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Impacts of Climate Change on Society in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS)

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EXECUTIVE SUMMARY

Caribbean fisheries are under threat due to changes in ocean currents and fish distribution, and loss of marine habitats. Coastal erosion is also compromising important fish landing beach sites.

Coastal flooding and erosion caused by cyclonic storms and also by sea-level rise is a growing concern for communities of Caribbean islands, which cluster near the coast along with most of the infrastructure, local institutions, tourist resorts and services.

Energy supply is at risk from storm damage as well as decreasing average rainfall and rising temperatures.

Raising temperatures, changing rainfall patterns and saltwater intrusions are compromising fresh water resources across the Caribbean Region.

A number of diseases and health conditions are on the rise in the Caribbean Region due to a combination of factors worsened by climate change. Rising sea temperatures imply a higher risk of disease and parasite outbreaks in marine organisms, which can have severe consequences for human health and the local economies.

Outbreaks of harmful and nuisance algae are expected to increase in frequency and extent as the Caribbean Sea warms.

Introduction

Small Island Developing States (SIDS) are a distinct group of developing countries facing specific social, economic and environmental vulnerabilities. The SIDS in the Caribbean geographical region include the following countries: Antigua and Barbuda, Belize, Dominica, Grenada, Guyana, Jamaica, St. Lucia, and St. Vincent and the Grenadines. The common challenges faced by SIDS are: a narrow resource base depriving them of the benefits of economies of scale; small domestic markets and heavy dependence on external and remote markets; high costs in terms of energy, infrastructure, transportation, communication and servicing; unpredictable international traffic volumes; little resilience to natural disasters; growing populations; fresh water shortages; volatile economies; limited opportunities for the private sector and a proportionately large reliance of their economies on their public sector; and fragile natural environments[1,2].

Sustainable development in SIDS depends largely on coastal and marine resources such as fisheries and aquaculture, as well

[1] SMALL ISLAND DEVELOPING STATES: Small Islands Big(ger) Stakes [http://unohrlls.org/custom-content/uploads/2013/08/SIDS-Small-Islands-Bigger-Stakes.pdf]

[2] BPOA (1994) - Barbados Programme of Action [http://www.sidsnet.org/about-sids/bpoa/]

as tourism, which together with agriculture are the main economic sectors in the Caribbean. These resources however are limited and very vulnerable to over-exploitation, as well as climate change impacts.

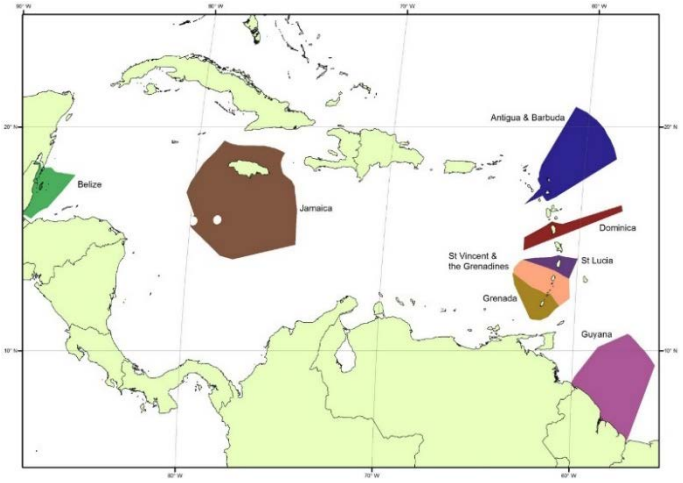

Figure 1: Maritime area of the Small Island Developing States in the Caribbean.

Current and future climate-related drivers of risk for small island states around the world during the 21st century include sea level rise, tropical and extratropical cyclones, increasing temperatures, and changing rainfall patterns (Nurse et al. 2014). Sea level rise, particularly, is threatening low-lying coastal areas on islands and atolls. Small islands do not have uniform climate change risk profiles and because of their high diversity climate change impacts, vulnerability, and adaptation, change from one region to another. There is increasing recognition of the risks to small islands from transboundary climate processes originating well beyond the borders, which are already having negative impacts (Nurse et al. 2014).

