2013

Ecosystem based approaches for climate change adaptation in Caribbean SIDS

REPORT

Bruno Chatenoux (UNIGE/GRID-Genève)
Dr. Alexander Wolf (ZMT - Leibniz Center for Tropical Marine Ecology)

UNIGE/GRID-Genève
UNEP/GRID-Geneva

Global Change& Vulnerability Unit
11, ch. Des Anémones
1219 Châtelaine
Geneva – Switzerland

Website: www.grid.unep.ch

Leibniz Center for Tropical Marine Ecology (ZMT) GmbH

CORE - Coral Reef Ecology Group
6, Fahrenheitstr.
28359 Bremen
Germany

Website: www.zmt-bremen.de/

Lead authors

Bruno Chatenoux (UNIGE/GRID-Genève) and Alex Wolf (Leibniz-Center for Tropical Marine Ecology ZMT)

Citation:

Chatenoux, B. and Wolf, A. (2013) Ecosystem based approaches for climate change adaptation in Caribbean SIDS. UNEP/GRID-Geneva and ZMT Leibniz Center for Tropical Marine Biology, pp.64.

Funding

This project implemented by UNEP/GRID-Geneva and ZMT for Caribbean Community Climate Change Centre is funded by the German development Bank (KfW).

Disclaimer

Acknowledgements

This report would not exist without the invaluable help of Dr. Pascal Peduzzi (UNEP/GRID-Geneva) and Dr. Josef Haider (KfW).

We would like to thank colleagues from the various environmental departments who provided us with important information, reports and contacts: Arlene Maheia, Colin Gillet (Coastal Zone Management Authority and Institute Belize), Dr. Leandra Cho-Ricketts (Environmental Research Institute Belize) and Dr. Melanie McField (Healthy Reef Initiative); Keith Nichols and Dr. Kenrick Leslie (Caribbean Community Climate Change Centre, Belize); Mrs. Yasa Belmar (Environmental Management Department, St. Vincent and the Grenadines); Ms. Black-Layne and Mr. Jason Williams (Department of Environment, Antigua and Barbuda); Dr. Chris Cox (CEHI, St. Lucia); Dr. Kim Baldwin and Prof. Robin Mahon (University of West Indies, Barbados); Dr. Amelia Moore and Dr. Craig Layman (Florida State Universtiy); Dr. Eddy Silva (TNC Haiti).

Azaidy Khan and Mr. Jerry Mitchell (Grenada) provided valuable information on ongoing and potential coral reef restoration projects, Dr. Gregg Moore (University of New Hampshire) who helped to gather information on mangroves in Grenada and the Grenadines and Prof. Thomas Goreau for interesting discussions on coral reef restoration.

Dr. Georg Heiss, Dr. Ruben Torres and colleagues from Reef Check as well as Dr. Judith Lang from AGRRA (Atlantic and Gulf Rapid Assessment - AGRRA).

We would like to thank Dr. David Smith and particularly Dr. Steve Schill and Dr. Ruth Blyther from the Nature Conservancy for their valuable contributions and discussions.

Prof. Christian Wild and Christian Jessen from the Leibniz-Center for Tropical Marine Ecology ZMT, for administrative and technical support.

Ecosystem based approaches for climate change adaptation in Caribbean SIDS

Report

2013

Bruno Chatenoux (UNIGE/GRID-Genève)
Dr. Alex Wolf (Leibniz-Center for Tropical Marine Ecology ZMT)

Contents

Executive summary.. 4
Introduction.. 5
Status and natural protection potential of ecosystems.. 6
Ecological importance of the most relevant marine ecosystems.. 7
Identification of major external stressors.. 8
    Sea level rise.. 8
    Elevated Sea Surface Temperature..10
    Coral bleaching..12
    Tropical cyclones..13
    Ocean acidification..14
    Anthropogenically-derived pollution of coastal zones..15
    Overfishing..16
Estimated impact of Climate Change in Caribbean SIDS..16
The potential of ecosystems for CCA activities..17
    Ranking countries..18
    Commitment to and implementation of coastal zone management efforts..19
Country description..21
    Antigua & Barbuda..22
    The Bahamas..23
    Barbados..24
    Belize..25
    Dominica..26
    Grenada..27
    Guyana and Suriname..30
    Haiti..31
    Jamaica..32
    Montserrat..38
    Saint Kitts and Nevis..39
    Saint Vincent and the Grenadines..41
    Santa Lucia..43
    Trinidad and Tobago..47
Tourism expenditure through time..48
Fish capture through time..48
Mangrove coverage through time – demo sites..50
Monitoring efforts & indicative list of Local Adaptation Measures (modified from KfW's Aide memoire_EBACC)..54
Conclusion and recommendations..57
    Factors ignored, limitations & additional information..57
Acronyms..58
References..59
Weblinks..64

Executive summary

Existing climate variability and global climate change are major threats to sustainable development in the Caribbean, particularly for the Small Island Developing States (SIDS). Hurricanes, storm surges and extreme rainfall events cause major damages to the assets of coastal populations, infrastructure and ecosystems. Climate projections suggest that sea level rise (SLR) and the increase of sea water temperature will continue, as well as the intensity and frequency of extreme weather events are likely to increase.

Ecosystem-based Adaptation (EbA) approaches, combining both engineered and community-based benefits, are promising to prepare SIDS for future climate change scenarios.

This review i) identifies Caribbean SIDS which highly depend on their marine ecosystems and are particularly vulnerable to climate change related risks and ii) provides a recommendation on SIDS which are most suitable for EbA approaches including restoration and climate change adaptation efforts. The selection was based on an assessment of the most important coastal ecosystems, namely mangrove forests, seagrass meadows and coral reefs, which can mitigate the consequences of climate change. In particular, the ecosystems' extent, status, and potential to climate change adaptation (CCA) were assessed. The existence of protected areas and the management of those areas were considered additional assets as they constitute absolute pre-requisites for any EbA approach addressing restoration efforts, to become successful in the long run.

The island states of Grenada, Santa Lucia, Jamaica, Saint Vincent & the Grenadines and The Bahamas display suitable conditions, given certain prerequisites are to be met, for restoration efforts of various kinds to be implemented in the near future.

- <u>Grenada</u> and <u>St. Lucia</u> could both be considered suitable due to the future importance of their (coral reef) ecosystems and the overall not too heavily degraded ecological conditions. Under changing climatic conditions, the services provided by those ecosystems will strongly contribute to the island states' socio-economical and ecological well-being. Furthermore, these small SIDS both received substantial "start-off" management help, e.g. via the IWCAM projects, which raised their awareness and tested their commitment to time consuming projects. Apparently, the local authorities and, for St. Lucia, also the communities showed the motivation to improve the environmental conditions.
- <u>Jamaica</u> could be considered a suitable SIDS effort due to its economically and ecologically valuable and large ecosystems. Likewise, <u>St. Vincent & Grenadines,</u> due to large areas of coral reef ecosystems and the strong dependence on its natural resources. Especially St. Vincent and the Grenadines currently receive valuable contributions from NGOs and the University of the West Indies in terms of capacity building and marine resource management. These recent improvements make SVG particularly attractive for upcoming EbA projects.
- <u>The Bahamas</u> could be considered as suitable, since they exhibit considerable ecological assets and the potential risk under climate change scenarios is very high. Also, they appear to have promising governmental programmes running already.

It is important to acknowledge the fact that this review is based on the evaluation of ecological assets of Caribbean SIDS and their potential to adapt to CCA scenarios. The review did not take into account, in a quantitative way, any socio-economic assessments to validate and specify the dependence of coastal communities on their natural resources, and the benefits deriving from them.

Introduction

Climatic (sea level and temperature rise, storm intensification, ocean acidification) and anthropogenic (coastal development, pollution) changes can directly impact coastal ecosystems and communities. Given their small size, Small Islands Developing States (SIDS) display the largest proportion of their territory as coastal zones, consequently exposing both the population and infrastructure to certain threats. Healthy ecosystems, such as coral reefs, mangroves and sea grass meadows can reduce the intensity of waves as well as provide other co-benefits (food supply, craft, tourism, cleaner water, and aesthetical values). Coral reef and seagrasses meadows were found to be highly efficient in mitigating beach erosion (Villanoy *et al.*, 2012; Velegrakis *et al.*, in press; Peduzzi *et al.* 2012; Elginoz *et al.*, 2011; Augustin *et al.*, 2009; Mendez & Losada, 2004). Mangroves were found to reduce impacts, especially from storm surges (Das, 2012; Vo-Luong & Massel, 2008; Badola & Husain, 2005; IFRC, 2002) as validated by local and regional studies, including laboratory and basin experiments or numerical models.

The SIDS in the Wider Caribbean Region are typical examples and are referred to as a “climate change vulnerability hotspots” by UNWTO, UNEP and WMO (Baastel, 2009).

The Caribbean is one of the most tourism-dependent regions in the world (Forster *et al.*, 2012), attracting annually more than 22 million tourists (CTO, 2011), mainly due to its exceptional natural resources (beach, coral, landscape). Annually, around 2 million people (12% of total labour forces) are employed in the tourist sector, generating around 47 billion USD of revenue in 2012, i.e. 14% of GDP and 25 billion USD of exports, 15% of total exports (WWTC, 2012).

There are different ways to address adaptation to climate change. A ”hard” approach based on engineered, infrastructure-based solutions, a “soft” approach using ecosystem-based solutions, as well as a hybrid approach, mixing engineered with ecosystems-based solutions.

Engineered solutions are often privileged as their impacts and costs can be determined with a greater precision than natural protections. They are perceived as punctual projects restricted to defined periods with an immediate effect. This last perception is incorrect as they need costly maintenance and replacement, moreover an inappropriate implementation or a lack of maintenance can even increase or modify the risks. Hard solutions have also the drawback to be hardly adaptable to changing risks and are complex to integrate in the natural environment.

Ecosystem-based adaptation (EbA) actions are being increasingly considered, although still largely under-represented. The reason is a generally larger uncertainty regarding their implementation. Being more recent, there are not as many studies which can show their costs versus benefices. However, they are increasingly being recognised as the "no regret" option, given that they are offering co-benefits (they support biodiversity, store carbon, have aesthetical value, provide recreational area, food supply, self maintenance and can usually be implemented by local communities after a small training).

Due to their multiple advantages, EbA approaches deserve more attention. Certainly, they cannot fulfil all purposes and caution should be taken when regarding the restoration of ecosystems. For example, large areas of mangroves were planted in inappropriate location after the 2004 tsunami leading to a loss of investments. Ensuring successful coral reef restoration demands water quality standards, often requiring actions to limit or remove sources of pollution and sedimentation in the upstream or surrounding watersheds.

EbA uses the capacity of nature to increase the resilience of human communities against the impact of climate change through the sustainable delivery of ecosystem related services. Whereas engineered solutions are usually performed by large companies, and, in the case of the Caribbean, foreign companies, requesting heavy machinery, EbA approaches can be sustained by local communities after guided implementation, using natural resources in a sustainable way. Adequate implementation requires sufficient communication between parties, and potentially capacity building or concomitant changes in environmental policies. The EbA approach is the one that will be promoted in this document.

The German Ministry for Economic Cooperation and Development (BMZ), in support of the Caribbean Community (CARICOM members) has financed the current project which addresses the role of coastal ecosystems (coral reefs, seagrass meadows and mangrove forests) and their contribution to the reduction of climate-related risks and climate change adaptation in the coastal zones of Caribbean States. This report presents the results of a preceding ecosystem survey, and contains the recommendation of 3 CARICOM countries where ecosystems based Disaster Risk Reduction (DRR) activities should be carried out in priority. The analysis is based on available databases as well as grey and peer-reviewed literature.

Status and natural protection potential of ecosystems

The potential protection from climate change related impacts varies depending on the type of environmental feature concerned.

The latest estimate of mangrove forest distribution indicates that in 2011, about 50% of its original global cover had disappeared and the majority of the remaining mangrove forests are in degraded conditions (Giri *et al.*, 2011), principally due to conversion for agriculture, aquaculture, tourism, urban development and overexploitation. Duke *et al.* (2007) even suggested that without a change in policy, protection and law enforcement, mangrove forests could disappear in the next 100 years.

Mangroves are recognised to strongly absorb wave energy, consequently reducing their impact inland (Das, 2012), and their effectiveness depends on tree density, stem and root diameter. Their resilience to sea level rise and consecutive shoreline evolution is generally considered efficient, although varying depending on the location, as soil accretion rates in mangrove forests are generally coping with sea-level rise (Alongi, 2008).

Mangrove forests are generally located in sheltered areas, and rarely exposed to high wave energy from the open ocean. Consequently, their protective role against wave energy has to be contextualized within their natural environment (Chatenoux and Peduzzi, 2005 and 2007).

Since first measurements in 1879, 29% of seagrass meadows disappeared at a rate of 110 km^2/yr (Waycott *et al.*, 2009), as a result of sediment loading, pollution and habitat destruction (mainly, mechanical damage, aquaculture fishery activities and burial). The effects of global climate change are not yet very well studied, but the resilience of seagrass meadows can be improved locally by sustainable coastal development practices along with conservation initiatives (Short *et al.*, 2011).

The effect of seagrass on wave attenuation is well known and described by many authors (Fonseca, 1996; Dubi & Torum, 1994; Gambi *et al.*, 1990; Christianen et al. 2013). Wave dumping occurs from the bottom (seafloor) throughout the water column (Augustin *et al.*, 2009), and the absorption of wave energy depends on the type of species (Mendez & Losada, 2004), as well as on the length of the leafs and the density of the underwater vegetation. Consequently, the potential of wave attenuation increases as the waves approach the shoreline and the ratio mangrove size / water depth increases. Seagrasses dissipate the wave energy gradually, as opposed to engineered breakwater (such as underwater walls) which is blocking it all at once (Elginoz *et al.*, 2011). The loss of seagrass beds has been linked to beach erosion in Jamaica (Long Bay and Bloody Bay, Negril).

Compared to mangrove forests, coral reefs occur throughout most coastal zones in the Wider Caribbean Region and constitute the major ecological asset of many islands against erosion processes and wave attenuation. To date, 75% of the Caribbean's coral reefs are threatened by local pressures, such as coastal development, unsustainable fishing practices, land- and marine-based pollution, as well as globally, by ocean warming and acidification (Hughes 2003).

Growth and accretion rates of coral reefs are in the same order of magnitude as sea level rise, highlighting the potential to sustain wave energy attenuation. However, this potential is expected to decrease in the near future due to accelerated sea level elevation and in the context of ocean acidification (Hoegh-Guldberg, 2011). At comparative width, coral reefs were found to be 23.5 times more efficient than seagrass for mitigating beach erosion (Peduzzi *et al.*, in prep.).

The International Union for Conservation of Nature (IUCN) assigned the status of elevated risk of extinction for 33% of the 704 coral reefs species worldwide, showing the dramatic increase of threat in recent decades (Carpenter *et al.* 2008).

Ecological importance of the most relevant marine ecosystems

Generally, the distribution of seagrass meadows, mangroves and coral reef ecosystems varies extensively across the Wider Caribbean region (see distinct country maps below).

Apart from their importance in shoreline protection, seagrass meadows are crucial (nursery) habitats for marine biodiversity in coastal ecosystems and show high rates of primary production. Furthermore, they help to stabilize sediment, maintain water clarity, and provide nutrient recycling. With regard to seagrass meadows, large areas (percentage cover, relative to land area) were found for Antigua & Barbuda, Belize, Dominica, St. Kitts & Nevis, and Barbados, the other countries feature patchy and small areas. One important criterion for successful restoration activities, i.e. to sustain the overall functionality of the ecosystem on the long run, is to assure sufficient connectivity of partly divided areas and an adequate size of the area to be restored. In that aspect, the five above-mentioned countries may be most suitable SIDS in terms of protection and reforestation efforts from a Disaster Risk Reduction (DRR) perspective. Generally, system-specific attributes can result in large differences in the sensitivity and susceptibility to eutrophication (Cloern 2001). Excessive nutrient inputs to tropical seagrass meadows have been found to increase macroalgal epiphyte loads, lowering seagrass productivity and ultimately causing seagrass die-off (Duarte 2002). Since seagrass populations respond cumulatively to continued eutrophication, they do often serve as ecological signatures of long-term water quality.

Mangrove forests are adapted to waterlogged, saline conditions, occur along a gradient from oligotrophic to eutrophic conditions.-There are three species commonly found in the Caribbean; Red (*Rhizophora mangle*), Black (*Avicennia germinans*), and White (*Laguncularia racemosa*) mangroves. They all provide habitats and (nursery) feeding grounds for fish, reptiles, mammals and birds. Especially the linkage between the productivity of coral reef fisheries and the health of nearby mangrove forests has been highlighted by many studies (Mumby et al. 2004; Nagelkerken et al. 2000). Mangroves are limited by nitrogen and/or phosphorus availability (Duke 2007; Lovelock 2004), many factors influence their nutrient cycling abilities (ion retention, nutrient uptake efficiency variations in tidal inundation, climatic disturbances), and they are thought to flourish in nutrient-poor environments primarily as the result of efficient mechanisms for retaining and recycling nutrients. Mostly, their productivity is negatively correlated with eutrophication (Linton and Warner 2003, Feller 2007). Especially the coastlines off continental countries such as Belize, Guyana and Suriname seem to have well connected and large areas of remaining mangrove forests, whereas all other SIDS only exhibit small, patchy remnants of mangrove areas.

