in the Pacific Islands: Adapting to Present Climate Variability and Extreme Weather Events in Navua (Fiji), Working Paper no.34, Assessments of Impacts and Adaptation to Climate Change (AIACC), 31 pp.

Maunsell Australia., 2009: Climate Change Risk Assessment for the Australian Indian Ocean Territories, Commonwealth Attorney General's Department, Canberra, Australia, 93 pp.

Mazaris, A.D., A.S. Kallimanis, S.P. Sgardelis, and J.D. Pantis, 2008: Do long-term changes in sea surface temperature at the breeding areas affect the breeding dates and reproduction performance of Mediterranean loggerhead turtles? Implications for climate change. *Journal of Experimental Marine Biology and Ecology,* **367(2)**, 219-226.

McClanahan, T.R., E. Weil, and J. Maina, 2009: Strong relationship between coral bleaching and growth anomalies in massive Porites. *Global Change Biology,* **15(7)**, 1804-1816.

McLeman, R.A. and L.M. Hunter, 2010: Migration in the context of vulnerability and adaptation to climate change: Insights from analogues. *Climate Change,* **1(3)**, 450-461.

Méheux, K., D. Dominey-Howes, and K. Lloyd, 2007: Natural hazard impacts in small island developing states: A review of current knowledge and future research needs. *Natural Hazards,* **40(2)**, 429-446.

Mercer, J., D. Dominey-Howes, I. Kelman, and K. Lloyd, 2007: The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards,* **7(4)**, 245-256.

Meron, D., R. Efrony, W.R. Johnson, A.L. Schaefer, P.J. Morris, E. Rosenberg, E.P. Greenberg, and E. Banin, 2009: Role of flagella in virulence of the coral pathogen *Vibrio coralliilyticus*. *Applied and Environmental Microbiology,* **75(17)**, 5704-5707.

Mertz, O., K. Halsnæs, J. Olesen, and K. Rasmussen, 2009: Adaptation to climate change in developing countries. *Environmental Management,* **43(5)**, 743-752.

Metz, B., O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyers (eds.), 2007: *Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK; New York, NY, USA,

Meyer, W.M., K.A. Hayes, and A.L. Meyer, 2008: Giant african snail, Achatina fulica, as a snail predator. *American Malacological Bulletin,* **24(1-2)**, 117-119.

Middleton, N., P. Yiallouros, S. Kleanthous, O. Kolokotroni, J. Schwartz, D.W. Dockery, P. Demokritou, and P. Koutrakis, 2008: A 10-year time-series analysis of respiratory and cardiovascular morbidity in Nicosia, Cyprus: The effect of short-term changes in air pollution and dust storms. *Environmental Health,* **7(39)**.

Miller, J., E. Muller, C. Rogers, R. Waara, A. Atkinson, K.R.T. Whelan, M. Patterson, and B. Witcher, 2009: Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands. *Coral Reefs,* **28(4)**, 925-937.

Mills, E., 2009: A global review of insurance industry responses to climate change. *The Geneva Papers,* **34(3)**, 323-359.

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

Moglia, M., P. Perez, and S. Burn, 2008: Water troubles in a Pacific atoll town. *Water Policy,* **10(6)**, 613-637.

Monteil, M., 2008: Saharan dust clouds and human health in the English-speaking Caribbean: What we know and don't know. *Environmental Geochemistry and Health,* **30(4)**, 339-343-343.

Monteil, M. and R. Antoine, 2009: African dust and asthma in the Caribbean: Medical and statistical perspectives. *International Journal of Biometeorology,* **53(5)**, 379-381.

Moore, W.R., 2010: The impact of climate change on Caribbean tourism demand. *Current Issues in Tourism,* **13(5)**, 495-505.

Moreno, A. and Becken.S., 2009: A climate change vulnerability assessment methodology for coastal tourism. *Journal of Sustainable Tourism,* **17(4)**, 473-488.

Moreno, A., 2010: Mediterranean tourism and climate (change): A survey-based study. *Tourism and Hospitality Planning & Development,* **7(3)**, 253-265.

Morrison, K., P. Prieto, A. Dominguez, D. Waltner-Toews, and J. FitzGibbon, 2008: Ciguatera fish poisoning in la Habana, Cuba: A study of local social-ecological resilience. *Ecohealth,* **5(3)**, 346-359.

Mortreux, C. and J. Barnett, 2009: Climate change, migration and adaptation in Funafuti, Tuvalu. *Global Environmental Change,* **19(1)**, 105-112.