The high concentration of people and services around the coastline in Caribbean SIDs makes them vulnerable to climate change impacts on storms, sea level rise, flooding, erosion and water availability. Marine ecosystem services are under threat as rising sea temperatures and storm damage accelerate the degradation of marine and coastal habitats and impact on commercial fisheries, as well as contribute to the spread of harmful pathogens. Future impacts from climate change, including increasing temperatures, higher incidence of severe storms and sea level rise will exacerbate these threats to coastal and marine environments and the settlements, communities and infrastructure they support.

For the society theme of this paper, climate change impacts on fisheries, tourism and settlements and infrastructure have been explored in more detail as separate 'key topic' papers. The importance of fisheries as a both a social and economic activity in the region, and the potential wide range of impacts on resource availability, capture fisheries, and subsequent processing and supply chain make it an important issue to explore. The high dependence of the region on tourism, its focus around the coastal fringe and the potential impacts on tourist attractions (e.g. coral reefs) meant this was important to include, as were the wider issues around the vulnerability of low lying settlements and infrastructure to climate change impacts.

As part of this overarching paper, issues around public health, harmful blooms and human health are also explored, along with freshwater availability.

Key topics

Some of the main issues for the fisheries, tourism and settlements and infrastructure key topics are briefly described here. More detail can be found in the full papers on these topics. The topic papers contain detailed sections on key messages, what is already happening, what could happen in the future, confidence in our understanding, knowledge gaps and socio-economic impacts.

Fisheries

Detection of climate change impacts is challenging owing to other human pressures (e.g. from overfishing and impacts on water quality), as well as natural climate variability. Although the evidence base on observed impacts is quite limited, there is some evidence that climate change is already impacting on important habitats through coral bleaching (high confidence), distribution and abundance of commercial species (medium-high confidence), and through the acidification of surface waters (medium confidence) (Nurse et al. 2014). Increasing temperatures in the Caribbean have also been implicated in the spread of diseases, parasites and introduced nuisance species in marine ecosystems. Evidence for recent change is also supported by studies of fish and invertebrate in the Gulf of Mexico, which show that assemblages shifted deeper in response to warmer surface temperatures during the period 1970s–2011 (Hoegh-Guldberg et al, 2014). Impacts are likely to increase in the future as the productivity of many fisheries will decrease as waters warm, acidify, and stratify, and as crucial habitat, such as coral reefs, degrades further.

On land, erosion and sea surges are causing beaches to shrink rapidly across the Caribbean islands, resulting in loss of critical landing sites and co-operative buildings (CCCCC, 2014). Average beach erosion rates of 0.5m per year have been reported in eight Caribbean islands from 1985 to 2000 (Nurse et al., 2014; Cambers 2009). High winds and hurricanes have caused significant losses to the fisheries sector by causing lost fishing days and damaging or destroying their boats and equipment, nets, fish factories and housing, as well as impacting critical fishery habitats like mangroves and coral reefs (Monnereau and Oxenford, 2017; Nurse et al., 2014). Worsening weather conditions in the windy season could further increase operational fishing costs (Monnereau and Oxenford, 2017). Heavy rain and floods will increase the quantity of freshwater outflow into estuaries causing localised desalination of coastal waters, and are also likely to cause sedimentation and nutrient enrichment. The long-term effect of localised desalination on fish, as well as on their critical habitats, is uncertain.