Coral reef ecosystems occur throughout most coastal zones in the Wider Caribbean Region. Their importance as marine habitats, feeding grounds and fisheries areas, as well as for sediment stabilization, production, and recycling processes, make their overall ecological and economic contribution an invaluable and irreplaceable asset for most Caribbean SIDS. Importantly, although coral reefs still cover partly vast areas in selective Caribbean countries, their original functionality is about to change and is partially impaired in many SIDS already. The commonly observed consequence of changed functionality is the shift from coral to macroalgal dominance and the absence of herbivorous fishes. Due to this change of functionality (or loss, if permanent), associated ecosystem services, most notably the protection from erosion and provision of sustainable livelihoods, will eventually subside and vanish (> 50-100 yrs.).

It is important to acknowledge, that the Wider Caribbean Basin is predisposed to disadvantageous environmental conditions, resulting in the generally low resilience of coral reefs, especially when compared to the Indo-Pacific (Roff 2012). Reasons are lower biodiversity, faster macroalgal growth, constant iron input from sub-Saharan aeolian dust, lower herbivore biomass, and missing groups of herbivores (impairing functional redundancy). This predisposal impairs fast recovery of coral reefs after natural disturbances such as hurricanes and elevated seawater temperatures. Qualitatively, coral cover, which can serve as measure for reef functionality, ranges between 5-15% (average) in most CARICOM countries. With regard to restoration efforts, the coral cover in reefs is thus a less important criterion for selection than the mere presence and general condition of reef systems.

Identification of major external stressors

The CARICOM environment is under stress from a large number of threats ranging from global to local. The main ones are presented in this chapter.

Sea level rise

Global Mean Sea level (GMSL) is monitored since the 50's (using tide gauges) and shows an average rise of ~1.8 mm/yr, principally due to the effects of global warming, i.e. the ocean's thermal expansion and land ice losses. Since the 90's, the sea level is closely measured by high precision satellite altimetry and shows an average increase of 3.2 mm/yr over the period 1992-2011 (Palanisamy *et al.*, 2012), 80% faster than the average IPCC projection from 1990 (Rahmstorf, 2010).

Changes in the oceans' sea levels vary geographically, mainly due to non-uniform ocean temperature and salinity (Lombard *et al.*, 2009), with a global maximum rise of 20 mm/yr (averaged over the period 1992-2012). In the Caribbean region, the values are comparatively smaller, remaining between a maximum rise of around 6 mm/yr in the Gulf of Mexico and a decrease of around 2 mm/yr in a few places outside the Caribbean Sea (Figure 1).

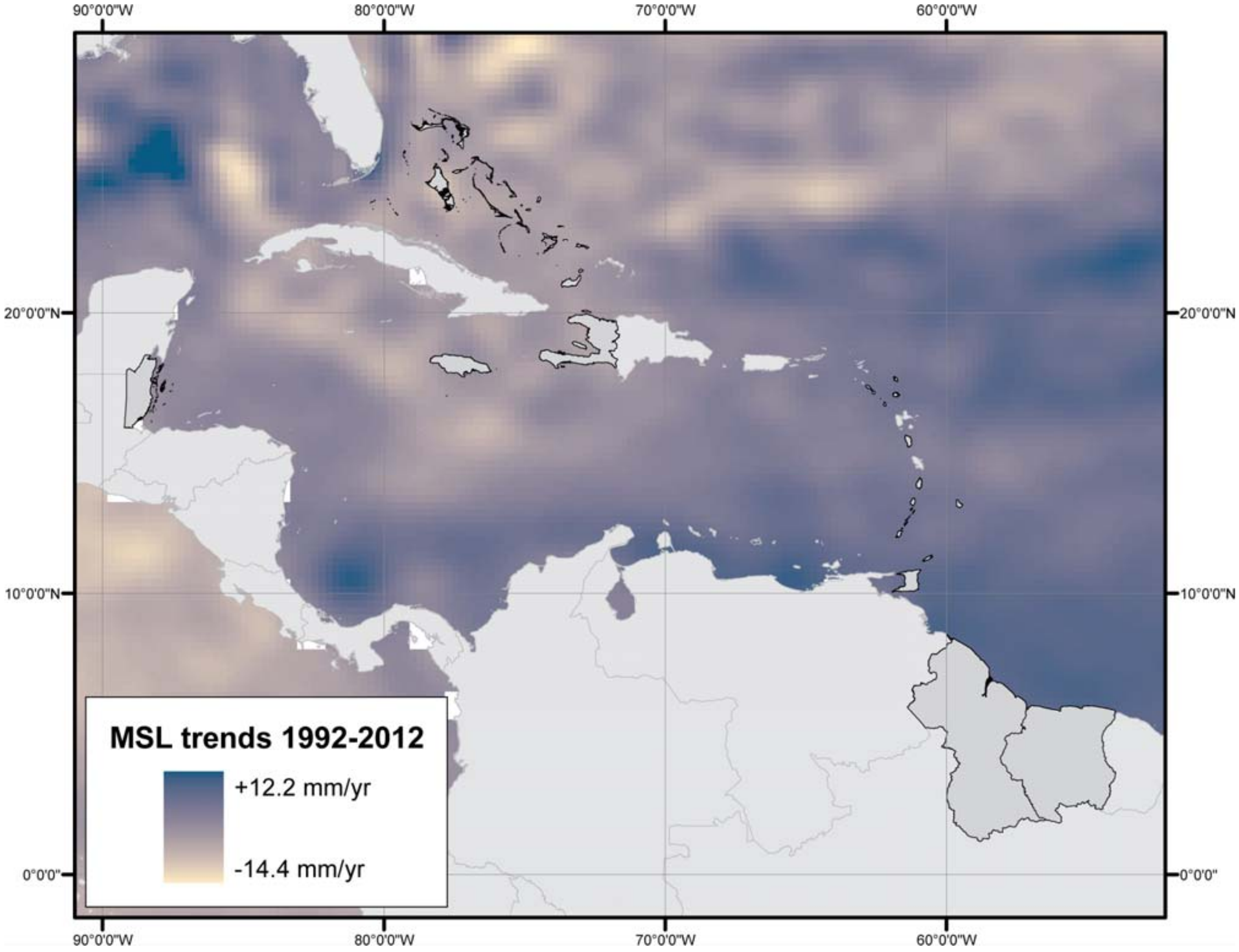


Figure 1 Mean sea level (MSL) change since 1992 (modeled by AVISO based on Topex/Poseidon data)

Country	MIN	MAX	MEAN
Antigua and Barbuda	2.5	2.8	2.8
Bahamas	-1.8	0.8	-0.5
Belize	0.7	1.4	1.0
Barbados	2.5	2.6	2.5
Dominica	1.9	2.1	2.0
Grenada	2.8	3.0	2.9
Guyana	3.3	4.2	3.6
Haiti	-0.5	0.6	0.0
Jamaica	0.0	1.1	0.8
Saint Kitts and Nevis	2.5	2.7	2.6
Saint Lucia	2.2	2.4	2.3
Montserrat	2.7	2.7	2.7
Suriname	3.3	4.1	3.6
Trinidad and Tobago	2.8	3.7	3.4
Saint Vincent and the Grenadines	2.6	2.8	2.7

Table 1 Minimum, maximum and mean sea level rise trends per CARICOM country (mm/yr as modeled by AVISO based on Topex/Poseidon data)

Table 1 above summarizes the sea level trends for each CARICOM country. The maximum values were found in countries facing the open ocean (Guyana and Suriname). All mean values are positive at the exception of the Bahamas which show a high range of variation, probably due to its large geographical extent.

It has to be flagged, the resolution of the current sea level change models remains quite rough (resolution of around 28 kilometres) and should only be used at a regional scale. Moreover, low-frequency (multidecadal) or chaotic phenomenon's (such as El Nino-Southern Oscillation or cyclonic activity) superimpose to the general trend. Consequently, regional studies use tide measuring stations to improve the model precision in the Caribbean region, e.g. Palanisamy *et al.* (2012) estimate the regional mean sea level trend to remain around 2 mm/yr, which is in line with Table 1 means.

Following the release of the IPCC AR4 publication (2007), the evaluation of the SLR magnitude revealed a maximum of 60 cm from 1990 to 2090, assuming a near zero net contribution of ice sheets. However, new studies highlighted the uncertainty of such forecasts, estimating the contribution of ice sheet melting to SLR to be 80% (Cazenave *et al.*, 2008; Meier *et al.*, 2007). Figure 2 displays the global SLR for various model outcomes, taking ice sheet melting and the recent acceleration in decline, into account (Steig *et al.*, 2009; Witze, 2008; Pfeffer *et al.*, 2008). According to Steffensen *et al.* (2008) and Grinsted *et al.* (2009), the SLR is estimated to exceed 2 m worldwide. On a global scale, the Caribbean region will be more strongly affected by SLR than other parts in the world, due to non-uniform distribution of water bodies on the earth's surface (Bamber *et al.* 2009).

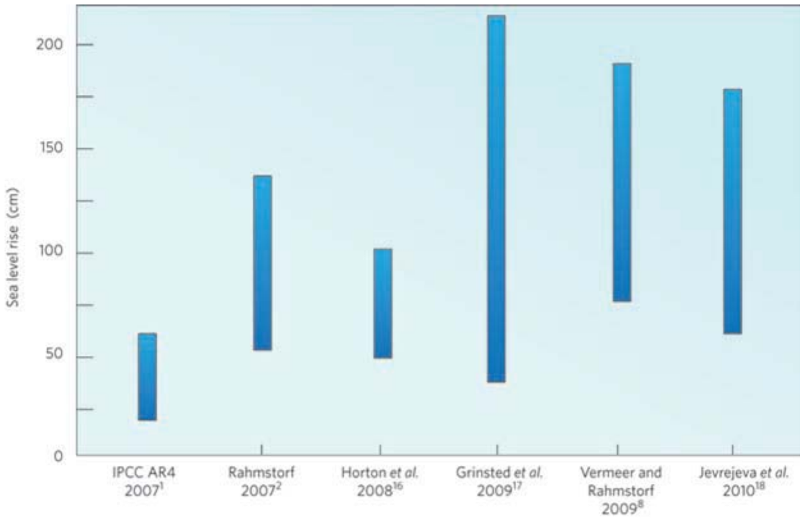


Figure 2 Ranges of sea level rise estimated for 2100 from semi-empirical models compared to IPCC AR4 (extracted from Rahmstorf 2010)

SLR will cause the submergence, flooding and erosion of coastal areas, including salt water intrusion into the groundwater. Furthermore, coastal wetlands such as mangroves and salt marshes will be heavily impacted since the steady supply of essential nutrients will be impaired without the necessary material to follow the sea level elevation (Nicholls and Cazenave, 2010).

Even a moderate elevation of the sea level, either slowly progressing or induced by sudden events, can become hazardous due to human activities such as drainage or ground water withdrawal in coastal areas. Examples are the infrastructural development in Tokyo, Japan, which led to subsidence effects reaching up to 5 meter during the 20th century. Likewise, risk has been artificially increased in wetland areas around New Orleans, where newly established protective infrastructures, which led to increased settlement, could not prevent significant damage during the flooding in 2005 (Nicholls *et al.*, 2008).

Elevated Sea Surface Temperature

The increase in the Sea Surface Temperature (SST) has become a major threat to coral reefs and is likely to affect tropical cyclone frequency and intensity (see two next chapters).

Several global models of SST were developed during the last decade. For the present study we use the Extended Reconstruction SST (ERSST) version 3, developed by the National Oceanic and Atmospheric Administration (NOAA), starting in 1854 (Smith *et al.*, 2008).

Eakin *et al.* (2010) used this dataset to compute time series of SST anomalies (reference period 1901-2000) for the Caribbean region (Figure 3), showing a net increasing trend since 2000.

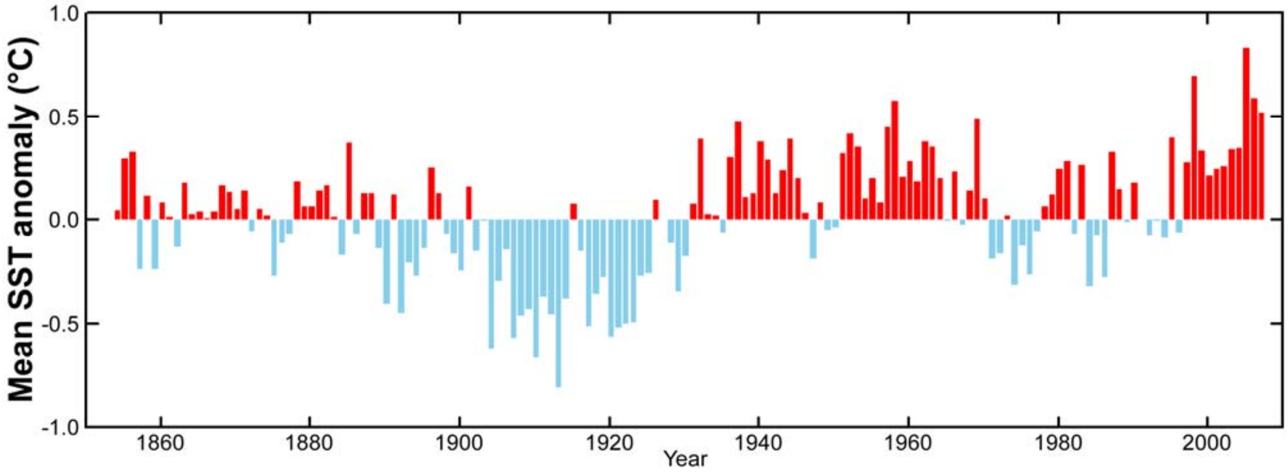


Figure 3 Long-term temperature anomalies in the Caribbean based on the reference period 1901–2000 (based on ERSST v.3b and extracted from Eakin *et al.*, 2010)

The World Meteorological Organization (WMO) recommends SST anomaly calculations to be based on a 30 year period (Xue, 2003), and the 1971-2000 period (ERSST v.3b website) was used as reference in figures 4 and 5.

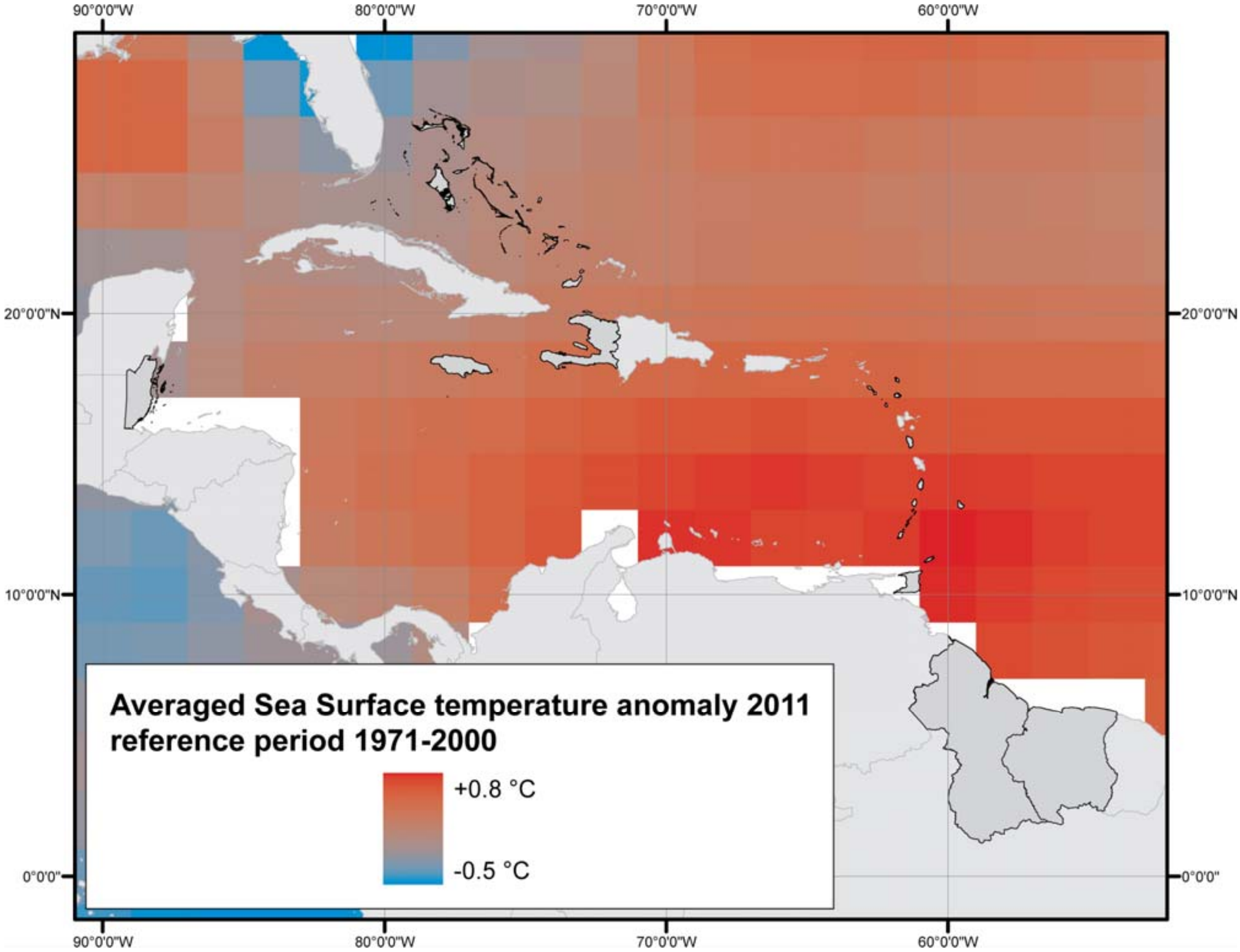


Figure 4 Average Sea Surface Temperature anomaly 2011 (source NOAA/ERSST v.3b)

Figure 4 represents the average values of SST in the CARICOM region during the year 2011, showing a generally increasing trend from North-West to South-East, minimum values in the northern part of the Bahamas and maximum values along the coast of Venezuela.