Myhre, S. and A. Acevedo-Gutierrez, 2007: Recovery of sea urchin Diadema antillarum populations is correlated to increased coral and reduced macroalgal cover. *Marine Ecology-Progress Series,* **329**, 205-210.

Nicholls, R.J., N. Marinova, J.A. Lowe, S. Brown, P. Vellinga, D. De Gusmao, J. Hinkel, and R.S.J. Tol, 2011: Sea-level rise and its possible impacts given a 'beyond 4 degrees C world' in the twenty-first century. *Philosophical Transactions of the Royal Society A Mathematical Physical and Engineering Sciences,* **369(1934)**, 161-181.

Nicoll, K.A., R.G. Harrison, and Z. Ulanowski, 2011: Observation of Saharan dust electrification. *Environmental Research Letters,* **6**, 014001 doi:10.1088/1748.9326/6/1/014001.

Novelo-Casanova, D.A. and G. Suarez, 2010: Natural and man-made hazards in the Cayman Islands. *Natural Hazards and Earth System Science,* **55(2)**, 441-466.

Nunkoo, R. and H. Ramkissoon, 2010: Small island urban tourism: A residents' perspective. *Current Issues in Tourism,* **13(1)**, 37-60.

Nunn, P.D., 2009: Responding to the challenges of climate change in the Pacific islands: Management and technological imperatives. *Climate Research,* **40(2-3)**, 211-231.

Nurse, L.A., G. Sem, J.E. Hay, A.G. Suarez, P.P. Wong, S. Briguglio, and S. Ragoonaden, 2001: Small island states. In: *Climate change 2001: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, pp. 843-912.

Ogston, A.S. and M.E. Field, 2010: Predictions of turbidity due to enhanced sediment resuspension resulting from sea-level rise on a fringing coral reef: Evidence from Molokai, Hawaii. *Journal of Coastal Research,* **26(6)**, 1027-1037.

Otero, P., S. Perez, A. Alfonso, C. Vale, P. Rodriguez, N.N. Gouveia, N. Gouveia, J. Delgado, P. Vale, M. Hirama, Y. Ishihara, J. Molgo, and L.M. Botana, 2010: First toxin profile of ciguateric fish in Madeira arquipelago (Europe). *Analytical Chemistry,* **82(14)**, 6032-6039.

Pike, D.A., R.L. Antworth, and J.C. Stiner, 2006: Earlier nesting contributes to shorter nesting seasons for the loggerhead seaturtle, *Caretta caretta*. *Journal of Herpetology,* **40(1)**, 91-94.

Piskorska, M., G. Smith, and E. Weil, 2007: Bacteria associated with the coral Echinopora lamellosa (Esper 1795) in the Indian Ocean - Zanzibar region. *African Journal of Environmental Science and Technology,* **1(5)**, 93-98.

Podesta, J. and P. Ogden, 2007: The security implications of climate change. *The Washington Quarterly,* **31(1)**, 115-138.

Polidoro, B.A., K.E. Carpenter, L. Collins, N.C. Duke, A.M. Ellison, J.C. Ellison, E.J. Farnsworth, E.S. Fernando, K. Kathiresan, N.E. Koedam, S.R. Livingstone, T. Miyagi, G.E. Moore, V.N. Nam, J.E. Ong, J.H. Primavera, S.G. Salmo, J.C. Sanciangco, S. Sukardjo, Y. Wang, and J.W.H. Yong, 2010: The loss of species: Mangrove extinction risk and geographic areas of global concern. *PLoS One,* **5(4)**, doi: 10.1371/journal.pone.0010095PMCID: PMC2851656.

Poloczanska, E.S., C.J. Limpus, and G.C. Hays, 2009: Vulnerability of marine turtles to climate change. In: *Advances in marine biology*. [David, W.S. (ed.)]. Academic Press, pp. 151-211.

Prospero, J.M., 2006: Case study:Saharan dust impacts and climate change. *Oceanography,* **19(2)**, 59-61.

Prospero, J.M., E. Blades, G. Mathison, and R. Naidu, 2005: Interhemispheric transport of viable fungi and bacteria from Africa to the Caribbean with soil dust. *Aerobiologia,* **21(1)**, 1-19.

Prospero, J.M. and P.J. Lamb, 2003: African droughts and dust transport to the Caribbean: Climate change implications. *Science,* **302(5647)**, 1024-1027.

Prospero, J., E. Blades, R. Naidu, G. Mathison, H. Thani, and M. Lavoie, 2008: Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. *International Journal of Biometeorology,* **52(8)**, 823-832; 832.