At the level of specific SIDs, example of impacts includes live coral cover in Belize declining by 25-30% due to an unusually

high frequency of intense storms (Hurricane Mitch in 1998, Hurricane Keith in 2000, Hurricane Iris in 2001, Hurricane Dean in 2007 and Hurricane Richard in 2010; CARIBSAVE, 2011b). The Dominican residents in Lagon, next to the coastline, are under constant threat from storm surges, sea swells and sea-level rise (CARIBSAVE, 2011c). In Guyana, sea inundation is damaging fish nursery areas in mangrove swamps (CCCCC, 2014). Examples of future impacts on SIDS include the potential effects on Antigua and Barbuda from temperature driven changes on breeding and migration patterns of pelagic fisheries such as blue marlin and sailfish (CARIBSAVE, 2011a), which are important for fisheries landings and game fishing. In Guyana, severe and frequent flooding is expected to destroy fish landing sites and cooperative buildings along the coast

Settlements and infrastructure

Most settlement, infrastructure, and development are located on lowlands along the coastal fringe of Caribbean SIDS, making populations, infrastructure, agricultural areas, and fresh groundwater supplies vulnerable to extreme tides, extreme wind, wave and surge events, and sea level rise. Coastal development, combined with population growth and tourism, continues to increase the stress on the coast of some islands and has resulted in dense aggregations of infrastructure and people in exposed locations (Nurse et al, 2014).

North Atlantic hurricanes and tropical storms appear to have increased in intensity over the last 30 years. Climate projections indicate that as the sea surface temperature continues to increase, so will increase in hurricane activity. This is likely to occur through increases in the intensity, rather than the frequency, of events. Other impacts of climate change, in particular sea-level rise, will accelerate coastal erosion. All of these changes are impacting on settlements and infrastructure. For example, climate change is already impacting on energy generation, distribution and transmission infrastructure as hurricanes damage lines and poles and power generation stations located on or near the coast are highly vulnerable to flooding from storm surges and sea-level rise and wind damage.

At the level of SIDS, flooding and storm surges have caused extensive damages in Antigua and Barbuda in recent years because of their low-lying bays and the low elevation. In Grenada sea surges caused by hurricanes and tropical storms are causing the erosion of low-lying areas and putting at risk the primary road that connects the coast with the communities in the interior. The main port in St George's, is very vulnerable to the impact of extreme weather events and the impact from extreme weather would threaten the supplies and food security of the whole country (CARIBSAVE, 2011d). Close to 80% of Guyana's population lives in areas of reclaimed land - narrow coastal plains most of which are below the mean high tide level (UNFCCC Guyana's 2nd SNC, 2012; Climate Hot Map, 2011) - whilst more than half the population of Jamaica lives within 1.5km of the coast (CARIBSAVE, 2011e). In Dominica for example, the road network and the only two airports of the island are particularly vulnerable. Ports and port lands are also under threat and at risk of inundation under scenarios of 1m sea-level rise (CARIBSAVE, 2011c).

Tourism

Most of the SIDS rely heavily on the foreign exchange from tourism to expand and develop their economies. Tourism in the Caribbean often relies on coastal and terrestrial ecosystems to provide visitor attractions and accommodation space (Nurse et al., 2014). A high proportion of GDP is dependent on tourism, for example in Antigua and Barbuda, tourism is reported to account for up to 60% of GDP directly and 26% of the labour force (CARIBSAVE, 2011a).

Severe weather-related events in a destination country can significantly influence visitors' vacation choices and beach erosion and coral bleaching have been found to negatively impact the desirability of various locations (Nurse et al, 2014). Tourism in the SIDS is often impacted by port and airport closures, even after schedules are restored, and after the passage of hurricanes there is a noticeable decline of long stay passengers and tourist expenditure, with significant consequences for the tourism sector and the wider economy. Extreme heat conditions, heavy rainfall and increased ocean turbidity also adversely affect visitor experiences (CARIBSAVE, 2011e) and are likely to be affected by climate change.