As for the mean sea level model, the resolution of the global model remains too rough for local analysis, and in-field measurements have to be used. Simpson *et al.* 2009 present the records of seven “virtual stations” (Figure 5), but without mentioning the source, the way of acquisition and coordinates of the stations. Again, all time series show a general increase in SST in the Caribbean region (Simpson *et al.*, 2010).

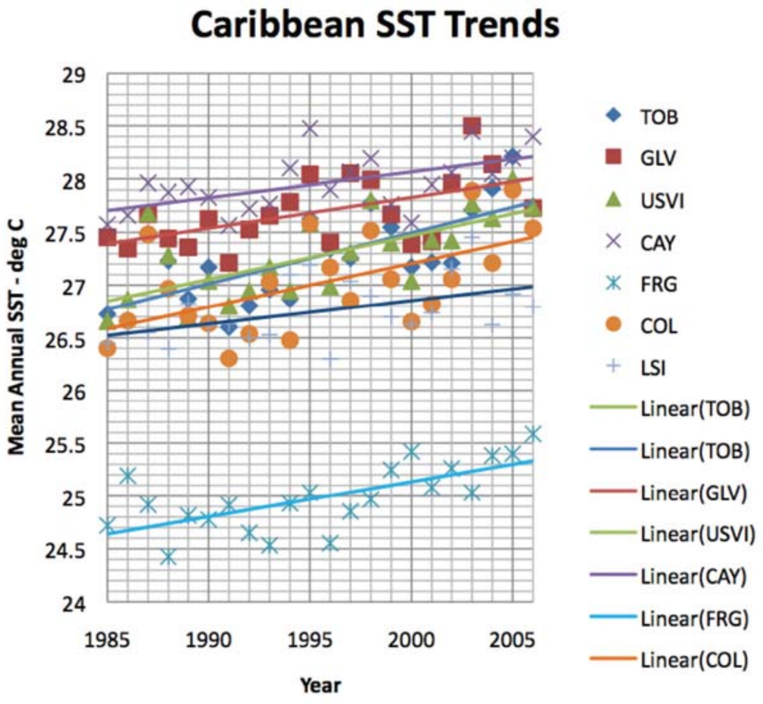


Figure 5 SST time series of seven representative Caribbean Virtual Stations (extracted from Simpson, *et al.*, 2009)

Coral bleaching

Coral bleaching occurs when scleractinian corals, the major reef building organisms, expel their symbiotic algae, the zooxanthellae, which provide nutrition but also the colour to the coral hosts. Coral bleaching can be caused by a variety of stressors, such as stressful light, temperature or salinity conditions, but also by factors such as cyanide fishing, herbicides, or bacterial infections. Bleaching can occur locally, in corals exposed to certain stressors, and globally, leading to mass bleaching events, mostly owed to increasing seawater temperatures (Hoegh-Guldberg, 2011). This process may be reversed when stressful conditions are limited in time or intensity, but may cause permanent bleaching and subsequent coral mortality under prolonged stressful circumstances.

10% of the world’s coral reefs are situated in the western half of the Atlantic Ocean, mainly in the Caribbean Sea and the Bahamas bank. At present, more than 90% of the reefs in these regions are endangered, 70% of them at a high level (Burke *et al.* 2011).

Eakin *et al.* (2010) and many others mention the year 2005 as causing the most severe bleaching event ever recorded in the Caribbean basin. McWilliams et al (2005) underline that events of elevated seawater temperatures will increase in intensity and constitute a permanent stressor to Caribbean reefs in the near future.

Numerous models (e.g. Simpson *et al.*, 2009) also conclude that conditions triggering bi-annual, severe bleaching events will be reached within 20 to 50 years. The gloomiest models estimated annual bleaching frequencies to occur within 30 years, surpassing the ability of coral reefs to recover, which may lead to an irreversible decline in coral species, similar to the last coral extinction in Cretaceous-Tertiary boundary when up to 45% of coral species disappeared (Carpenter *et al.*, 2008).

Tropical cyclones

Hurricanes in the Atlantic basin have been thoroughly studied due to the quantity, quality and extent of observation records compared to other parts of the World.

Risk in general and human mortality risk in particular are mainly related to hurricane intensity, exposure and poverty (Peduzzi *et al.* 2012). Alarming evidences suggests that hurricane frequencies will probably decrease and intensities increase. Especially in the Western Atlantic north of 20° latitude, highest-category events are predicted to increase in intensity and frequency (Bender *et al.*, 2010; Knutson *et al.*, 2010; Elsner *et al.*, 2008).

Figure 6 represents the hurricanes' best track and the maximum Saffir-Simpson categories (related to wind intensities) recorded by satellite in the CARICOM region over the period 1970-2011. An important channel oriented from East to North-West can be seen between the continental part of Central America and the main islands of the region, and a second one of less importance in the north of these islands.

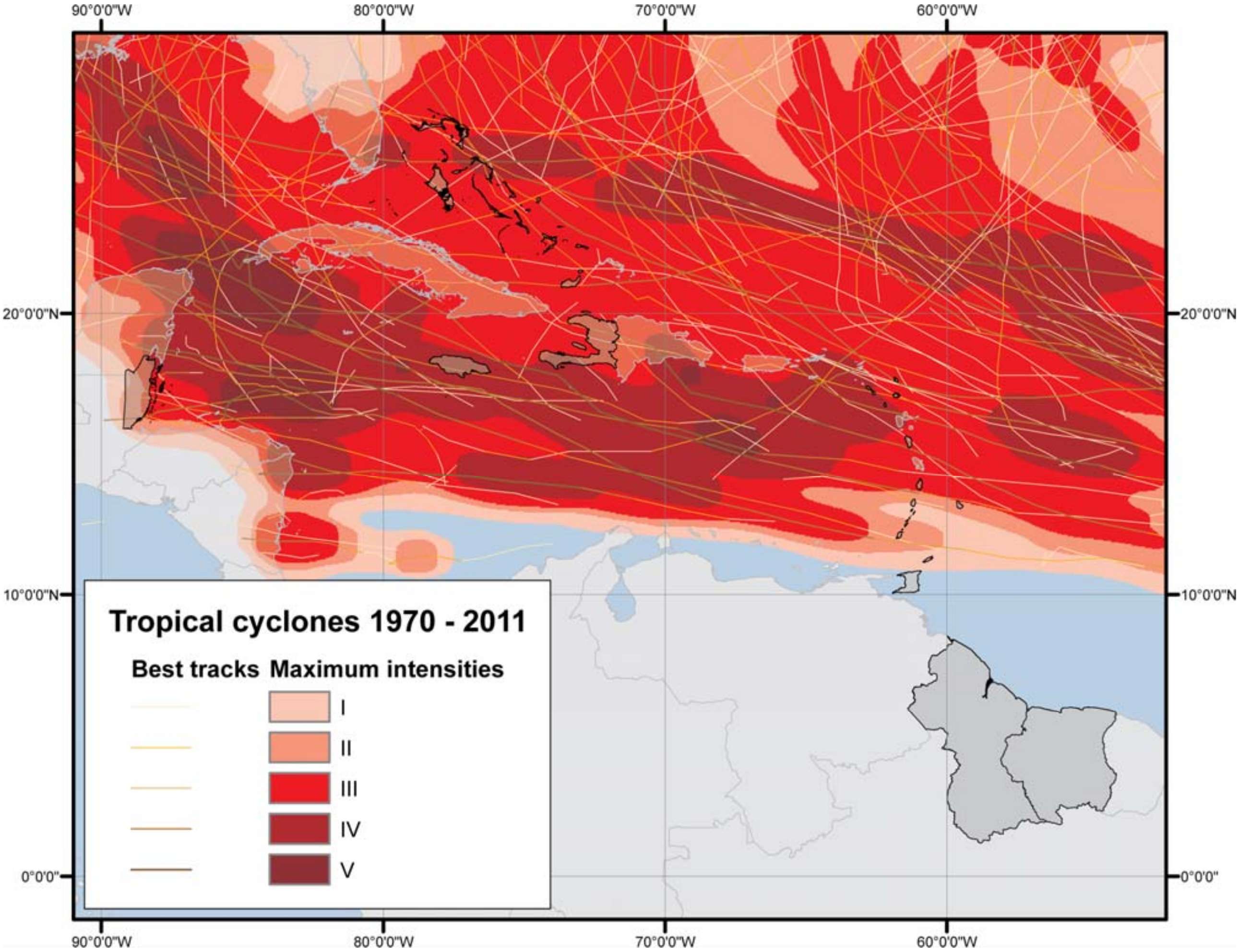


Figure 6 Tropical cyclones best tracks and maximum Saffir-Simpson intensities over the period 1970-2011 (source: UNEP/GRID-Geneva PREVIEW, 2012)

Figure 7 synthesizes the number of cyclones per Saffir-Simpson category in the CARICOM region, confirming a net increase of cyclone frequencies and intensities. A study in Jamaica (UNEP 2010) estimated that even using the most favourable model, more than one third of the beaches affected by a 50 year return storm surge would totally disappear by 2060.

Palanisamy *et al.* (2012) mention that during the last decade, more damage was caused to Caribbean coastal areas by cyclonic events than by SLR itself.

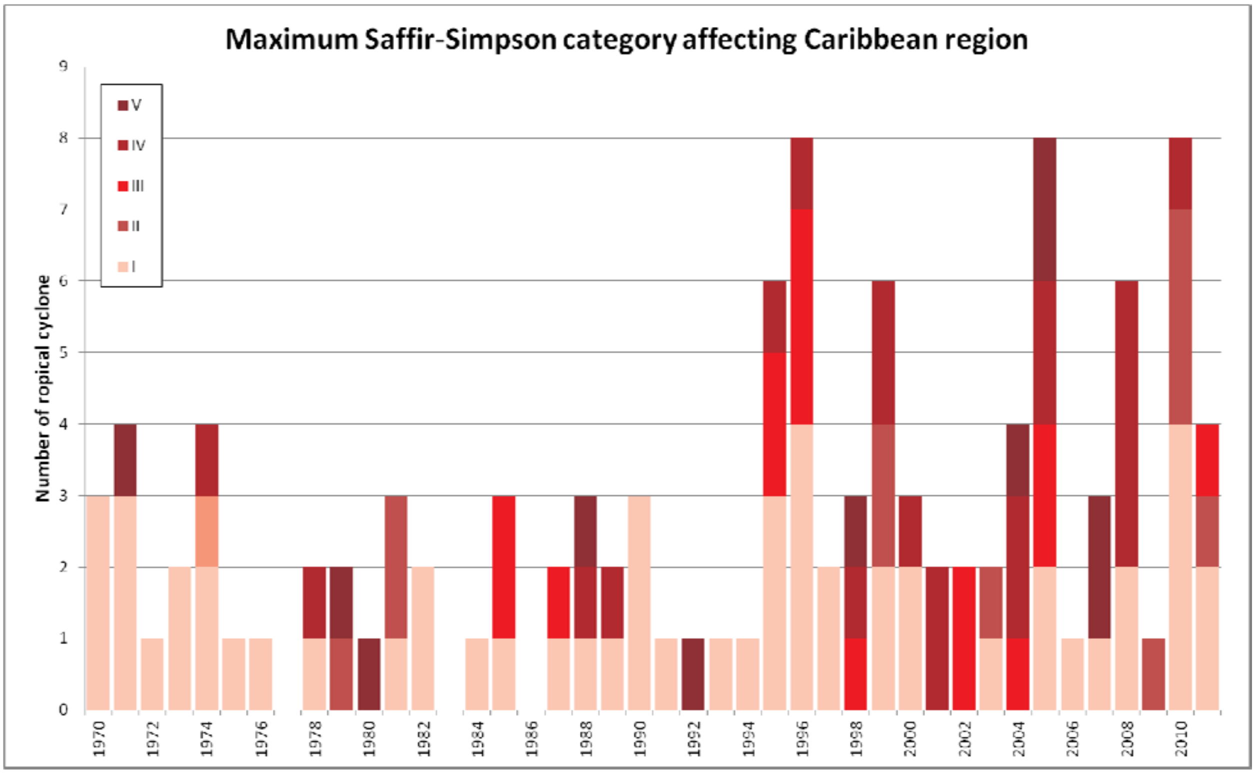


Figure 7 Maximum Saffir-Simpson categories affecting the Caribbean region, modeled over the period 1970-2011 (source: UNEP/GRID-Geneva PREVIEW)

Ocean acidification

Due to the absorption of atmospheric CO_2, the world's oceans are storing the equivalent of around one third of all anthropogenic emissions (Sabine *et al*., 2004). CO_2 reacts with water (H_2O) to form carbonic acid (H_2CO_3), reducing the pH of seawater. Likewise, the Aragonite Saturation State (ASS), which is closely related to the calcification rate of carbonate forming organisms such as corals, the major reef builders of coral reefs , and other skeleton-forming organisms (Gledhill *et al*. 2008), is reduced. The average pre-industrial level of the ocean pH was 8.2, now being 8.1 and may be reduced to 7.9 or 7.8 at the end of this century (UNEP, 2010). Although the oceans will remain basic (acidic solutions have a pH lower than 7.0), the reduction of seawater pH implies several important consequences.

Two examples, how elevated CO_2 levels may impact marine organisms have to be mentioned here: Firstly, both the larval dispersal and the homing behavior of coral reef fishes, i.e. the ability to localize their natural habitat, have been shown to be disturbed under high CO_2 conditions (Munday et al. 2009). Secondly, all organisms which are using carbonate ions to produce their shells or aragonite skeletons (gastropods, scleractinian corals) will be affected, since their capacity to absorb carbonate ions will be reduced. Coral reefs are affected by ocean acidification at various scales, from the impediment of coral larvae recruitment, which is crucial for the replenishment of reefs, towards the aggravated recovery of adult corals in already degraded reef ecosystems (Doropoulus et al. 2012; Hoegh-Guldberg 2011; Rau et al. 2012).

Gledhill and others (2008) combined in situ measurements, satellite remote sensing and modelling to estimate the spatio-temporal variability of ASS in the Greater Caribbean region over the period 1996-2006. They found the highest and most stable state in ASS to occur in the central part of the Greater Caribbean region in carbonate platforms of the Bahamas and Greater Antilles, potentially saving those areas some time compared to less favourably located island states. The study confirmed the clear decrease of the ASS, also on a long term scale, and a net increase in acidification (Figure 8), directly endangering calcifying organisms such as corals and gastropods and indirectly entire ecosystems.

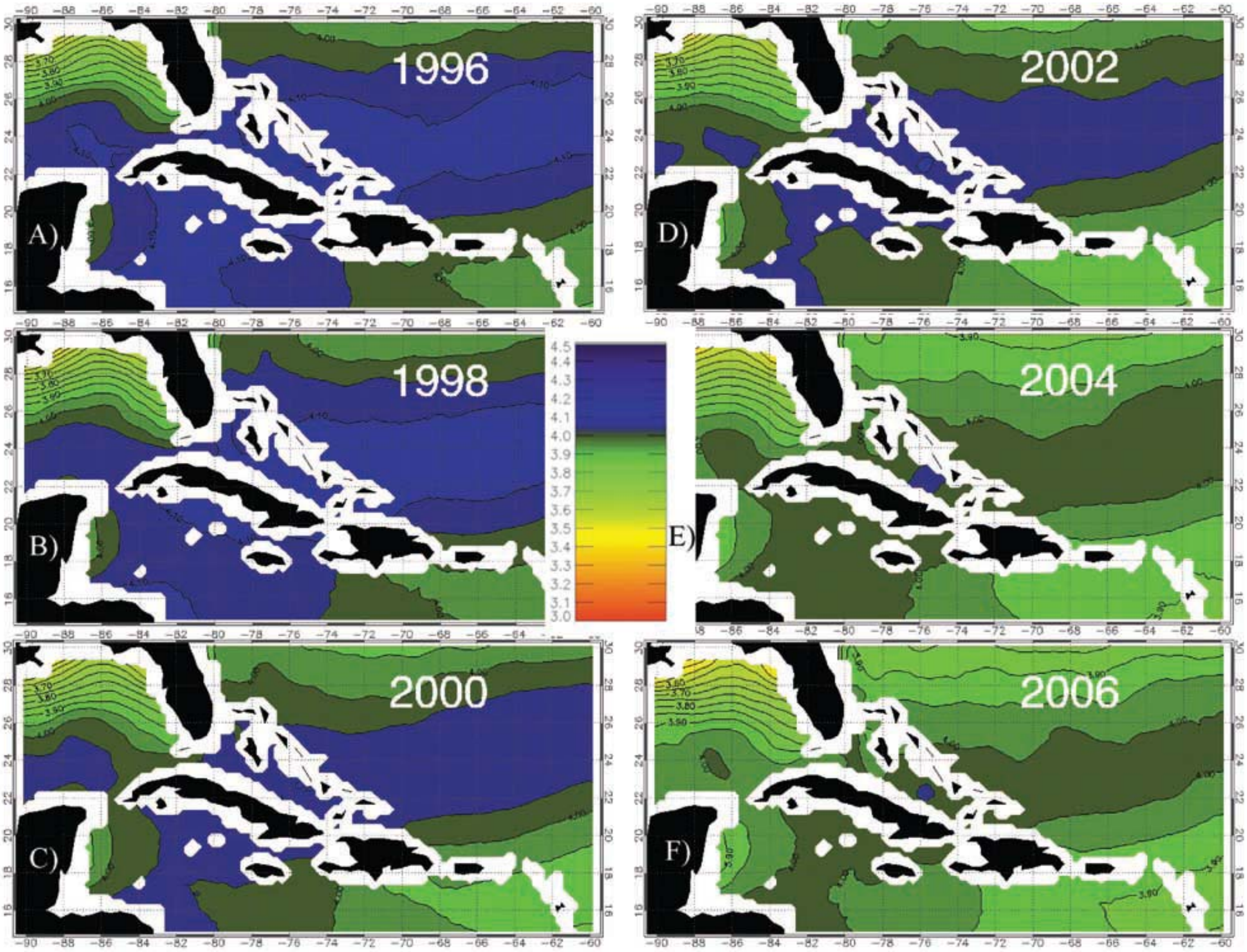


Figure 8 Calculated annual mean value of sea-surface Aragonite Saturation State (extracted from Gledhill *et al.* 2008)

Anthropogenically-derived pollution of coastal zones

Unregulated nutrient input into estuaries and coastal zones, caused by the discharge of untreated sewage and agricultural run-off, is by far the **most important source of pollution** in the Wider Caribbean Region (GESAMP 2001). Other sources include aquacultural and industrial facilities and the atmospheric deposition of pollutants. In aquatic systems, especially nitrogen and phosphorus compounds are most influential in determining and limiting the biomass of primary producers like algae and aquatic plants (UNEP & Gems Water 2006).