Ralph, P.J., M.J. Durako, S. Enriquez, C.J. Collier, and M.A. Doblin, 2007: Impact of light limitation on seagrasses. *Journal of Experimental Marine Biology and Ecology,* **350(1-2)**, 176-193.

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

Rawlins, S.C., A. Hinds, and J.M. Rawlins, 2008: Malaria and its vectors in the Caribbean: The continuing challenge of the disease forty-five years after eradication from the islands. *West Indian Medical Journal,* **57(5)**, 462-469.

Read, R., 2010: Trade, economic vulnerability, resilience and the implications of climate change on small island and littoral developing economies. In: *Programme on competitiveness and sustainable development*. [International Centre for Trade and Sustainable Development (ICTSD) (ed.)]. International Centre for Trade and Sustainable Development, Geneva, Switzerland, pp. 35.

Reaser, J.K., L.A. Meyerson, Q. Cronk, M. De Poorter, L.G. Eldrege, E. Green, M. Kairo, P. Latasi, R.N. Mack, J. Mauremootoo, D. O'Dowd, W. Orapa, S. Sastroutomo, A. Saunders, C. Shine, S. Thrainsson, and L. Vaiutu, 2007: Ecological and socioeconomic impacts of invasive alien species in island ecosystems. *Environmental Conservation,* **34(02)**, 98-111.
Rees, W.J., 1950: The giant African snail. *Proceedings of the Zoological Society of London,* **120(3)**, 577–599.
Ricardo, J.M., 2010: Ciguatera, presentación de un caso (sea water fish poisoning case presentation). *Revista Habanera De Ciencias Médicas [Online],* **9(4)**, 487-490.
Robinson, R.A., H.Q.P. Crick, J.A. Learmonth, I.M.D. Maclean, C.D. Thomas, F. Bairlein, M.C. Forchhammer, C.M. Francis, J.A. Gill, B.J. Godley, J. Harwood, G.C. Hays, B. Huntley, A.M. Hutson, G.J. Pierce, M.M. Rehfisch, D.W. Sims, B.M. Santos, T.H. Sparks, D.A. Stroud, and M.E. Visser, 2009: Travelling through a warming world: Climate change and migratory species. *Endangered Species Research,* **7(2)**, 87-99.
Rocha, S., I. Ineich, and J. Harris, 2009: Cryptic variation and recent bipolar range expansion within the stumped-toed gecko *Gehyra mutilata* across Indian and Pacific ocean islands. *Contributions to Zoology,* **78(1)**, 1-8.
Rongo, T. and R. van Woesik, 2011: Ciguatera poisoning in Rarotonga, southern Cook Islands. *Harmful Algae,* **10(4)**, 345-355.
Rosenberg, E. and A. Kushmaro, 2011: Microbial diseases of corals: Pathology and ecology. In: *Coral reefs: An ecosystem in transition.* [Dubinsky, Z. and N. Stambler(eds.)]. Springer Netherlands, Dordrecht; Heidelberg; London; New York, pp. 451-464.
Rosenberg, E., A. Kushmaro, E. Kramarsky-Winter, E. Banin, and L. Yossi, 2008: The role of microorganisms in coral bleaching. *The ISME Journal,* **3(2)**, 139-146.
Rotjan, R. and S. Lewis, 2008: Impact of coral predators on tropical reefs. *Marine Ecology Progress Series,* **367**, 73-91.
Russell, L., 2009: Poverty, Climate Change and Health in Pacific Island Countries, Menzies Centre for Health Policy, Sydney and Canberra, 55 pp pp.
Rutty, M. and D. Scott, 2010: Will the Mediterranean become 'Too hot' for tourism? A reassessment. *Tourism and Hospitality Planning & Development,* **7(3)**, 267-281.
Rypien, K., 2008: African dust is an unlikely source of *Aspergillus sydowii*, the causative agent of sea fan disease. *Marine Ecology Progress Series,* **367**, 125-131.
Santese, M., M.R. Perrone, A.S. Zakey, F. De Tomasi, and F. Giorgi, 2010: Modeling of Saharan dust outbreaks over the Mediterranean by RegCM3: Case studies. *Atmospheric Chemistry and Physics Discussions,* **10(1)**, 133-156.
Schipper, L. and M. Pelling, 2006: Disaster risk, climate change and international development: Scope for, and challenges to, integration. *Disasters (Special Issue on Climate Change and Disasters),* **30(1)**, 19-38.
Schlacher, T.A., J. Dugan, D.S. Schoeman, M. Lastra, A. Jones, F. Scapini, A. McLachlan, and O. Defeo, 2007: Sandy beaches at the brink. *Diversity and Distributions,* **13(5)**, 556-560.
Schlacher, T.A., D.S. Schoeman, J. Dugan, M. Lastra, A. Jones, F. Scapini, and A. McLachlan, 2008: Sandy beach ecosystems: Key features, sampling issues, management challenges and climate change impacts. *Marine Ecology-an Evolutionary Perspective,* **29**, 70-90.
Schleupner, C., 2008: Evaluation of coastal squeeze and its consequences for the Caribbean island Martinique. *Ocean & Coastal Management,* **51(5)**, 383-390.
Schulz, N.B., 2010: Delving into the carbon footprints of Singapore-comparing direct and indirect greenhouse gas emissions of a small and open economic system. *Energy Policy,* **38(9)**, 4848-4855.
Simpson, M.C., 2010: The Caribsave Partnership and Climate Change. 38 pp.
Spennemann, D.H.R., 1996: Nontraditional settlement patterns and typhoon hazard on contemporary Majuro atoll, Republic of the Marshall island. *Environmental Management,* **20(3)**, 337-348.
Srinivasan, U.T., 2010: Economics of climate change: Risk and responsibility by world region. *Climate Policy,* **10(3)**, 298-316.
Stage, J., 2010: Economic valuation of climate change adaptation in developing countries. *Annals of the New York Academy of Sciences, Ecological Economics Reviews,* **1185**, 150-163.
Steinberger, J.K., J. van Niel, and D. Bourg, 2009: Profiting from negawatts: Reducing absolute consumption and emissions through a performance-based energy economy. *Energy Policy,* **37(1)**, 361-370.
Storey, D. and S. Hunter, 2010: Kiribati: An environmental 'perfect storm'. *Australian Geographer,* **41(2)**, 167-181.
Stuart, E.K., 2006: Energizing the island community: A review of policy standpoints for energy in small island states and territories. *Sustainable Development,* **14(2)**, 139-147.