In the future, a scenario of 1m sea level rise by 2100 would be a potential risk to Caribbean tourism, resulting in the loss or damage of 21 airports, inundation of land surrounding 35 ports, and at least 149 multi-million-dollar tourism resorts damaged or lost from erosion to the coastal beach areas (Wong et al, 2014). The presence of coastal tourism infrastructure will continue to exacerbate beach reduction and coastal ecosystems squeeze under rising sea levels. Carbonate reef structures would degrade under a scenario of at least 2°C by 2050–2100 with serious consequences for tourism destinations in the Caribbean.

Projected increases in the frequency or magnitude of certain weather and climate extremes (e.g. heat waves, droughts, floods, tropical cyclones) as a result of projected climate change will affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses (e.g. insurance, backup water and power systems, and evacuations), and business interruptions (Simpson, Gössling, & Scott, 2008). It is considered that climate change will dictate the type and quality of tourist attractions (CZMAI, 2016). Water is another critical factor for the tourism industry. Drought and water shortages can adversely affect comfort and destination perception and in a warm weather destination like the Caribbean it may prove to be an unpleasant experience (Layne, 2017).

At the individual SIDS level, there are a number of examples of impacts on settlements and infrastructure. In Antigua and Barbuda much of the tourism is concentrated along the coast and the low-lying bays and a succession of hurricanes in the last two decades (Hurricanes Luis 1995, George 1998, Lenny and Jose 1999, Omar 2008 and Earl 2010) have caused severe damage and destruction to low and middle level hotels and

restaurants, roads, ports and airports (CARIBSAVE, 2011a). In the future, annual reductions in the contribution of tourism to Antigua and Barbuda's national Gross Domestic Product (GDP) as a result of the reduced amenity value from beach loss due to sea-level rise is estimated to be between US $102 million in 2050 to over US $340 million in 2080 (based on a mid-range seal-level rise scenario). A similar situation presents in Belize, where 45-70% of the tourism sector is highly vulnerable to the effects of climate change (CARIBSAVE, 2011b). In Dominica, the predicted changes in coastal profile according to various sea-level rise scenarios will transform coastal tourism with serious implications for property value, insurance costs and employment (CARIBSAVE, 2011c). The main impact of climate change to the tourism sector in Guyana will be sea-level rise, with the loss of national landmarks, administration buildings, transportation and communication networks (CCCCC, 2014). The tourism sector in Jamaica will also become increasingly at risk as sea-levels continue to rise, creating the possibility of storm surges around the island (CARIBSAVE, 2011e).

Wider impacts

Water resources

Freshwater supply in small island environments has always presented challenges and has been an issue raised in a number of IPCC reports (Nurse et al., 2014). Rapidly growing demand, land use change, urbanization, and tourism are already placing significant strain on the limited freshwater reserves in small island environments, making most of them water-scarce countries (Emmanuel and Spence, 2009; Nurse et al., 2014). Climate change is expected to exacerbate these issues through decreasing rainfall and increasing temperature (Nurse et al, 2014), as well as saltwater intrusions and flooding caused by sea-level rise, sea surges and heavy rainfall, which cause salinization, water saturation, sedimentation and contamination of sources of potable water.

Droughts are slow onset with long-lasting effects (Cashman and Nagdee, 2017). Five severe droughts have affected various parts of the Caribbean since 2000 and their effects on urban areas were particularly serious. Revenue from water sales dropped while operating costs increased due to the need of tankering services and overtime. There was a loss of productivity as workers arrived late for work after waiting for water, and there was an increase in young children needing treatment for oral rehydration or diarrhoea (Cashman and Nagdee, 2017). Droughts affect coastal groundwater aquifers which supply urban areas. In these instances, reduced recharge from rainfall and runoff coupled with reliance and continued abstraction from these aquifers in order to meet water demand of urban areas has resulted in saline intrusion due to over-pumping (Cashman and Nagdee, 2017).