Consequences of eutrophication of marine ecosystems include increased nutrient concentrations, enrichment with particulate organic matter, light reduction from turbidity and increased sedimentation (Fabricius 2005). Although nutrients are not necessarily the primary cause for ecosystems to degrade, they are the major factor to “lock” these systems in a degraded state and prevent them from recovery after natural disturbances (e.g. storms). Examples are the expanding occurrences of macroalgal dominated reef ecosystems and the functional impairment of seagrass meadows (Lapointe 2004; Smith 2003).

Addressing the issue of anthropogenic pollution of coastal zones should have the **highest priority** for any SIDS government in order to make their valuable ecosystems as resilient to and prepared for climatic changes as possible. It is of utmost importance to realize that only by addressing the underlying causes of environmental degradation, long-term EbA projects will be successful. Addressing adaptation by means of sea built structures is purely symptomatic and will, ultimately not provide the same level of security and economic benefits as ecosystem-based adaptation procedures are able to.

Overfishing

The term functional redundancy describes the ability of one species or functional group of species to take over the tasks of another one once that one has been removed from the ecosystem. Marine ecosystems are the striking example where functional redundancy has preserved the overall functioning of the system, despite the uninterrupted and ongoing removal, i.e. overfishing, of marine species for a long time (Jackson et al. 2001, Hughes 1994).

Jackson et al. (2001) summarizes well the mechanisms of (historical) overfishing and the consequences that finally led and continuously leads to the collapse of coastal ecosystems worldwide. Consequences are eutrophication, outbreaks of disease, or species introductions. Evidence for the loss of functional redundancy is plentiful among marine ecosystems and ranges from kelp forests to coral reefs, seagrass meadows and oyster beds in estuaries.

Western Atlantic reef corals suffered a sudden but catastrophic mortality in the 1980s. The reason for that was overgrowth and out-competition by macroalgae that exploded in abundance after the last remaining grazer, the sea urchin *Diadema antillarum*, died off due to a viral epidemic (Hughes 1994). Although herbivorous fishes were already rare in the Caribbean before, macroalgae only prolifertated once *Diadema* sea urchins were removed from the ecosystem.

Dulvy et al. (2004) illustrated such cascading effects between overfishing, corallivory, and coral community structure. Increased overfishing (namely the removal of predators of *Acanthaster planci*, a coral-eating seastar responsible for the dramatic reduction of scleractinian corals in the Indo-Pacific) of coral reefs along an island gradient led to the explosion of *A. planci*, which in turn caused large-scale structural changes including a 35 % decline in reef-building corals in the most intensively fished areas.

Bruno et al. (2009) demonstrated that there are fewer macroalgae-dominated reefs than assumed worldwide; yet, he confirms the critical and worsening situation Caribbean reefs are facing today (Done 1992; Hughes 2004). Roff and Mumby (2012) speculate that herbivore, i.e. fishes exceedingly feeding on algae, control may not suffice *per se* for controlling macroalgal blooms, yet they are the key step in the Caribbean. Thus, the control of anthropogenically derived eutrophication, overfishing and the maintenance of herbivore biomass should be of highest concern for the management of Caribbean reefs, in order to prevent emerging or existing disturbances to proliferate.

Estimated impact of Climate Change in Caribbean SIDS

The CARIBSAVE partnership is a not-for-profit regional organisation collaborating with the Caribbean Community Climate Change Centre (CCCCC) and the University of Oxford. CARIBSAVE is developing the CARIBSAVE Climate Change Risk Atlas (CCCRA) which should ultimately provide country profiles for states in the CARICOM region.

Simpson *et al.* (2010) provided the first comprehensive assessment of the consequences of SLR for CARICOM populations and economies (Simpson *et al.*, 2009), using GIS. For comparability, the way of estimating the consequences was similar to the World Bank study on 84 developing countries (Dasgupta *et al.* 2009). The impact of storm surges is obtained from the atlas of probable storm effects (APSE) in the Caribbean Sea (Organisation of American States website) and superimposed to the SLR (Simpson *et al.*, 2010).

Under a 1 meter SLR scenario, the CARIBSAVE study conservatively predicts the displacement of at least 111,000 people. Within the economic sector, touristic infrastructures, located along the countries' coastlines, would be most heavily impacted. The agricultural sector, critical for food supply, security and livelihoods in most countries, would be comparable less impacted. One weakness of the study is that it does not address environmental factors and the biodiversity of the region.

Table 2 presents the results of a storm surge (100 yrs return period) added to a 1 meter SLR, which is a realistic scenario for the Caribbean region (the table synthesizes the impact of SLR, coastal erosion, meteorological events, floods and landslides on each country).

	Land Area	Population(2010 est.)	Urban Area	Wetland Area	Agricultural Land	Crop and Plantation Land	Major Tourism Resorts	Airports	Road Network
Antigua & Barbuda	11%	13%	11%	*	10%	9%	53%	100%	11%
Barbados	2%	2%	1%	*	1%	0%	45%	0%	0%
Belize	9%	13%	15%	36%	9%	17%	95%	100%	16%
Dominica	1%	2%	1%	*	8%	0%	18%	100%	16%
Grenada	4%	4%	2%	*	10%	3%	38%	100%	1%
Haiti	2%	3%	5%	19%	9%	3%	71%	50%	3%
Jamaica	2%	2%	2%	3%	6%	3%	38%	80%	3%
Montserrat	3%	3%	*	*	9%	2%	0%	0%	5%
St. Kitts & Nevis	6%	6%	4%	*	17%	3%	86%	50%	3%
St. Lucia	2%	3%	2%	*	3%	3%	37%	100%	2%
St. Vincent & the Grenadines	3%	3%	1%	*	7%	2%	67%	100%	2%
The Bahamas	21%	23%	15%	22%	24%	16%	63%	66%	27%

Table 2 Estimated impact of a centenary storm surge combined with a 1 meter Sea Level Rise (extracted from Simpson *et al.*, 2010), the * values means no were available

The model applied is basic and static and does not take into account accelerating coastal erosion, changes in hurricane frequencies and intensities, and the evolution of populations and the environment through time.

Several countries emerged from this analysis:

- The Bahamas, always ranked first or second in all categories except touristic infrastructures (still, in this category, more than 50% of the assets would be impacted), with almost one quarter of its land flooded by a centenary storm surge.
- Belize, ranked first in more than half of the categories, with almost 100% of its touristic infrastructures affected.
- Antigua & Barbuda, ranked first or second in more than 50% of the categories, with 100% of airports impacted.

The erosion of the coastline was treated apart and confirmed the previous results. In the Bahamas, Belize, Antigua & Barbuda, 77, 42 and 34 resorts were affected, respectively. Furthermore, 2 new countries emerged from the analysis, that being Barbados and Jamaica (42 and 34 resorts affected). Unfortunately, the report does not mention the percentage of infrastructures impacted. In summary, 46% of the tourism resorts in the Caribbean region would be affected in case of a 1 meter SLR, and 57% in case of a 2 meter SLR, which is of high concern given the economical importance of this sector for many countries.

The potential of ecosystems for CCA activities

The information above clearly indicates an increasing threat to coastal areas in the Caribbean (coinciding almost with the size of the countries in the case of small islands) that can only be reduced by applying global (climate change mitigation projects) and local measures such as improved management and adaptation projects.

We evaluated the potential protection from environmental features for each country, using freely-available data from the WCMC – Ocean Data Viewer website. The website provides an overview and access to the most applicable and globally-accessible marine datasets. The following datasets are used and presented as maps for the respective countries:

- Global Distribution of Coral Reefs (2010),

- Global Mangroves USGS (2011),
- Global distribution of Seagrasses (points and polygons, 2005),
- Marine protected areas (WDPA 2010).

Figure 9 synthesizes, at country level, the coverage (%, respective to country size) of the ecosystems and protected areas. If we focus on the top 3 countries highlighted previously, Antigua & the Barbados and the Bahamas have designated only few areas as protected, although both countries possess large quantities of environmental features able to reduce the climate change related impacts.

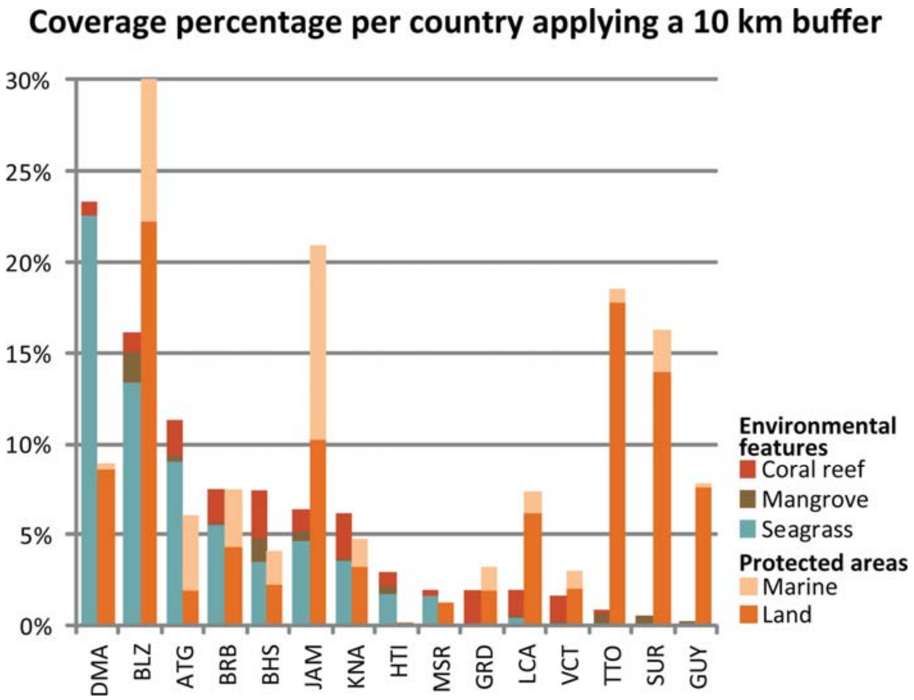


Figure 9 Percentage of environmental features and protected areas in CARICOM countries including a 10 kilometer buffer

Ranking countries

Using GIS, the following parameters were calculated for each country, taking into account all protected areas and environmental features intersecting with each country, and extended with a 10 km buffer (extension of the border outside the country):

- pcWDPAland: percentage surface of land protected areas,
- countWDPAland: number of land protected areas without extent,
- pcWDPAocean: percentage surface of marine protected areas,
- countWDPAocean: number of marine protected areas without extent,
- pcSeagrass: percentage surface of seagrass meadows,
- countSeagrass: number of seagrass meadows without extent,
- pcMangrove: percentage surface of mangrove forest,
- pcCoral: percentage surface of coral reefs.

Table 3 presents a country ranking of each parameter above and a synthetically weighted average ranking calculated with the following rules: the marine protected areas and environmental ranking were averaged and ranked separately, before to be averaged. Protected areas located in-land were not included in the analyses, since they have limited impacts on coastal areas.

	pcWDPAland	countWDPAland	pcWDPAocean	countWDPAocean	pcSeagrass	countSeagrass	pcMangrove	pcCoral	weighted average
The Bahamas	10	5	6	1	7	4	2	1	1.0
Antigua & Barbuda	13	9	3	6	3	7	7	3	2.5
Belize	1	14	2	11	2	2	1	9	4.0
Jamaica	4	14	1	11	5	3	4	8	4.0
Barbados	8	8	4	9	4	7	13	4	6.0
St. Lucia	7	1	9	1	10	7	9	6	6.0
St. Vincent & the Grenadines	11	3	10	1	11	11	11	7	7.5
Trinidad & Tobago	2	2	11	5	12	1	3	13	8.0
Grenada	12	3	8	4	14	13	10	5	8.5
St. Kitts & Nevis	9	7	7	7	6	13	12	2	9.5
Dominica	5	11	12	8	1	5	14	11	10.0
Haiti	15	9	14	11	8	6	6	10	11.0
Suriname	3	13	5	11	14	10	5	14	11.5
Guyana	6	12	13	11	13	11	8	14	14.0
Montserrat	14	5	14	9	9	13	14	12	14.0

Table 3 Ranking of protection and environmental parameters

Surprisingly, the top three countries mentioned in the previous chapter (plus the two countries when including the shoreline erosion) remain the same, which is reassuring as the countries with the highest environmental protection are the ones with the highest risk. Prior to a detailed country per country description, it is important to highlight that the ranking is biased due to the poorly furnished dataset available in some countries.

Commitment to and implementation of coastal zone management efforts

The commitment in targeting the effects of anthropogenic impacts, displayed by adequate coastal zone management practices, will ultimately decide over a sustained functionality of any ecosystem and associated restoration projects.

Four international coastal zone management programmes are described below, all striving to oblige the Cartagena Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region. Although careful conclusions should be drawn as to actual improvements of environmental conditions due to the different projects, the proven ability of a SID for cooperation can be considered an important component for selection.

The Global Environment Facility (GEF) coordinated the large-scale Integrating Watersheds and Coastal Areas Management (IWCAM) Project (2005-2011) in the Caribbean SIDS Antigua & Barbuda, The Bahamas, Barbados, Dominica, Grenada, Haiti, Jamaica, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & the Grenadines and Trinidad and Tobago. The overall objective of the project was to strengthen the commitment and capacity of the participating countries to implement an integrated approach for the management of watersheds and coastal areas. The respective studies could serve as measure for a SIDS's ability and capacity to implement or at least contribute to successful management programmes. Investigation of the IWCAM studies for St. Lucia, the Bahamas, Jamaica, St. Kitts & Nevis, Trinidad & Tobago revealed similar problems during implementation; that being the lack of aid to address the primate causes and roots of many underlying problems.

The Caribbean Challenge, launched in 2008 by the Bahamas' government, alongside leaders of Jamaica, Grenada, the Dominican Republic, and St. Vincent and the Grenadines, is a region-wide The Nature Conservancy (TNC) campaign to protect the health of the Caribbean's lands and waters. To date, participating governments include: Antigua and Barbuda, The Bahamas, Grenada, Jamaica, St. Kitts and

Nevis, St. Lucia, and St. Vincent and the Grenadines. These countries have committed to protecting nearly 20 percent of their marine and coastal habitat by 2020 and developed sustainable financing for protected areas through the establishment of the Caribbean Biodiversity fund, which currently has funding commitments of over USD $40 million.

The pilot programme for climate resilience (PPCR, 2008-2012) is funded by the Strategic Climate Fund (SCF) within the Climate Investment Funds (CIF) framework. The PPCR aims to pilot ways in which climate risk and resilience may be integrated into core development planning and implementation by providing incentives for scaled-up action and initiated transformational change. Participating Caribbean countries are Jamaica, Dominica, St. Lucia, St. Vincent and the Grenadines, and Grenada. Although still ongoing, the acknowledged commitment of all contributing island states has been considered positively in the selection process.

Economic valuation of ecosystem services is an additional, increasingly important method with a clear output to raise awareness among Caribbean countries. Under the Coastal Capital project, the World Resources Institute (WRI) conducted coral reef valuations in five Caribbean countries (St. Lucia, Tobago, Belize, Jamaica, and the Dominican Republic) between 2005 and 2011 (Kushner 2012). The results from these studies have been used to identify and build support for policies that help to ensure healthy coastal ecosystems and sustainable economies. Specifically, the studies have raised awareness about the economic importance of coastal ecosystems. However, only a few valuation studies have had an influence on policy, conservation priorities, coastal zone management, or investment in the region. Nevertheless, the governmental and stakeholders acceptance and distribution of the outcome of the studies was considered satisfactory in Belize, Jamaica, Tobago and St. Lucia, and less satisfactory for the Dominican Republic.