Swart, R. and F. Raes, 2007: Making integration of adaptation and mitigation work: Mainstreaming into sustainable development policies. *Climate Policy,* **7(4)**, 288-303.
Tegart, W.J.M., G.W. Sheldon, and D.C. Griffiths, 1990: Executive summary. In: *Climate change: The IPCC Impacts Assessment. Contribution of Working Group II to the First Assessment Report of the Intergovernmental Panel on Climate Change*. [Tegart, W.J.M., G.W. Sheldon, and D.C. Griffiths (eds.)]. Australian Government Publishing Service, Canberra, Australia, pp. 1-5.
Terry, J.P. and A.C. Falkland, 2010: Responses of atoll freshwater lenses to storm-surge overwash in the northern Cook Islands. *Hydrogeology Journal,* **18(3)**, 749-759.
Tester, P.A., R.L. Feldman, A.W. Nau, S.R. Kibler, and R. Wayne Litaker, 2010: Ciguatera fish poisoning and sea surface temperatures in the Caribbean Sea and the West Indies. *Toxicon,* **56(5)**, 698-710.
Thiengo, S.C., A. Maldonado, E.M. Mota, E.J.L. Torres, R. Caldeira, O.S. Carvalho, A.P.M. Oliveira, R.O. Simoes, M.A. Fernandez, and R.M. Lanfredi, 2010: The giant African snail *Achatina fulica* as natural intermediate host of *angiostrongylus cantonensis* in Pernambuco, northeast Brazil. *Acta Tropica,* **115(3)**, 194-199.
Thiengo, S., F. Faraco, N. Salgado, R. Cowie, and M. Fernandez, 2007: Rapid spread of an invasive snail in South America: The giant African snail, *Achatina fulica*, in Brasil. *Biological Invasions,* **9(6)**, 693-702.
Thomas-Hope, E. and A. Jardine-Comrie, 2007: Valuation of environmental resources for tourism in small island developing states: Implications for planning in Jamaica. *International Development Planning Review,* **29(1)**, 93-112.
Tisdell, C., 2008: Global warming and the future of Pacific island countries. *International Journal of Social Economics,* **35(12)**, 889-903.
Tompkins, E.L., W.N. Adger, E. Boyd, S. Nicholson-Cole, K. Weatherhead, and N. Arnell, 2010: Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Global Environmental Change,* **20(4)**, 627-635.
Tsyban, A., J.T. Everett, and J. Titus, 1990: World oceans and coastal zones. In: *Climate change: The IPCC impacts assessment*. [McG. Tegart, W.J., G.W. Sheldon, and D.C. Griffiths(eds.)]. Australian Government Publishing Service, Canberra, pp. 6.1-6.28.
UNCTAD, United Nations Conference on Trade and Development, 1997: The Vulnerability of Small Island Developing States in the Context of Globalization: Common Issues and Remedies. Discussion Paper Prepared by the United Nations Conference on Trade and Development, United Nations Conference on Trade and Development (UNCTAD), Geneva, .
van Alphen, K., W. van Sark, and M.P. Hekkert, 2007: Renewable energy technologies in the Maldives - determining the potential. *Renewable & Sustainable Energy Reviews,* **11(8)**, 1650-1674.
van Vuuren, D.P., M. Isaac, Z.W. Kundzewicz, N. Arnell, T. Barker, P. Criqui, F. Berkhout, H. Hilderink, J. Hinkel, A. Hof, A. Kitous, T. Kram, R. Mechler, and S. Scrieciu, 2011: The use of scenarios as the basis for combined assessment of climate change mitigation and adaptation. *Global Environmental Change,* **21(2)**, 575-591.
Vargas-Ángel, B., 2009: Coral health and disease assessment in the U.S. Pacific remote island areas. *Bulletin of Marine Science,* **84(2)**, 211-227.
Vassie, J.M., P.L. Woodworth, and M.W. Holt, 2004: An example of north Atlantic deep-ocean swell impacting ascension and St. Helena islands in the central south Atlantic. *Journal of Atmospheric and Oceanic Technology,* **21(7)**, 1095-1103.
Veron, J.E.N., O. Hoegh-Guldberg, T.M. Lenton, J.M. Lough, D.Q. Obura, P. Pearce-Kelly, C.R.C. Sheppard, M. Spalding, M.G. Stafford-Smith, and A.D. Rogers, 2009: The coral reef crisis: The critical importance of <350 ppm CO2. *Marine Pollution Bulletin,* **58**, 1428-1436.
Warren, R., J. Price, A. Fischlin, G. Midgley, and S.d.l.N. Santos, 2009: Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise. *IOP Conference Series: Earth and Environmental Science,* **6(30)**, 302037.
Warrick, O., 2009: Ethics and methods in research for community-based adaptation: Reflections from rural Vanuatu. *Participatory Learning and Action,* **60**, 76-87.
Waycott, M., C.M. Duarte, T.J.B. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, A. Calladine, J.W. Fourqurean, K.L. Heck, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, F.T. Short, and S.L. Williams, 2009: Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences,* **106(30)**, 12377-12381.