In the case of agriculture, the main climate hazards seem to be the extreme variability in rainfall (from long drought to heavy rains which cause water saturation and flash floods) and high winds during hurricanes and storms. Saltwater intrusions are a special concern in some countries such as Guyana, were agricultural activities are based near the coastline (CCCCC, 2014). In Barbuda and Guyana, the main water source for domestic use is aquifers, but the reservoirs are located near the surface and are highly vulnerable to saltwater intrusion from sea-level rise (CARIBSAVE, 2011a). During the dry seasons, salt-water intrusion will be much greater as the river basins are depleted of freshwater. In Belize, there are concerns that changes in tidal patterns are causing higher than normal tides and raising the level of the sea, with the consequence of saltwater invading groundwater aquifers (CARIBSAVE, 2011b). Jamaica has considerable surface and groundwater resources with groundwater meeting most of the local demand (CARIBSAVE, 2011e), however there is a predisposition to saltwater intrusions into the country's coastal groundwater supplies. Most water consumed in Dominica, the wettest island in the Caribbean, is sourced from rivers and streams, and so groundwater resources have not been exploited to the extent of other islands (CARIBSAVE, 2011c).

Public health

The potential effects of climate change on public health are multiple and often overlap. They can be both direct or indirect. Direct effects include:

- Hurricanes and storms can cause loss of live and injuries. Public health facilities, usually located near the coast, may be damaged by extreme weather thus compromising medical and humanitarian assistance to the local communities.
- The displacement and loss of shelter experienced by people during natural disasters such as hurricanes or flash floods carry its own mental and physical impacts.
- Extreme weather can cause water shortages during prolonged droughts.
- Increasing temperatures and heat waves cause heat stress, heat exhaustion and dehydration. Exposure to higher temperatures can also contribute to an increase in skin diseases and cardio-respiratory conditions. Tourists, particularly elderly travellers, are at risk of suffering cardiovascular complaints due to the extreme heat.
- The repercussions of extreme weather to communities in the SIDS continue to affect the people and their health for a long time after.

As well as those direct effects, climate change is also driving other negative impacts on public health. The tropical climate of the Caribbean Region provides suitable conditions for vector-borne diseases, such as malaria and dengue fever, due to the proliferation of mosquitos on flooded, stagnant areas.

It is expected as climate change drives further temperature increases, it will exacerbate heat-related illnesses (Nurse et al., 2014). Similarly, under sea-level rise scenarios the hazard of disease spread through stagnant contaminated water will also increase (CCCCC, 2014).

Table 1: Some examples of projected impacts associated with 1m and 2m sea level rise scenarios and 50m and 100m beach erosion scenarios for Caribbean SIDs. Dashed lines indicate there are projected figures available.

			Tourist Attractions		Transportation Infrastructure		
			Major Tourism Resorts	Sea Turtle Nesting Sites	Airports	Major Road Networks	Ports
Antigua and Barbuda (CARIBSAVE, 2011a).	SLR	1.0m	10%	12%	0%	2%	100%
		2.0m	18%	18%	100%	6%	-
	Erosion	50m	34%	50%	-	-	-
		100m	44%	65%	-	-	-
Belize (CARIBSAVE, 2011b)	SLR	1.0m	73%	44%	50%	4%	40%
		2.0m	86%	60%	-	6%	-
	Erosion	50m	95%	100%	-	-	-
		100m	100%		-	-	-
Dominica (CARIBSAVE, 2011c)	SLR	1.0m	0%	7%	0%	14%	67%
		2.0m	6%	10%	50%	15%	-
	Erosion	50m	29%	17%	-	-	-
		100m	35%	19%	-	-	-
Grenada (CARIBSAVE, 2011d)	SLR	1.0m	73%	44%	50%	4%	40%
		2.0m	86%	60%	-	6%	-
	Erosion	50m	95%	100%	-	-	-
		100m	100%		-	-	-
St Lucia (CARIBSAVE, 2011f)	SLR	1.0m	7%	6%	50%	0%	100%
		2.0m	10%	10%	50%	0%	100%
	Erosion	50m	2%	30%	-	-	-
		100m	30%	53%	-	-	-
St. Vincent and Grenadines (CARIBSAVE, 2011g)	SLR	1.0m	10%	11%	50%	1%	67%
		2.0m	24%	16%	75%	1%	67%
	Erosion	50m	38%	34%	-	-	-
		100m	76%	47%	-	-	-