Country description

Two factors were considered useful for the identification of suitable SIDS for marine ecosystem restoration efforts:

i) the existence and distribution of larger, possibly connected mangrove, seagrass, or coral reef areas (but, in case of reef ecosystems, not the actual coral cover, since no qualitative comparisons are available).

ii) the existence of or former participation in governmental or non-governmental programmes served as a measure for the ability of a country to successfully implement and sustain EbA approaches.

The retrieval of ecological data among SIDS is the major difficulty for such evaluations. Furthermore, data often are hardly comparable and good data availability remains restricted to larger or scientifically more active SIDS. Consequently, the evaluation is partly based on selected studies or hampered by the lack of available data.

Information on the present status of relevant ecosystems (e.g. on vitality and grade of degradation), has not been equally available due to the lack of i) existing scientific information or ii) contributions of environmental departments with regard to that information. Many departments never responded to any queries, as has also been seen for the questionnaire distributed amongst respective departments (only 3 questionnaires were received at the time of writing this report).
Especially seagrass beds and coral reefs are prone to rapid (< 5 yrs) changes, depending on the impact of storms and other environmental hazards. Therefore, only recently conducted studies (> 2008), e.g. from Reef check, were mentioned and used to draw site-specific conclusions. Dated surveys may not be accurate and bias first recommendations for base line studies already.

Where available, we also refer to specific studies and modeling results for respective SIDS, depicting the capacity and consequences of existing – or degrading – ecosystems to storm surges and SLR.

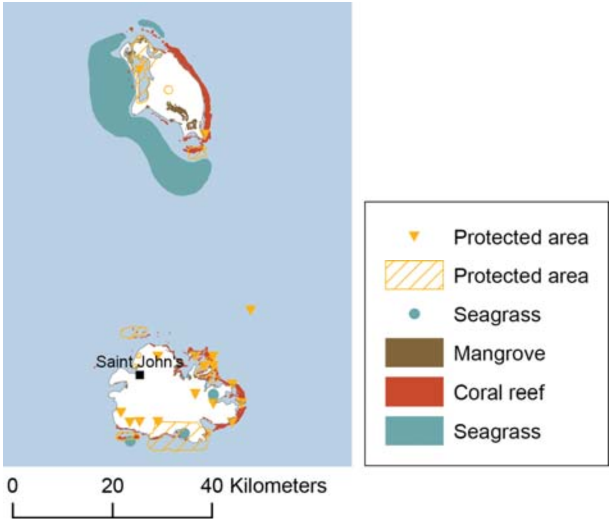
Modeling outcomes can precisely define the relevance and impact of a particular ecosystem to reduce coastal erosion or counteract storm surges. Such data has been provided by Smith Warner International Ltd. (2013) for three specific sites along Jamaica’s, Grenada’s and the Bahamas coastline. Caribsave’s (2012) model outcomes provide further examples how increased storm surge and beach erosion will impact an islands’ major tourism resorts and the coastline, underlining the consequences of (partly) lacking ecosystems. These site-specific examples are referred to in the respective country description of each SIDS.

Overall, modeling predictions suggested that all ecosystems concerned are able to significantly reduce coastal erosion and storm surge. The specific ability to reduce coastal erosion and storm surges varies, e.g. mangrove stands being more important to reduce storm surges than seagrass meadows (Smith Warner; 2013).

According to Smith Warner (2013), the loss of mangrove habitat demonstrated the greatest increase on storm surge at the project site, while with other ecosystems the wave height, storm surge and beach erosion were more impacted by the increase in storm intensity than the loss of ecosystem itself. Once more, especially coral reefs will be of utmost importance to counteract these stressors and guarantee economic benefits from fisheries and tourism industries.

Antigua & Barbuda

This country is ranking second in Table 3, based on the presence of ecosystems and their protection status. Barbuda has an important, but generally unprotected, environmental feature (seagrass) covering a large extent, while Antigua, with smaller and punctual environmental potential, still requests data completion prior to define a location for CCA project(s).



Seagrass meadow	9.0%
Mangrove forest	0.3%
Coral reef	2.0%
Inland protected area	1.9%
Marine protected area	4.2%

Very limited scientific information has been found to assess the ecological assets on Antigua & Barbuda. Despite a rich cultural fishing history, the major industry over the past several decades for Antigua and Barbuda has been tourism (Carr 2009). Antigua and Barbuda exhibit relatively high levels of biodiversity, particularly in the coastal and marine environment. Sedimentation, nutrient enrichment and poor boating practices are degrading the quality of coastal waters and damaging marine habitats. Over-extraction and harmful fishing practices are increasing threats to seagrass beds and coral reefs whose conditions are considered poor when compared to historic indicators (Wilkinson 2000). Antigua and Barbuda is facing the serious risk of overexploiting its marine resources within the near future (Carr 2009).

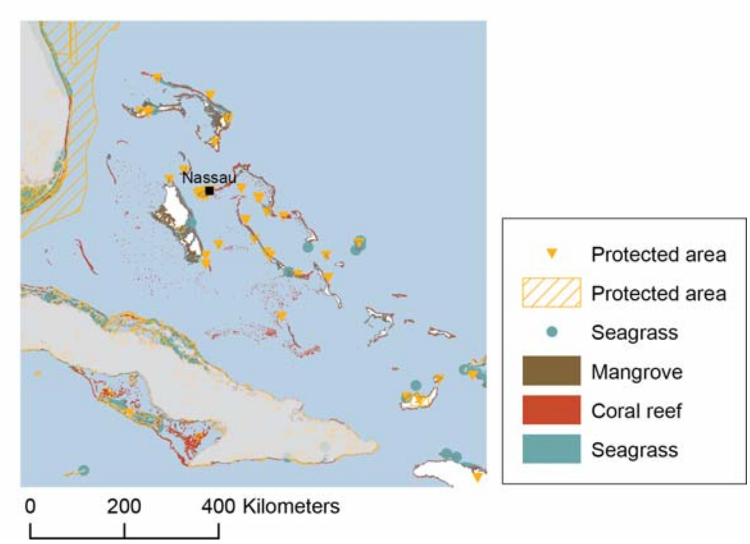
There is no municipal wastewater treatment plant on the islands and septic tanks and soakaways are usually poorly built resulting in groundwater contamination and impacts on downstream coastal waters. A GEF project attempted to address the lack of adequate sewage treatment at Siboney Beach, but has yet to develop a working solution.

According to Caribsave (2012), a *Draft Integrated Water Resource Management Strategy and a Draft Drought Management Plan* have been prepared, but robust land management policies are needed to reduce the discharge of pollutants, rehabilitate watersheds and establish watershed protection. The implementation of Integrated Water Resources Management (IWRM) has encountered several issues, including the lack of political will and commitment, the lack of an IWRM policy, and the lack of stakeholder participation. Up to date, Antigua & Barbuda has limited political tools and environmental programmes which could guarantee the long-term success of (coral reef) restoration efforts.

Caribsave (2012) estimated the impact of 50 and 100 m beach erosion to affect 34 and 44 % of all major tourism resorts and 50 and 65 % of all sea turtle nesting sites, an important tourist attraction. Regarding Barbuda, both vast seagrass meadows areas along the west coast and coral reefs along the north eastern coast are equally important with regard to coastal erosion and should both be the primary focus of any protection and restoration measures. Antigua's focus should be on the extensive coral reef protected shoreline areas along the northern and eastern coast.

The Bahamas

Even if the country information regarding area extent of marine protected areas is lacking for many sites, it is ranking first, due to the largest percentage of coral reefs and second largest percentage in mangrove coverage (Table 3). The Bahamas' 29 main islands and 661 cays and total surface (about 14000 Km^2) offer a large panel of potential locations for CCA projects, but this will also make the selection processes more complex. The completion of the protected areas dataset with finer resolution datasets will undoubtedly be necessary in order to select the project locations.



Seagrass meadow	3.5%
Mangrove forest	1.2%
Coral reef	2.7%
Inland protected area	2.2%
Marine protected area	1.9%

All ecosystems concerned here are relevant to reduce coastal erosion due to their spatial distribution and relative coverages. Caribsave (2012) estimated that 58 and 70% of major tourism resorts will be impacted by beach erosion of 50 and 100 m, respectively.

Effects of anthropogenic influences, i.e. coastal development, have been investigated by Sealey (2004). With the exception of downtown Nassau and some large resorts, wastewater treatment and disposal in "soakaways" or cesspit systems constructed onsite is common.

Despite slight changes in the appearance of coral reef ecosystems, nutrient input between developed and undeveloped coastal zones remained comparable. The central Bahamas is unique in its shallow-water banks system and oceanographic dynamics at the bank margins. Patch reefs often develop in channels adjacent to the platform margin, and experience strong tidal circulation which may be crucial in maintaining good water quality for nearshore reefs, despite development. The North Sound, a mangrove-fringed Bahamian lagoon, is an area of distinct biodiversity and has recently been included in a MPA (Gruber 2009). These shallow mangrove and coral reef lagoons which serve as nursery for key species like lemon sharks, spiny lobsters and queen conch, represent important ecological assets for the Bahamas (Chapman 2009).

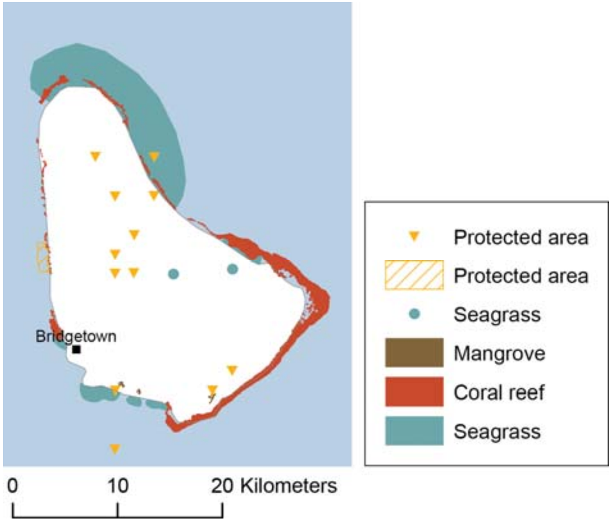
The Bahamian government has approved setting aside 30 No-take MPAs (Central Bahamas) to protect the coastal marine environment. Subsequently, Stoffle and Minnis (2007) evaluated the community responses of Bahamian fishermen towards the introduction of MPAs. MPAs can impact in either positive or negative ways i) community resilience by eliminating or supporting some components of their traditional adaptations to social and natural environments, and (ii) community identity by precluding or protecting customary marine access. Thus, MPA impacts to local communities determine whether those communities will support or resist proposed MPAs.

The GEF-IWCAM case study "Marina Waste Management at Elizabeth Harbour, Exuma, Bahamas" engaged stakeholders to actively participate in the harbor management and to invest in environmental management technologies. Another GEF-IWCAM case study, "Land and Sea Use Planning for Water Recharge Protection and Management in Andros, Bahamas" was also successful and provided the inventory of resources, web based tools for accessing natural resources and various management plans (Land and Sea Use, Ecotourism, Water Conservation Strategy, Economic Valuation of Natural Resources). According to Caribsave's risk assessment (2012), the Bahamas is committed to adapting to climate change, as evidenced by policy responses, current practices and planned actions; as well as the recognition of the importance of The Bahamas' natural resources to livelihoods and the economy.

Barbados

The eastern coast of the island is quite well covered by seagrass in the North and coral in the South, but along its Western coast, environmental remnants are scarce and patchy. Mangrove forest presence is anecdotal in the country. As for the Bahamas, the level of legal protection is difficult to estimate as the database is mainly constituted of point records without information regarding area extent. Most of the protected areas are located inland.

The environmental context varies within the island, but good potential for CCA projects exist. The completion of protected areas database has the highest priority.



Seagrass meadow	5.5%
Mangrove forest	0.0%
Coral reef	1.9%
Inland protected area	4.3%
Marine protected area	3.2%

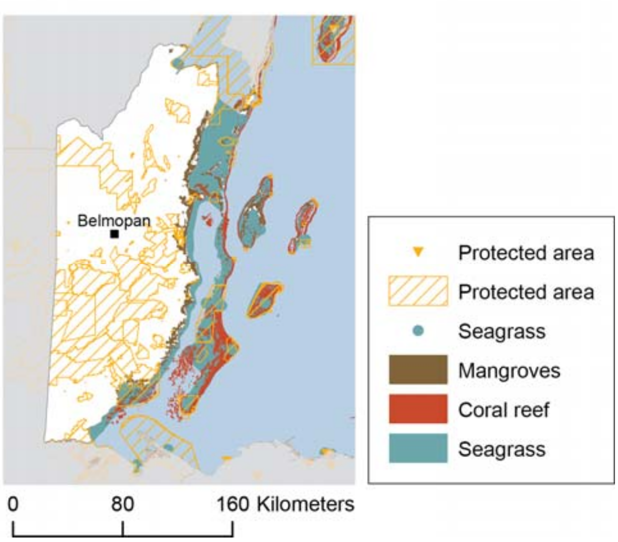
Oxenford *et al.* (2008) observed severe coral bleaching and subsequent mortality in various reef locations, confirming the susceptibility of Caribbean coral reefs to environmental stress. Pandolfi and Jackson (2006) pointed out to human-induced changes in Barbados' coral reef ecosystems. The authors emphasized the country's need to take urgent practical steps to improve effective management of their coral reefs to enhance resilience to major disturbances. Macintyre (2007) could attribute the demise of ancient *Acropora palmata* dominated coral reefs to agricultural land-use practices during the industrialisation and heavy storm damage. Paired with the lack of herbivorous fishes, the environmental conditions prevented the recovery of hard corals, leading to a macroalgal dominated ecosystems. Caribsave (2012) reported Barbados to be highly dependent on tourism, and, despite degraded conditions, to thrive on especially the coral-reef associated diving industry.

Caribsave's estimate (2012) with regard to beach erosion and SLR revealed that, although only 8 and 3 % of major tourism resorts and sea turtle nesting sites would be affected by 1 m SLR, more than half (56 and 67 %) of all major tourism sites will be impacted by 50 and 100 m beach erosion, respectively. The critical beach assets would thus be affected much earlier than the SLR induced erosion damages to tourism infrastructure. Therefore, both seagrass meadows, especially around the north-eastern coastline, and the fringing coral reefs around the eastern and south-eastern coastline present the most relevant ecosystems to counteract coastal erosion and should therefore have the top priority when it comes to remediation measures.

The Government of Barbados is committed to adapting to climate change. Tourism-related water demand led to Barbados' long history of policy development relevant to water resources development and the institutional capacity for managing water resources is extensive. Significant on-going investment in sewage disposal facilities is taking place (CEP technical report 66), where sewage is piped from the southern coastline extending inland, undergoing primary treatment, before being discharged 1.1 km out to sea. Adaptive capacity in the institutions across Barbados is generally quite good, but efforts are restricted by limited financial and technical resources and limited enforcement of policy and laws.

Belize

Although Belize is a continental country, it is listed as SIDS. It is a small country if compared with other continental countries, however, a large SIDS with 22700 Km^2 surface area (more than twice the size of Jamaica). This country includes a high number of protected areas (with large area extent) and environmental features. Belize has the world's second largest coral reef, is ranking first for mangrove and second for seagrass and has a good availability of different datasets. Consequently, this is a country where CCA projects could be implemented effectively without delay.



Seagrass meadow	13.4%
Mangrove forest	1.6%
Coral reef	1.1%
Inland protected area	22.2%
Marine protected area	8.1%

Aronson *et al* (2012) evaluated the 2009 earthquake-related catastrophic impact on coral reefs in the central sector of the Belizean barrier reef. Together with coral diseases and bleaching events, the recovery of these reef assemblages to a coral-dominated state is considered unlikely in the near future. Nevertheless, McIntyre (2007) observed large, healthy colonies of fast-growing *A. palmata* corals around Carrie Bow Cay, indicating the possible return of important reef-building corals, under suitable environmental conditions. The ecological importance of Belize's well-connected ecosystems (mangroves-seagrass-reefs), for nutrient recycling and transient fish species, has been emphasized by Vaslet (2012). The discharge of improperly treated wastewater effluent is one of the main contributors to coastal zone degradation in Jamaica (CEP technical report 66) and the primary cause for concern here.

The vast abundance of seagrass meadows and stretched shoreline fringed by mangrove stands generally supports restoration and management efforts towards those ecosystems, in light of reduction of coastal erosion. The Mesoamerican barrier reef off Belize equally benefits both tourism and fisheries. No priority can be given to either ecosystem based on general estimates only, and efforts should be addressed in a case-to-case way. Caribsave's (2012) climate change projections reveal dramatic impacts of both SLR and erosion processes for continental areas and off-shore islands: 1 m SLR would impact 73 and 44 % of major tourism resorts and sea turtle nesting sites. However, 50 m beach erosion will already impact 95 and 100 % of tourism resorts and turtle nesting sites, respectively. Furthermore, distinct tourist attraction such as Caye Calker and Rocky Point (North Ambergris Caye) are projected to lose almost entirely the beach area by even a 0.5 m SLR.