Webb, A.P., and P.S. Kench, 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(3)**, 234-246.

Weil, E. and A. Cróquer, 2009: Spatial variability in distribution and prevalence of Caribbean scleractinian coral and octocoral diseases. I. Community-level analysis. *Diseases of Aquatic Organisms,* **83(3)**, 195-208.

Weil, E. and C.S. Rogers, 2011: Coral reef diseases in the Atlantic-Caribbean. In: *Coral reefs: An ecosystem in transition*. [Dubinsky, Z. and N. Stambler (eds.)]. Springer Netherlands, Dordrecht; Heidelberg; London; New York, pp. 465-491-491.

Westphal, M., M. Browne, K. MacKinnon, and I. Noble, 2008: The link between international trade and the global distribution of invasive alien species. *Biological Invasions,* **10(4)**, 391-398.

White, I. and T. Falkland, 2010: Management of freshwater lenses in small Pacific islands. *Hydrogeology Journal,* **18(1)**, 227-246.

White, I., T. Falkland, T. Metutera, E. Metai, M. Overmars, P. Perez, and A. Dray, 2007: Climatic and human influences on groundwater in low atolls. *Vadose Zone Journal,* **6(3)**, 581-590.

Williams, G.J., I.S. Ingrid S. Knappa, J.E. Maragos, and S.K. Davy, 2010: Modeling patterns of coral bleaching at a remote central Pacific atoll. *Marine Pollution Bulletin,* **60(9)**, 1467-1476.

Woinarski, J.C.Z., 2010: Biodiversity conservation in tropical forest landscapes of Oceania. *Biological Conservation,* **143(10)**, 2385-2394.

World Tourism Organisation and United Nations Environment Programme, 2008: *Climate change and tourism: Responding to global challenges*. World Tourism Organization and the United Nations Environment Programme, Madrid, Spain; Paris, France, pp. 256.