Harmful algal blooms

As seas become warmer due to climate change, harmful algal blooms are expected to increase which could present health risks. Ciguatera fish poisoning (CFP) is one such risk. Distribution and abundance of the organisms that produce these toxins, chiefly dinoflagellates of the genus *Gambierdiscus*, are reported to correlate positively with water temperature. Consequently, there is growing concern that increasing temperatures associated with climate change could increase the incidence of CFP in the island regions of the Caribbean (Morrison et al., 2008). There are indications that warmer sea temperatures may drive outbreaks of CFP (Tester et al., 2010; CARIBSAVE, 2011c; Nurse et al., 2014).

Another example of nuisance algal blooms, in this case a macroalgal bloom, started in the autumn of 2014 and culminated in August 2015. A massive bloom of *Sargassum* invaded the Caribbean Sea and ended up choking the coastlines of many countries from Trinidad to Mexico[3]. It was thought to have been caused by a combination of factors: warming sea temperatures, the increased nutrient loading of the surface waters, and the reduction of *Sargassum* transport due to Gulf Stream slowing. The pestilent sulfuric odour and the sheer thickness of the algae mat (as dense as 10 feet in places) caused a widespread emergency situation.

Mass algal blooms of this scale can potentially cause serious nuisance to local communities and visitors, and they can also be harmful to the marine ecosystem[4].

Responding to impacts – what is already happening

An example of regional initiative to understand the impacts of climate change across sectors is the CARIBSAVE Climate Change Risk Atlas (CCRA) project. The CCRA project employs an evidence-based, inter-sectoral approach to examine vulnerability and adaptive capacities of key sectors with the aim to maintain a sustainable tourism industry in the face of a changing climate, tourism being a fundamental part of the economy of Caribbean nations.

There are also national examples of emerging adaptation initiatives. The government of Antigua and Barbuda is developing a national climate change adaptation policy and some of the ministries are incorporating climate change considerations into their policies and plans (CARIBSAVE, 2011a). The government of Grenada is also committed to adapting to climate change and they recently developed the Strategic Program for Climate Resilience which includes practices and actions for adaptation and mitigation of climate change impacts to this island (CARIBSAVE, 2011d). The Belize Climate Change Adaptation Policy aims to get all government agencies to incorporate climate change in their activities and policies, with a heavy focus on public awareness and education (CARIBSAVE, 2011b).

Examples of resilience-building that could indirectly help support adaptation

The Aquatic Living Resources Act aims to rewrite the fisheries law in Belize to ensure the long-term sustainability of the aquatic resources. There is a growing number of Marine Protected Areas (MPAs) in Belize, covering approximately 250,000ha of marine area (Cooper et al. 2009). Belize has a strong history of environmental research and monitoring compared to other Caribbean countries and the Coastal Zone Management Authority and Institute (CZMAI) is gradually building capacity (CZMAI, 2016). Belize also benefits from hosting several regional agencies under official CARICOM mandates, including the Caribbean Community Climate Change Centre (CCCCC or 5Cs) and the Caribbean Regional Fisheries Mechanism (CRFM). Mangrove rehabilitation is underway in Belize; the Riley Encased Methodology has proven successful in some exposed locations.