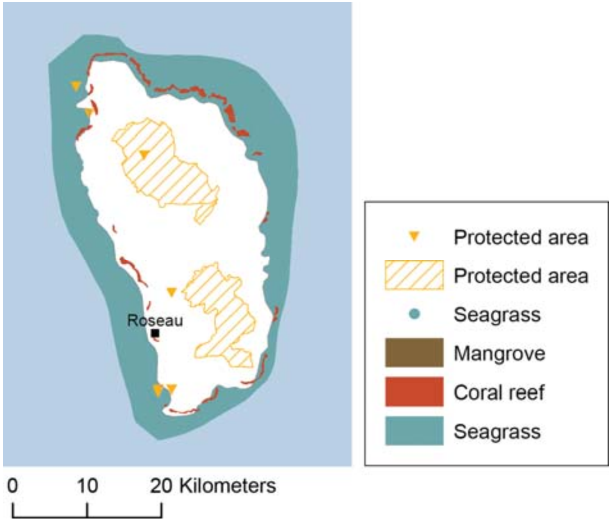
Tourism is an important threat to the Belize Barrier Reef, but represents both a motivation and source of resources for its conservation, according to Diedrich (2007). Coastal communities are in varying stages of a socio-economic shift from dependence on fishing to dependence on tourism and Diedrich's study proved a positive correlation between tourism development and coral reef conservation. Furthermore, there is a positive relationship between local perception that MPAs attract tourism and support for MPAs.

Belize has a strong history of natural resource management and monitoring, and benefits from the presence of regional agencies, including the Caribbean Community Climate Change Centre (CCCCC) and the Caribbean Regional Fisheries Mechanism (CRFM), which provide the country with additional human and technical capacity to examine key issues relevant to natural resource management, climate change and development (Caribsave 2012).

Although Belize does possess large, well-connected coastal ecosystems, and is in that aspect suitable for potential restoration efforts, ongoing (impaired) management national practices and resulting environmental conditions may pose reasonable risks to effective and long term restoration efforts.

Dominica

Even if this island presents by far the largest coverage in term of seagrass meadows (Table 3), its ranking is low mainly due to the lack of marine protected areas; also mangrove forest are completey absent. This country represents a unique opportunity for a CCA project using seagrass meadows on the scale of a single medium-sized island. But the state and extent of its marine protected areas needs to be determined in a preliminary step.



Seagrass meadow	22.6%
Mangrove forest	0.0%
Coral reef	0.7%
Inland protected area	8.6%
Marine protected area	0.3%

Dominica is almost entirely surrounded by seagrass meadows which are essential to counteract coastal erosion to maintain climate resilient livelihoods in terms of fisheries. Furthermore, its coral reefs along the north eastern coastline provide additional protection and ecosystem services. No priority can be given in terms of relevance for climate change adaption, as both ecosystems exist in sufficient range and scale. Caribsave's (2012) projection with regard to beach erosion shows that 29 and 35 % of all major tourist resorts would be affected by 50 and 100 m beach erosion, respectively. Regarding tourism, this is, in comparison, less than for other SIDS, and assumingly less threatening. Regarding fisheries and associated livelihoods, however, the well-functioning and protection of both ecosystems remains essential.

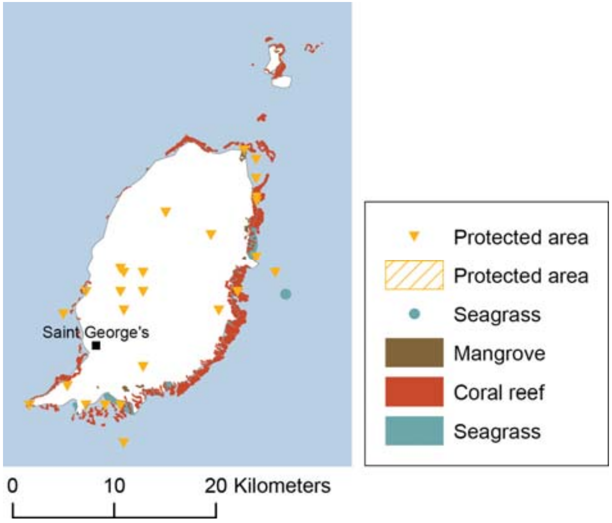
Steiner *et al.* (2010) offered the first comprehensive assessment of the distribution and size of the island's near-shore sublittoral habitats and benthic communities in 2007. Surprisingly, the benthic cover of Dominica's coral reefs (70 ha) is evidently far below the previously reported 7 000 ha (as was then listed in Bruke & Maidens 2004). Such discrepancies highlight the need for environmental assessments in cases like Dominica where marginal marine resources exist in spatial proximity to each other and human settlements. Likewise, information on Dominica's largest ecosystem resource, seagrass meadows, is scarce, but its extent was confirmed during the assessment.

Bruckner *et al.* (2010) investigated two coral reef restoration efforts, led by the Oceanographic Institute of Dominica (OID), in collaboration with the Reef Ball Development Group (Georgia, USA). The projects were not considered successful in terms of restoration of the reefs, and merely contributed to the understanding of species-specific coral survivorship. Conclusively, future restoration efforts clearly require better evaluation in order to select appropriate restoration sites, coral species and best suitable practices. Still, OID's activities could contribute to the conservation and recovery of Dominica's coral reefs if management measures are well-planned and better implemented.

Dominica is considered the wettest island in the Caribbean and ground water resources have not been exploited extensively (Caribsave 2012). At present, the pressure on terrestrial and marine ecosystems, and water resources from increasing development and poor land use practices is rising. Dominica does not have a well defined National Water Policy, an entity responsible for Watershed Management, or a land use policy. According to Caribsave, the Dominican government should still be commended for the collaboration with other agencies, the development of policies that address environmental issues and the implementation of monitoring strategies to boost the resilience of its biodiversity.

Grenada

The status of this country is similar to Saint Kitts and Nevis, with information regarding area extent of protected areas missing on most of the points provided. It possesses long patches of coral reefs and large extents of seagrass meadows, allowing the implementation of punctual CCA projects.



Seagrass meadow	0.0%
Mangrove forest	0.1%
Coral reef	1.8%
Inland protected area	1.9%
Marine protected area	1.3%

The fact that the vast majority of Grenada's eastern coastline is protected by fringing coral reefs, thus providing a natural protection from erosion, may put Grenada forward for reef restoration efforts, although marine protected areas are few. The problem of overfishing and associated coral reef decline has finally been recognized and Marine Protected Areas (MPAs) have been established.

In March 2006, the government adopted the Grenada 25-25 Declaration to "Effectively conserve at least 25% of the near-shore marine resources and at least 25% of the terrestrial resources across Grenada by 2020." This declaration increased Grenada's commitments made under the Conservation on Biological Diversity. Under this commitment, the Fisheries Division has been actively engaged in the set-up, management and governance of: Molinere/Beausejour Marine Protected Area (MBMPA) and Woburn/Clark's Court Bay Marine Protected Area (WCCBMPA) on the mainland, and Carriacou's Sandy Island/Oyster Bed Marine Protected Area (SIOBMPA).

According to McConney (2007), Grenada's co-management practices are not well developed yet. Both Spiny lobster and beach seine co-management initiatives were at the pre-implementation stage in 2007. Grant (2007) defined Grenada's fishermen as relying on observation, experimentation, and experience through the feedback of fish catches and evaluation, learning adaptively to improve their understanding of the marine ecosystem and the resources. This continuous learning and the ability to deal flexibly with new situations has made these fishers adaptive experts (Fazey *et al.*, 2005) and the way they deal with environmental uncertainty can be considered a kind of adaptive management.

Grenada is also part of the Pilot Programme for Climate Resilience (PPCR), whose water resource management is a key area of interest. Through this initiative, Grenada has made good progress in the implementation of its integrated water resource management (IWRM). Grenada is increasingly dependent on tourism, which is strengthened by the diversity of natural assets. However, many local livelihoods are also very dependent on these resources. According to Caribsave (2012), it is clear that the government is committed to adapting to climate change, as evidenced by the recent development of the Strategic Programme for Climate Resilience (SPCR), which includes new practices and planned actions for adaptation and mitigation of climate change impacts.

Caribsave's (2012) projections estimated that 95 % of all major tourism resorts would be affected by beach erosion of 50 m and a 1 m SLR would place 73 % of the island's tourism resorts at risk.

Regarding the reduction of coastal erosion and both fisheries and tourism related industries, the fringing reefs along the southern and eastern coastline should be of major relevance and receive high priority when it comes to restoration or management efforts. On the eastern coastline, a high rate of erosion is noticeable in Levera, Conference, Telescope and Pearls, where several meters of land are lost annually.

Grenada has increased efforts to stop the use of beach sand in construction and presently there is limited extraction of beach sand by that state agency.

According to technical experts, land-based pollution is one of the main contributing factors to the degradation of the coastal environment and coastal restoration efforts would be limited or ineffective if land based sources of pollution were not addressed. Five rivers (St. Johns and Beausejour on the western coast, Richmond Hill and Chemin on the southern coast and Soubise on the eastern coastline) have been identified as contributing high levels of pollution and siltation to the coastal environment (Monitoring by St. George's University, SGU). Especially, these rivers cause high levels of nitrification to the sea, which could impede coastal restoration efforts on coral reef and mangrove areas.

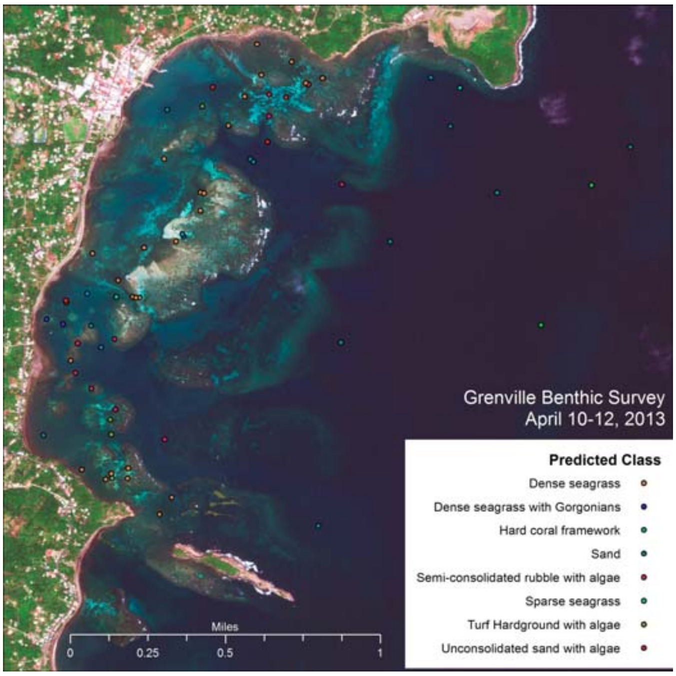
An estimated 385 hectares of mangroves located at 22 sites still exist, particularly prominent in Lauriston Airport, Petite Carenage and Tyrrel Bay (Carriacou) and on the northern, eastern and southern coastlines. Other significant areas include Levera Pond, Conference Beach, Westerhall – Fort Judy and Woburn. Seagrass beds are located mostly in shallow sheltered areas throughout all coastal waters of Grenada, Carriacou and Petite Martinique. The species of seagrass found in Grenada include turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).

The Grenada reef system supports the most extensive coral reefs in the South-eastern Caribbean, and is vital in supplying the Northern Caribbean with larval coral and fish. A project for coral reef restoration has been proposed – and meanwhile been rejected - by the Grenada Fund for Conservation, which aims to cooperate with TNC's At the Water's Edge: Climate Resilience for Grenada and St Vincent and the Grenadines; Caribsave; Caribbean Marine Protected Areas Managers (CAMPAM); the GEF; and the Grenada Fisheries Division MPA programme.

TNC has intensive working experience on Grenada. Dr. Steve Schill and his team recently selected Greenville bay on Grenada's Eastern coastline as an important, highly vulnerable site, suitable for ecosystem-based conservation. Decisive factors for site selection were the relatively high impact of climate change and simultaneously, a relatively low adaptive capacity of the area and the communities. Note that the identification and modeling outcomes have been based on both ecological and socio-economic data. Such a multi-facetted approach is recommended for all potential project sites of the concerned SIDS.

TNC's recent benthic survey (04/2013) gives an impression on the status of the bay and reef ecosystems (Schill , Trip report Grenville, Grenada 2013):

"…The inner bay displayed low visibility, and is dominated by seagrass (two species) and algae with heavy siltation. Near coastal areas less than 10m are being impacted by heavy sediment and high algal growth. The seagrass areas appear healthy with occasional smaller conch observed on the snorkel surveys. Fishers are harvesting a lot of large conch, but have to dive 80m+ using compressed air. Brain corals were occasionally seen in areas of sparse seagrass/rubble. In terms of reef, the only healthy reef we saw was at depth of 15-20m well beyond the reef crest. These deeper areas are where we saw the largest fish, although rare. The shallow reef areas (algal rim) were very worn down with little coral cover (<10%) and high algal growth with abundant *Diadema* sea urchins. Many of the shallow reef areas had large rubble fields with evidence of past palmata growth. …"



Dr. Gregg Moore (University of New Hampshire, US) is about to publish two manuscripts regarding suitable restoration sites for both Grenada and SVG. Suitable partner NGOs have been identified by TNC as the Grenada Fund for Conservation (GFC) and Woburn/ Calivigny Development Organisation. GFC has had many years of experience growing mangrove in Carriacou and Grenada and can provide guidance to projects concerning mangrove restoration work. Coral reef related projects may encompass fisheries (co) – management issues and coral restoration; suitable partner NGOs have been identified by TNC as Sandy Island Oyster Bed MPA; SusGren; St. Patrick's Organization for Development.

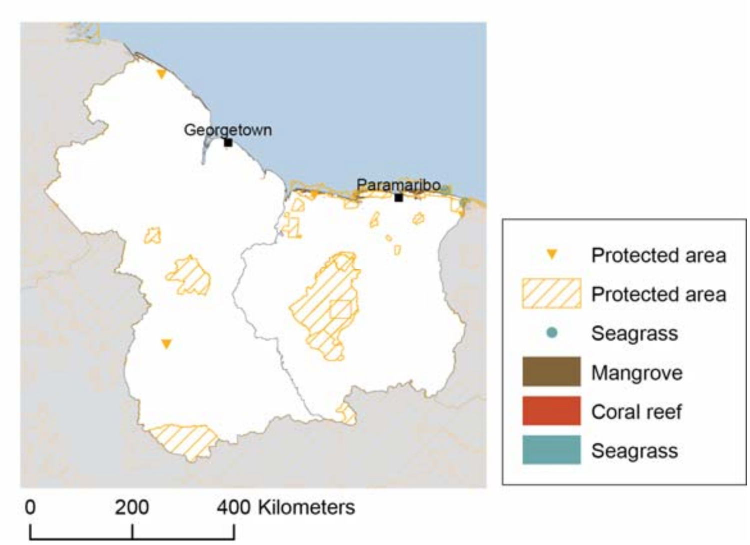
Without ground truthing, one (first) exploratory step is to identify potential areas where synergies of multiple ecosystems could emerge. These are, based on satellite imagery:

- Grenville Bay, Grenada (East coast); both seagrass meadows and coral reefs present
- Calivigny, Grenada (South-eastern tip); mangrove stands, seagrass meadows and coral reefs present
- Argyle, Carriacou (South-western tip); both mangrove stands and coral reefs present

Concerning Grenada, those areas could be of interest for follow-up base line studies, and if evaluated positively, would require further socio-economic assessments: Additional satellite imagery with regard to past and present coverage of mangroves could be obtained for Argyle on Carriacou (see page 48).

Guyana and Suriname

The low ranking of these two continental countries is mainly due to their large area extent (compared to others CARICOM countries), meaning that any area of features or protected area expressed in percentage, will be smaller than for “real” SIDS (both countries are listed as SIDS despite being large and continental). However, both countries possess important stretches of mangrove forests along their coast which could be used for CCA projects. Suriname contains larger stretches of mangrove forests and higher percentages of protected areas, and consequently offers the better potential.



	Guy.	Sur.
Seagrass meadow	0.0%	0.0%
Mangrove forest	0.1%	0.5%
Coral reef	0.0%	0.0%
Inland protected area	7.6%	13.9%
Marine protected area	0.2%	2.3%

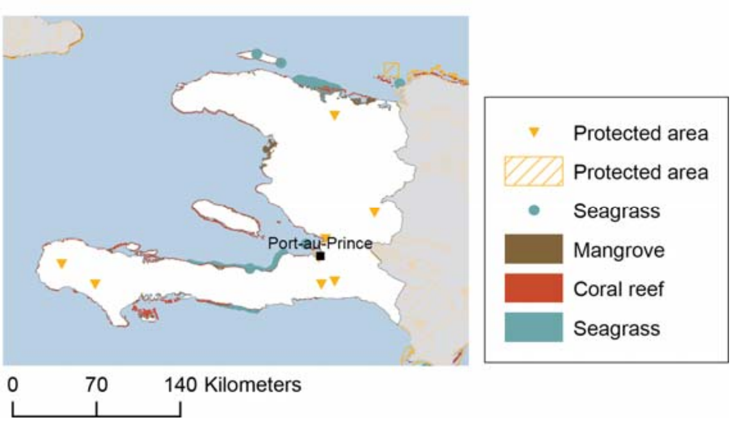
Suriname is one of only 11 countries worldwide that can be categorised as “high forest, low deforestation” (Caribsave 2012). An estimated 85% of Suriname’s land area is still forested, of which 13% is inside protected areas. Suriname is actively involved in the REDD (Reducing Emissions from Deforestation and Forest Degradation) programme and advocates for compensation for conserving forests and applying sustainable forest management. Next to mangroves and coastal rainforests with extensive mudflats, Suriname also exhibits sandy beaches which can serve as habitat for leatherback sea turtles nesting grounds (Fossette 2008). Overall, available scientific information for Suriname and especially for Guyana is very limited. Suitable biodiversity studies were presented at regional conferences in 1999 (see Singh & Persaud: Biodiversity in Guyana: Its management and benefits and Mohadin & Julen: Biodiversity in Suriname: Its management and benefits. 9th Meeting of the Caribbean Foresters; Dominican Republic)

The Ministry of Agriculture, Livestock and Fisheries aims to make Suriname the main supplier of the basic foods consumed in the Caribbean and agricultural activities are concentrated in coastal zones, according to Caribsave’s risk assessment (2012). An “Agro-technology and Climate Change” project is recommended. Since there are no sewage treatment systems, improper disposal practices threaten the quality of water supplies in the Suriname River, and very likely of coastal zones and ecosystems. The Government of Suriname has undertaken extensive studies focusing on the promotion of sustainable livelihoods in the coastal zone and has also carried out an Integrated Coastal Zone Management Project.