Yamano, H., H. Kayanne, T. Yamaguchi, Y. Kuwhara, H. Yokoki, and M. Chicamori, 2007: Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale island, Funafuti atoll, Tuvalu. *Global and Planetary Change,* **57(3-4)**, 407-416

Table 29-1: Projected changes to selected key features of Pacific surface climate and ocean relative to 1980-1999 values (after SPC, 2011: Tables 1 and 2).

Climate/Ocean feature	2035		2100	
	B1	A2	B1	A2
Air temp (^{0}C)	+0.5 to 1.0	+0.5 to 1.0	+1.0 to 1.5	+1.0 to 1.5
Rainfall	+5 to 20% in equatorial regions		+10 to 20% in equatorial regions	
	5 to10% decrease in subtropics	5 to 20% decrease in subtropics		
	• Extremes become more extreme			
Prevailing circulation	• More vigorous hydrological cycle + enhanced Hadley circulation • Expansion of area covered by 'tropics'			
ENSO	• ENSO events continue as source of climate variability			
Sea Level	+20 to 30 cm	+70 to 110 cm	+90 to 140 cm	
Sea Surface temperature	+0.7^{0}C	+0.8^{0}C	+1.0 to 1.5^{0}C	+2.5 to 3.0^{0}C
Ocean temp at 80 m depth	+0.5^{0}C		+1.0^{0}C	+1.8^{0}C
Ocean currents	• S Equatorial Current decreases at equator • Equatorial Undercurrent becomes shallower • S Equatorial Countercurrent decreases, retracts westward			
Warm pool	• Extends eastward; water warms, area of warmest water increases			
Nutrient supply	• Decrease due to increased stratification & shallower mixed layer			
Waves	• Slight increase (up to 10%) in swell wave height • Patterns depend on ENSO and tropical cyclones			

Table 29-2: Projected estimated percentage or percentage change in habitat area, reef cover, coastal (demersal) fish production (after SPC, 2011, Tables 4, 5, 6 and 8).

Habitat/reefcover/fish production	SRES Scenario	2035		2100	
		B1	A2	B1	A2
Mangroves		-10 to > -10%		-50 to -70%	-6 to-80%
Seagrass		< -5 to -20%		-5 to -35%	-10 to -50%
Coral cover	Strong	15 to 30%		10 to 20%	< 2 %
	Poor	15%		< 5%	< 2%
Algal cover	Strong	40%		50%	> 95%
	Poor	40 to 60%		80%	> 95%
Coastal (demersal) fish		-2 to -5%		-20%	-20 to -50%
Freshwater fish, area change	Tropics	-5 to +10%		-5 to +20%	-5 to +20%
	Subtropics	-5 to +5-10%		-10 to+10%	-20 to+20%

Table 29-3: Preliminary projected percentage changes in tuna catches relative to the 20 year average (1980-2000) and estimated percentage change in government revenue resulting from projected changes in the catch of skipjack tuna in 2030 and 2100 (after SPC, 2011: Tables 7, 11 and 12).

SRES Scenario		2035	2100	
		B1/A2	B1	A2
Skipjack tuna	Western fishery	+ 11%	-0.2%	-21%
	Eastern fishery	+37%	+43%	+27%
Bigeye tuna	Western fishery	-2%	-12%	-24%
	Eastern fishery	+3%	-4%	-18%
Skipjack tuna	Total	+19%	+12%	-7%
Bigeye tuna	Total	+0.3%	-9%	-27%
Change to Government Revenue (Percent)	FSM	0.8 to 1.7%	-0.9 to -1.9%	
	Solomon Is	0.01 to 0.16%	-0.03 to0.77%	
	Kiribati	+11 to 18.4%	+7.2 to12.0%	
	Tuvalu	+3.7 to 9.2%	+2.5 to6.2%	

Table 29-4: Economic structure of small islands and areas of potential emissions reduction.

Type of economy	*Sectors with significant emissions reduction potential*						
	Energy supply	Transport	Buildings (commercial /residential)	Industry	Agriculture	Forestry	Waste management and sewage
Aid dependent	X	X	x	X	?	?	X
Services dependent	√	?	√	X	?	X	√
Natural resource exporting	?	X	√	?	√	√	?
Diversified with manufacturing	√	?	√	√	?	?	?

Notes:
X = unlikely to offer potential for emissions reduction due to excessive cost or limited effectiveness
? = possible area for emissions reduction, although likely to depend on capacities within the islands
√ = rich area for exploring emissions reduction