There is an initiative called the Green City programme in Portsmouth, Dominica, which may help Portsmouth on its way to adapting to climate change. The disaster management system in Dominica has a satisfactory capacity to adapt to climate change and to respond to disasters, although there are areas of improvement to help reduce the vulnerability of the country. The Government of Saint Lucia is working towards achieving sustainable development and climate resilience; a key policy undertaken is the Saint Lucia National Climate Change Policy and Adaptation Policy and Plan. The long history of natural disasters has motivated the National Emergency Management Organisation (NEMO) to produce hazard maps and seek to reduce loss of lives and livelihoods. Another government initiative to improve disaster management and raise awareness in Saint Lucia is the Strategic Programme for Climate Resilience (SPCR), aimed to reduce vulnerability to current and future disasters. There is also some climate change awareness amongst the communities in Saint Lucia. In Jamaica, the Office of Disaster Preparedness and Emergency Management (ODPEM) aim to build adaptive capacity. The Caribbean Disaster Emergency Management Agency (CDEMA) have also conducted programmes in Jamaica and provided vulnerability data. The Dominican government has developed various policies to address environmental issues and has begun to implement strategies to monitor and build resilience to climate change (CARIBSAVE, 2011c).

To address the issue of disaster management in Antigua and Barbuda, the Ministry of Tourism has committed to leading a partnership between public and private sector stakeholders to ensure information on hygiene, safety and disaster risks are managed and guests and staff are prepared for any emergency situation (Kingdome Consultants Ltd, 2004).

[3] https://www.theguardian.com/environment/2015/aug/10/caribbean-bound-tourists-cancel-holidays-due-to-foul-smelling-seaweed

[4] https://robertscribbler.com/2015/08/19/massive-sargasso-seaweed-bloom-is-choking-the-caribbean-climate-change-a-likely-culprit/

There is an Integrated Water Resources Management Plan being prepared for the SIDS, as part of the Integrated Watershed and Coastal Areas Management Project for Caribbean SIDS. There are a number of initiatives taking place in Caribbean countries to develop and deliver healthcare policies, food safety training and early disease warning systems.

Further development of understanding to support adaptation

Some key areas where further understanding is required in order to support adaptation efforts are given below.

Data collection

Detection of long-term statistical changes in precipitation is needed to allow better understanding of the impacts of climate change in small island hydrology and water resources.

An inventory of existing sea defences is a priority, to allow climate change adaptation to be integrated into development plans, tourism plans and for government insurance policies to take sea-level rise into account.

Public engagement

Disaster education and response training are needed to stimulate a more proactive attitude towards storm preparation and risk mitigation.

Evaluate the complex mix of factors that determine destination choices for tourists under a changing climate. For example, mass coral bleaching and mortality can diminish the appeal of destinations for diving-related tourism, although the level of awareness of tourists of impacts and expected economic impacts are uncertain (Hoegh-Guldberg et al, 2014).

Valuation studies and impact assessment

In the Caribbean, valuation could shed light on a number of important policy questions related to the protection, restoration, and sustainable use of coastal ecosystems – including questions related to tourism, fisheries, coastal erosion and climate change (Waite, et al. 2014). Most valuation studies focus on the impact of extreme events such as hurricanes or droughts on the agricultural, tourism and fisheries sectors, based on the market value of infrastructure, hardware or produce (Bueno et al., 2008). There is an urgent need however to project estimations of the cost of climate change impacts on the environmental services of marine and coastal habitats across the Caribbean Region like coral reefs, mangroves, beaches and seagrass beds. Examples of coastal ecosystem goods and services include: provisioning services (food, water, raw materials, medicines); regulating services (flood/storm/erosion protection, climate regulation); cultural services (tourism and recreation, history, culture, traditions, science, education, knowledge); supporting services (primary production, nutrient cycling, species and ecosystem protection) (Waite et al. 2014).

- A more detailed analysis of the impacts of sea-level rise for major tourism resorts, critical beach assets, cruise ship ports and supporting infrastructure is needed, in order to accurately assess the implications for inundation and erosion along the coast.

The individual topic papers on fisheries, settlements and infrastructure and tourism include more detailed information on knowledge gaps and how to address them.

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