Due to the pressure of economic development, the coastal zone of neighbouring Guyana is progressively being transformed into agricultural land and aquaculture estates, protected by coastal dikes. Anthony *et al.* (2012) describe in detail the potential destabilization of the muddy coast, caused by large-scale mangrove destruction. The stability of the coast, which is part of one of the world’s most extensive mangrove coasts, depends on large mud banks migrating alongshore from the mouth of the Amazon River and on the mangrove colonisation of these banks. Artificial dikes are less effective in dissipating wave energy than mud banks. They also hinder the various processes involved in the consolidation and subsequent mangrove colonisation of the banks, notably by enclosing mature mangrove forests and preventing propagule transport from the forests to mud banks. The progressive breakdown in the mud-bank and associated mangrove system will likely result in large-scale coastal erosion that can only be countered by further engineering structures at prohibitive costs. The only coastal defence strategy, sound and viable over the long term, with regards to both environmental conservation and costs, consists in restoring a dynamic mud-bank and mangrove system on this wave-exposed coastline.

Haiti

The environment is known to be highly degraded; the political and humanitarian situation remains difficult. The low ranking of Haiti is due to the poor environmental status and difficult political and humanitarian context.



Seagrass meadow	1.7%
Mangrove forest	0.4%
Coral reef	0.8%
Inland protected area	0.2%
Marine protected area	0.0%

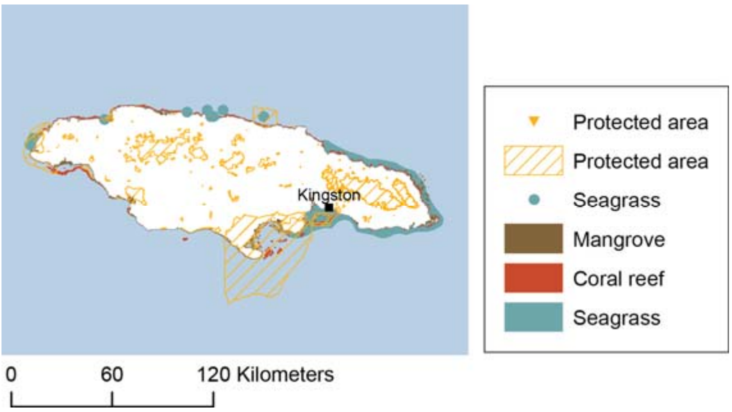
Reefs at Risk Revisited (Burke et al., 2011) catalogs Haiti as one of the nine countries most vulnerable to the effects of coral reef degradation; due to high dependence on coral reefs and low adaptive capacity.

The Nature Conservancy (TNC) conducted a coastal and marine baseline assessment in the south-west of the country (TNC baseline assessment report 2012). Generally, an extremely low fish biomass was observed related to excessive overfishing and unsustainable fishing practices. Concerning the benthic community composition, sandy sediments covered 64% of the total area monitored. Furthermore, the benthos exhibited 19% vegetated sediment areas, 8% macroalgal and gorgonian cover, and 1.6% coral cover. Field observations confirmed that heavy sedimentation is occurring in most coastal bays near the mainland, significantly impacting remaining reefs. It is important to emphasize the extreme deforestation of Haiti's watersheds (>80% of watersheds are completely deforested; MDE 2006), certainly contributing to the observed sedimentation in coastal areas.

Given an a priori implementation of conservation actions and proper fisheries management, the de la Folle barrier reef on the northeastern end of Ile à Vache would be given the highest priority for coral reef restoration efforts (using *Acropora palmata*), since this area is very nutrient rich, fed and replenished by ocean currents. Moreover, the area around St. Jean du Sud has been given a high priority due to large expanse of mangroves, sea grasses and interspersed tidal channels, relatively un-impacted and in healthy condition. The area northeast Île à Vache Mangrove Bay has been identified as nursery habitat for numerous species of fish (parrotfish, snapper, grunts), but the relatively small size of the bay limits its importance at a large scale.

Despite the integrated watershed-based management efforts and other adaptation actions (e.g. PPCR participation), there are numerous challenges that need to be overcome to effectively implement adaptation actions in Haiti (SSII; 2011). Haiti's political turbulence and instability and the lack of coordination for environmental projects increase the reluctance of donors to support adaptation initiatives and impair the population to engage in government programs. The acute food shortage affecting the majority of the population displaces concerns about environmental protection. With such urgent needs and near-term uncertainty, it will be difficult for Haiti to adapt to the long-term uncertainty imposed by climate change. Given these circumstances, the priority for EbA approaches in the country has to be considered low, compared to political and socio-economic needs Haiti requires.

Jamaica



Its high ranking is mainly due to its large percentage of protected area in the Kingston region, but some other important marine protected areas exist in the island. The availability of information on the island is unequal and will need to be improved, however Jamaica benefits from strong institutions which could help in the data completion process. Past experiences on working with Jamaica, revealed strong institutional commitment for the environment (also demonstrated by the adoption of the vision 2030 development plan), easy access to data. This is facilitated by the presence of the University of West Indies, the United Nations Environment Programme, Caribbean Environment Programme (CEP) and links with the Planning Institute of Jamaica, which can facilitate data access.

Seagrass meadow	4.6%
Mangrove forest	0.6%
Coral reef	1.2%
Inland protected area	10.2%
Marine protected area	10.7%

Being a key species of reef restoration programmes worldwide, the recovery of *Acropora palmata* corals 3 decades after the initial reef degradation in Discovery Bay is of importance for potential restoration programmes on site (Quinn 2008). Unfortunately, a coral bleaching event in 2005 led to the renewed die-off of the coral population, and fast recovery is unlikely, due to the coral's impaired reproductive abilities after such disturbance events. Nevertheless, the northern coastline's environmental conditions preceding the bleaching event were apparently sufficient to allow for initial recovery of the corals.

According to AGRRA's senior scientist Judith Lang, the attempt to secure funding to repeat the 2000 coastal Jamaican surveys again this year (2013) was not successful; therefore no comprehensive, recent dataset on Jamaica's status regarding coral reefs is available from AGRRA. Yet, a comprehensive dataset could be analyzed from Reef Check (below).

Lapointe (2011) found the coral reefs in the Negril Marine Park (NMP) to be increasingly impacted by nutrient pollution and macroalgal blooms, after decades of intensive development as a major tourist destination. Although having implemented a sewage collection and treatment project, the wastewater returned via the South Negril River and impacted the coastal area including the coral reefs. According to Carr (2009), Jamaica is considered a cautionary example of the potential socioeconomic and ecological consequences caused by resource overexploitation and mismanagement within the various economic sectors. On the other side, successful projects like the GEF-IWCAM project and tools like the Environmental Impact Assessment (EIA), which enables environmental factors to be given due weight, along with economic or social factors, are positive assets. Jamaica's biodiversity is playing a vital role in research, financing, management and public awareness and education. Participatory governance (Co-management) arrangements are also beneficial and the newly designated fish sanctuaries are to be managed in conjunction with local non-governmental organizations (NGOs) and private sector stakeholders.

Jamaica should be considered a suitable SIDS for restoration efforts due to its economically and ecologically valuable and large ecosystems. Caribsave's assessment (2012) is ambiguous with regard to Jamaica's ability to effectively manage the resources under increasing pressure and resource users with little or no awareness which continue to degrade or over-extract from marine and terrestrial ecosystems in an effort to sustain themselves.

According to Caribsave (2012), more than half of Jamaica's population lives within 1.5 km of the shoreline and approximately 90% of the island's GDP (through tourism, industry, fisheries, agriculture) is produced within its coastal zone. The high density of development (particularly related to tourism) increases the risk of degradation of coastal and marine biodiversity thereby reducing its resilience to climate change impacts including SLR and storm surge. Although no comprehensive projections regarding the consequences of SLR and beach erosion are available, the area around Portland Cottage was used as an example in the SWI report (2012), and model projections indicate increased inundation levels and storm surge values of up to 2.8 m for a scenario with mangrove-deprived habitat and increased storm intensity.

Without ground truthing, one (first) exploratory step is to identify potential areas where synergies of multiple ecosystems could emerge. These are, based on satellite imagery:

- North-Western Jamaica (Montego-Bay); both seagrass meadows and coral reefs present
- North-Eastern Jamaica (Port Antonio); both seagrass meadows and coral reefs present
- South-Western Jamaica (Savanna la Mar); both seagrass meadows and coral reefs present

Concerning Jamaica, those areas could be of interest for follow-up base line studies, and if evaluated positively, would require further socio-economic assessments: Additional satellite imagery with regard to past and present coverage of mangroves could be obtained for Annoto Bay (North-Eastern Jamaica), Golden Grove (Eastern tip) and Savanna la mar (South-Western Jamaica) (see page 49).

Reef check performed a relatively recent (2000-2012) comprehensive survey on 25 different reef sites around Jamaica. Partly repeated (n=1-4) surveys were conducted in shallow water areas (depth range between 3 - 12 m). Data were obtained via belt and line-transect methodology and point counts. Transect length was 80 m (5 m width for belt transects). Data displayed here correspond to total observations in case of fish/fauna or percentages of coverage (Mean ± SE).

I. Site description, environmental conditions and hazards

Reef Name	City/Town	Distance to river (km)	Distance to Pop. (km)	Reason for site selection	Visibility	Anthropogenic impact	Siltation	Dynamite Fishing	Poison Fishing	Tourist impact	Sewage pollution
Jack's Bay	Robins Bay	1.4	3	survey	15	high	often	none	none	low	moderate
Long Hole	Robins Bay	1.5	2	survey	10	low	occasionally	none	none	none	none
Lime Cay	Port Royal	6	3	MPA, research	10	moderate	occasionally	none	none	low	low
Drunkenman's Cay	Port Royal	7	2	MPA, research	10	high	often	none	none	low	moderate
Wreck Reef	Port Royal	5	5	MPA, research	10	low	occasionally	none	none	none	none
Pigeon Island West	Lionel Town	18	12	MPA, research	10	moderate	occasionally	low	none	none	low
Big Pelican West	Lionel Town	6	4	MPA, research	10	low	never	none	none	none	none
Pear Tree Bottom	Runaway Bay	0.4	1.6	dive site, research	20	low	occasionally	none	none	moderate	low
Dairy Bull	Discovery Bay	4		research	20	moderate	occasionally	none	none	none	none
Mooring 1		1	1	research	10	moderate	occasionally	none	none	none	none
Dancing Lady	Discovery Bay	4		research	20	low	often	none	none	none	none
Oyster Bay	Falmouth	1	1.5	research	15	low	occasionally	none	none	low	none
Relocation 3	Falmouth	1.4	1	coral relocation site	10	low	often	none	none	none	none
Dickies Reef	Ocho Rios	1.2	2	MPA, dive site	20	low	occasionally	none	none	high	none
Doctor's Cave Buoy	Montego Bay	3	0.3	MPA, dive site	10	moderate	occasionally	none	none	high	low
Airport Reef West	Montego Bay	3.2	2.3	MPA, dive site	10	high	occasionally	none	none	moderate	low
Sunset Beach Mooring	Montego Bay	1.8	2	MPA, dive site	10	moderate	occasionally	none	none	low	low
Sandals Reef	Belmont	10	13	dive site	10	moderate	occasionally	none	none	high	none
Sewage End	Ocho Rios	1.6	3	MPA	10	low	never	none	none	none	low
RIU Nursery	Ocho Rios	2.5	2.5	MPA, dive site	10	low	occasionally	none	none	high	low
Little Bay	Negril		0.4	MPA, survey	10	moderate	always	none	none	none	none
Peter Tosh Reef	Belmont	3	13	dive site	10	low	occasionally	none	none	high	none
Ireland Pen	Negril	0.6	5	MPA, survey	10	low	often	none	none	low	low
Bloody Bay (Gallery)	Negril	2	0.5	MPA, survey	10	low	occasionally	none	none	high	low
El Punto Negrilo	Negril	5	5	MPA, survey	15	low	occasionally	none	none	low	low

Reef Name	City/Town	Industrial pollution	Commercial fishing	Artisinal/ recreational	Site protected	Enforced protection	Level of poaching	Spear-fishing	Shell collection	Anchoring	Diving	Other (specify)
Jack's Bay	Robins Bay	low	none	high	no							
Long Hole	Robins Bay	none	none	moderate	no							
Lime Cay	Port Royal	low	low	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Drunkenman's Cay	Port Royal	low	low	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Wreck Reef	Port Royal	none	none	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Pigeon Island West	Lionel Town	moderate	high	moderate	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Big Pelican West	Lionel Town	none	low	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Pear Tree Bottom	Runaway Bay	none	moderate	moderate	no							
Dairy Bull	Discovery Bay	none	high	moderate	no							
Mooring 1		none	high	moderate	yes	yes	medium	no	yes	no	no	seasonal fishery for lobster and conch
Dancing Lady	Discovery Bay	none	low	moderate	no							
Oyster Bay	Falmouth	none	low	low	no							
Relocation 3	Falmouth	none	none	low	no							
Dickies Reef	Ocho Rios	none	none	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Doctor's Cave Buoy	Montego Bay	none	low	low	yes	no	medium	yes	yes	no	no	
Airport Reef West	Montego Bay	none	low	low	yes	no	medium	yes	yes	no	no	
Sunset Beach Mooring	Montego Bay	none	low	low	yes	no	medium	yes	yes	no	no	
Sandals Reef	Belmont	none	low	low	no							
Sewage End	Ocho Rios	none	none	moderate	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
RIU Nursery	Ocho Rios	none	none	low	yes	no		no	yes	no	no	seasonal fishery for lobster and conch
Little Bay	Negril	none	high	high	yes	no	medium	no	yes	no	no	seasonal fishery for lobster and conch
Peter Tosh Reef	Belmont	none	moderate	low	no							
Ireland Pen	Negril	low	moderate	low	yes	no	medium	no	yes	no	no	seasonal fishery for lobster and conch
Bloody Bay (Gallery)	Negril	none	none	moderate	yes	no	medium	no	yes	no	no	seasonal fishery for lobster and conch
El Punto Negrilo	Negril	low	moderate	moderate	yes	no	medium	no	yes	no	no	seasonal fishery for lobster and conch

Result:

These tables provide some interesting results: It is surprising that the anthropogenic impact is only rarely categorized as “high” and mostly as “moderate” or “low”. Furthermore, fishing practices seem to be non-destructive (no poisoning or dynamite fishing), commercial fishing is categorized as low – moderate, and industrial pollution almost absent. Ultimately, sites are partly protected, although the protection appears not to be enforced.

Part 2 and 3, i.e. benthic community composition and the analysis of marine biodiversity provide additional, helpful information.

II. Benthic community composition

Reef Name	Hard coral (HC)		Macroalgae (NIA)		Others (OT)		Rubble (RB)		Rock (RC)		Recently killed coral (RKC)		Soft coral (SC)		Sand (SD)		Silt (SI)		Sponge (SP)		Transect segments	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	data points	n
Jack's Bay	**15.0**	0.9	**60.6**	1.5	4.4	0.8	0.0	0.0	**16.9**	1.3	0.0	0.0	0.0	0.0	**1.9**	0.5	0.0	0.0	1.3	0.3	160	4
Long Hole	**11.9**	2.2	**51.9**	2.6	0.6	0.3	0.0	0.0	**30.0**	2.0	0.0	0.0	0.0	0.0	**1.9**	0.3	0.0	0.0	3.8	0.6	160	4
Lime Cay	**10.2**	1.3	**44.8**	3.1	6.0	0.6	13.3	1.2	**11.5**	1.2	0.0	0.0	2.3	0.4	**7.9**	0.9	1.3	0.3	2.7	0.6	480	12
Drunkenman's Cay	**26.9**	1.3	**7.5**	0.9	1.5	0.2	11.5	1.4	**24.2**	1.4	0.0	0.0	2.3	0.3	**13.8**	1.5	11.3	1.8	1.3	0.4	480	12
Wreck Reef	**10.6**	0.5	**22.2**	2.4	0.9	0.3	15.0	1.8	**27.8**	2.2	0.0	0.0	0.9	0.5	**21.6**	1.0	0.0	0.0	0.9	0.3	320	8
Pigeon Island West	**7.9**	0.9	**29.2**	1.7	14.0	1.7	5.8	0.9	**25.6**	2.2	0.0	0.0	1.9	0.5	**15.4**	1.9	0.0	0.0	0.2	0.1	480	12
Big Pelican West	**6.6**	0.7	**59.4**	2.6	10.9	1.4	0.0	0.0	**21.6**	1.6	0.0	0.0	0.9	0.2	**0.6**	0.2	0.0	0.0	0.0	0.0	320	8
Pear Tree Bottom	**12.5**	1.2	**51.7**	5.6	4.6	0.5	0.4	0.1	**21.0**	2.1	0.0	0.0	0.2	0.1	**7.3**	1.4	0.0	0.0	2.3	0.4	480	12
Dairy Bull	**25.6**	2.0	**38.8**	2.3	10.0	1.1	1.6	0.4	**13.1**	0.9	0.0	0.0	0.0	0.0	**10.0**	1.0	0.0	0.0	0.9	0.4	320	8
Mooring 1	**9.4**	0.8	**53.8**	3.0	5.6	0.9	0.0	0.0	**7.5**	1.0	0.6	0.3	0.0	0.0	**21.3**	3.8	0.0	0.0	1.9	0.3	160	4
Dancing Lady	**12.5**	0.8	**52.2**	1.5	3.8	0.4	1.9	0.4	**10.3**	1.3	0.0	0.0	0.6	0.2	**17.8**	1.1	0.0	0.0	0.9	0.2	320	8
Oyster Bay	**21.9**	2.8	**30.0**	3.8	1.9	0.8	0.0	0.0	**25.6**	3.4	0.0	0.0	0.0	0.0	**11.3**	2.5	0.0	0.0	9.4	1.7	160	4
Relocation 1+3	**10.0**	0.7	**56.9**	1.7	2.2	0.5	0.6	0.2	**20.0**	0.9	0.0	0.0	0.0	0.0	**9.1**	1.2	0.0	0.0	1.3	0.3	320	8
Dickies Reef	**31.9**	2.8	**25.6**	4.6	2.5	0.7	0.0	0.0	**28.8**	3.9	0.0	0.0	0.0	0.0	**10.0**	1.5	0.0	0.0	1.3	0.3	160	4
Doctor's Cave Buoy	**20.6**	1.4	**16.3**	1.2	0.0	0.0	0.0	0.0	**50.6**	2.6	0.0	0.0	8.1	1.8	**0.0**	0.0	0.0	0.0	4.4	0.5	160	4
Airport Reef West	**35.6**	2.5	**6.3**	1.9	0.6	0.3	0.6	0.3	**42.5**	2.2	0.6	0.3	0.0	0.0	**6.3**	1.7	0.0	0.0	7.5	0.7	160	4
Sunset Beach Mooring	**20.3**	0.9	**40.3**	1.1	1.3	0.3	1.3	0.3	**22.5**	1.2	0.0	0.0	0.0	0.0	**13.1**	1.1	0.0	0.0	1.3	0.3	320	8
Sandals Reef	**12.5**	0.8	**31.3**	3.5	3.1	0.9	0.0	0.0	**36.3**	2.3	0.0	0.0	0.0	0.0	**16.3**	2.3	0.0	0.0	0.6	0.3	160	4
Sewage End	**37.5**	1.6	**1.3**	0.3	3.8	0.3	0.0	0.0	**55.0**	2.2	0.0	0.0	0.0	0.0	**0.6**	0.3	0.0	0.0	1.9	0.8	160	4
RIU Nursery	**11.9**	0.5	**38.1**	2.2	10.6	0.6	0.0	0.0	**32.5**	1.5	0.0	0.0	0.0	0.0	**4.4**	1.0	0.0	0.0	2.5	0.7	160	4
Little Bay	**21.6**	0.8	**28.1**	1.5	12.0	1.0	1.9	0.3	**18.1**	1.0	0.0	0.0	0.3	0.1	**15.0**	1.0	0.0	0.0	3.0	0.3	640	16
Peter Tosh Reef	**11.3**	1.0	**34.4**	1.7	20.6	1.0	6.3	1.0	**14.4**	1.3	0.0	0.0	0.6	0.3	**11.9**	0.5	0.0	0.0	0.6	0.3	160	4
Ireland Pen	**13.3**	0.6	**40.2**	1.5	4.4	0.7	0.2	0.1	**21.6**	0.9	0.0	0.0	0.0	0.0	**16.6**	0.8	0.2	0.1	3.8	0.3	640	16
Bloody Bay + Gallery	**19.3**	0.8	**31.4**	1.1	3.3	0.5	0.8	0.1	**26.3**	1.1	0.1	0.1	2.9	0.3	**9.6**	0.9	0.0	0.0	6.5	0.4	800	20
El Punto Negrilo	**20.6**	1.0	**14.4**	0.9	0.2	0.1	0.0	0.0	**41.9**	1.7	0.0	0.0	0.0	0.0	**6.3**	0.8	1.7	0.4	15.0	0.7	480	12

Reef check operates the following categories (See Hodgson protocol 2006):

Hard Coral (HC): Live coral including bleached live coral

Soft Coral (SC): Include zoanthids, but not sea anemones (the latter go into "Other")

Recently Killed Coral (RKC): Coral that has died within the past year (may be standing or broken into pieces). RKC appears fresh and white *or* with corallite structures still recognizable (i.e. their structure is still complete/not yet eroded)

Nutrient Indicator Algae (NIA): The NIA definition was changed to include all algae except coralline, calcareous (such as *Halimeda*) and turf. Turf algae are defined as being shorter than 3 cm. When turf algae are present, record the substrate directly beneath the algae

Sponge (SP): All sponges (but no tunicates) are included

Rock (RC): Any hard substrate whether it is covered in e.g. turf or encrusting coralline algae, barnacles, oysters etc. Rock also includes dead coral that is more than about 1 year old, i.e. corallite structures still visible

Rubble (RB): Includes rocks between 0.5 and 15 cm diameter in the longest direction. If larger, it is rock, if smaller, it is sand

Sand (SD): Particles smaller than 0.5 cm. In the water, sand falls quickly to the bottom after being dropped

Silt/Clay (SI): Sediment that remains in suspension if disturbed
Other (OT): Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrate

III. Coral reef and associated fauna description

Reef location	Gorgonian & Coral diseases				Lionfish (*Pterois volitans*)	Coral Bleaching (% all populations)	Fauna										Gorgonians (spp.)
	Aspergillosis	Black Band	White Band	White Plague			Turtles	Sharks	Parrotfish (Scaridae)	Grouper (*Serranidae*)	Snapper (*Lutjanidae*)	Triton (*Charonia var.*)	Spiny /Slipper Lobster	Black Sea urchin (*Diadema ant.*)	Pencil Urchin (*Eucidaris spp.*)	Collector urchin (*Tripneustes* sp.)	
Jack's Bay	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	2.0	0.0	11.0	0.0	0.0	4.0	0.0	0.0	95.0
Long Hole	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	164.0	0.0	118.0	60.0
Lime Cay	0.0	0.0	0.0	0.0	0.3	0.8	0.0	0.3	3.7	0.0	1.3	0.0	0.3	50.3	7.3	0.3	438.3
Drunkenman's Cay	0.0	0.0	0.0	0.0	0.7	1.2	0.0	0.3	2.3	0.0	6.3	0.0	3.0	49.7	37.0	1.7	798.3
Wreck Reef	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.5	118.5	21.5	18.0	139.0
Pigeon Island West	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	4.7	0.0	0.7	9.0	2.7	2.0	524.3
Big Pelican West	1.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	5.0	0.0	2.0	0.0	5.5	7.3	8.0	0.5	163.5
Pear Tree Bottom	0.0	0.0	0.0	0.0	0.3	4.6	0.0	0.0	3.0	0.0	1.7	0.0	0.3	108.3	2.0	11.3	109.3
Dairy Bull	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	5.0	0.0	1.0	0.0	0.5	52.3	0.5	13.5	120.0
Mooring 1	0.0	0.0	0.0	0.0	1.0	45.0	0.0	1.0	8.0	0.0	9.0	0.0	0.0	9.0	0.0	6.0	107.0
Dancing Lady	0.0	0.0	0.0	0.0	4.5	17.5	0.5	0.0	4.5	0.0	4.5	0.0	0.0	4.3	0.0	27.5	69.0
Oyster Bay	3.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	425.0	16.0	38.0	709.0
Relocation 3	0.0	2.5	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	1.0	0.5	342.0
Dickies Reef	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	417.0	0.0	6.0	176.0
Doctor's Cave Buoy	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	10.0	0.0	3.0	0.0	3.0	235.0	32.0	15.0	1.0
Airport Reef West	0.0	1.0	0.0	1.0	0.0	1.3	0.0	0.0	4.0	1.0	0.0	0.0	0.0	756.0	2.0	3.0	53.0
Sunset Beach Mooring	0.0	0.0	0.0	0.5	1.5	0.3	0.0	0.0	17.0	0.0	2.5	0.0	1.0	1.7	3.0	6.0	38.5
Sandals Reef	0.0	0.0	0.0	0.0	5.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	4.0	12.0	43.0
Sewage End	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	1251.0	3.0	5.0	72.0
RIU Nursery	0.0	0.0	0.0	0.0	2.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	21.0	24.0
Little Bay	0.0	0.0	0.0	0.0	2.0	2.3	0.0	0.0	1.5	0.0	2.8	0.0	2.3	6.8	20.5	6.3	32.0
Peter Tosh Reef	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	1.0	0.0	81.0
Ireland Pen	0.0	0.0	0.0	0.8	2.8	3.9	0.0	0.0	2.8	0.0	9.0	0.0	0.3	27.0	1.3	2.5	314.8
Bloody Bay (Gallery)	0.0	0.0	0.2	0.0	0.4	4.2	0.0	0.0	1.8	0.0	1.0	0.2	0.8	141.6	20.8	2.4	193.4
El Punto Negrilo	0.0	2.3	0.0	0.0	5.0	2.7	0.0	0.0	1.3	0.0	3.0	0.0	0.0	293.7	14.0	6.7	127.3

The abundance of snapper, parrotfish, grouper, Nassau Grouper (no observations), Black sea urchin and lobster can also be used to indicate the impact of overfishing for selected areas. The abundance of Pencil urchin and Triton shells can be used to indicate the impact of Curio or ornamental trade.

Result: The last table indicated that overfishing, i. e. the absence of many important fish and invertebrate taxa, constitutes a serious problem on many reef locations around Jamaica’s coastline. Benthic community data indicate the vast presence of macroalgae and bare substratum, and the relatively lower coverage of hard corals. Interestingly, sea urchins are increasingly present on various reef sites. The importance of these grazers for ecosystem functioning has been described before.

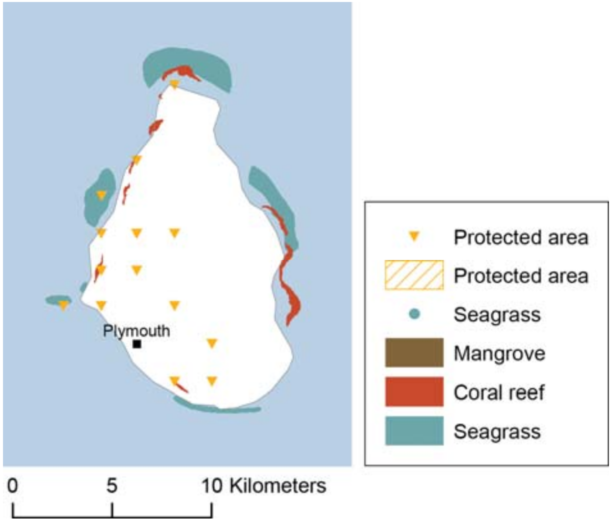
It is important to mention that reef sites, chosen by Reef Check, often present coral reefs in rather good conditions, at least in relative terms. Therefore, these assessments should be considered on the upper range in terms of possible ecosystem conditions.

Evidence prevails that the synergistic effects of environmental conditions, anthropogenic influences and overfishing, lead to degrading ecosystem conditions in many places. Therefore, any EbA project to be implemented has to start with a comprehensive analysis of the ecological and socio-economic conditions before action is taken.

Montserrat

This island features wide patches of seagrass meadows and coral reefs located along the coast of the northern half of the island, with a few protected areas without information regarding extent (3 points) on its north-western shoreline.

The island is poorly covered by environmental features and even if it presents several protected areas, their extent remains to be defined before any CCA project site can be selected.



Seagrass meadow	1.6%
Mangrove forest	0.0%
Coral reef	0.3%
Inland protected area	1.2%
Marine protected area	0.0%

No suitable scientific information to evaluate the ecological assets of Montserrat was available. Baseline data collection should be implemented/or continued in order to illustrate the island state's potential suitability for restoration efforts.

Saint Kitts and Nevis

The situation of this country is similar with the one in Grenada, with an important number of protected areas without information regarding their area extent. Thick and long patches of coral reefs and large extents of seagrass meadows can be found in the southern part of the country, allowing the implementation of punctual CCA projects.

Seagrass meadow	3.6%
Mangrove forest	0.0%
Coral reef	2.5%
Inland protected area	3.3%
Marine protected area	1.5%

The quality and quantity of available scientific information regarding the ecological assets of St. Kitts and Nevis is very limited. Suitable biodiversity studies were presented at regional conferences in 1999 (see Farrell & Fenton: Biological diversity in the Federation of St. Kitts and Nevis: Its management and benefits. 9th Meeting of the Caribbean Foresters; Dominican Republic).

Rawlins *et al* (2007) determined the level of understanding of the issues of climate change/variability by populations of St Kitts and Nevis. 62% of respondents showed some understanding of the concept of climate change (CC) and distinguished this from climate variability (CV). 48% of people attributed CC to green houses gases, holes in the ozone layer burning of vegetation and vehicular exhaust gases. 39% people did not answer this question.

A municipal sewage collection or treatment facility on St. Kitts is absent; homes use septic tank and soak-away systems and controls on the discharge of industrial and agro industrial effluents are insufficient. This may be due to the absence of legislative provision for environmental audits; a monitoring agency to examine effluent disposal; and/or the absence of legislation enforcing the need for permits or licenses for the disposal of wastewater from industrial or agricultural processing plants.

The Saint Kitts & Nevis GEF-IWCAM project attempted adequate rehabilitation and management of the aquifers in the Basseterre valley watershed, including the mitigation of threats from agricultural and domestic pollutants, the protection of the valley and its ecosystems, and the development of a resource management plan to mitigate leakages and wastage. A Water Resource Management Plan (WRMP) for the Basseterre Valley Aquifer and a Management Plan for the Proposed SKN Capitol National Park in the Basseterre Valley were provided.

Coastal ecosystems and water resources in particular, are already facing serious pressure from increasing and poorly planned development and poor land management practices. Additionally, resource users with little or incomplete awareness of their risks and alternative courses of action continue to degrade or over-extract from marine and terrestrial ecosystems in an effort to sustain themselves. Enforcement of laws to protect biodiversity remains a challenge, as does land use planning and regulation of settlements.

Regarding St. Kitts and Nevis, the seagrass meadows between both island parts and coral reefs are equally relevant for climate change adaptation. With regard to coastal erosion and subsequent impacts on tourism, these ecosystems should both be the primary focus of any future protection and restoration measures (Schill et al 2011). Caribsave (2012) estimated that 82% of all major tourism resorts in St. Kitts & Nevis will be impacted by beach erosion of 100 m. An alternative model, using a SLR of 0.5 m, estimates the loss of total beach area to range between 36-54 %.

Extensive maps regarding specific ecological and socio-economic features (benthos, coastlines, fishing areas, etc) is provided in TNC's marine zoning report (2012); underneath the benthic habitat map and total seabed coverage for both islands combined (Table 1; modified after TNC MZR 2012).

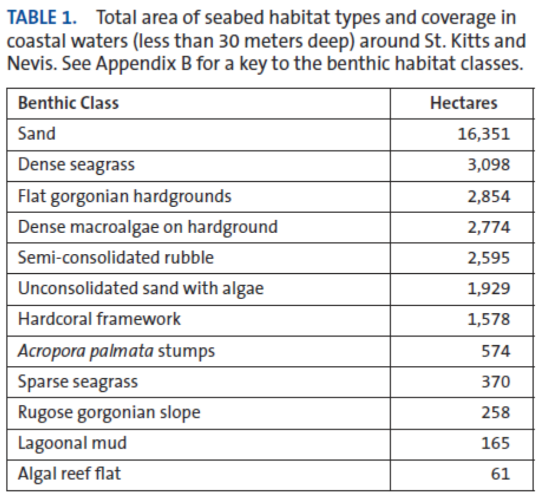
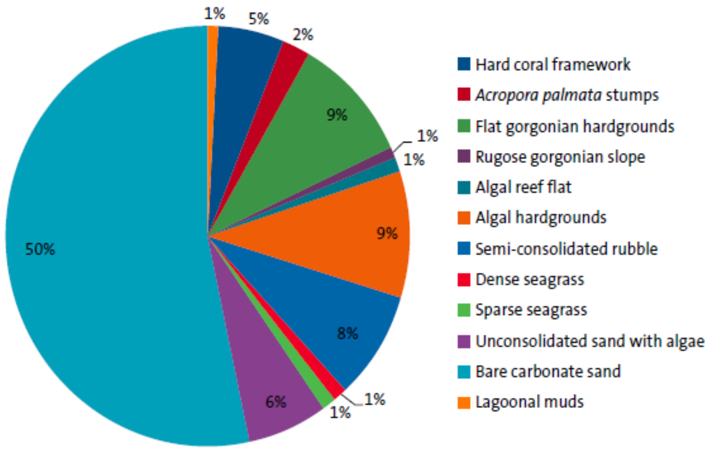


TABLE 1. Total area of seabed habitat types and coverage in coastal waters (less than 30 meters deep) around St. Kitts and Nevis. See Appendix B for a key to the benthic habitat classes.

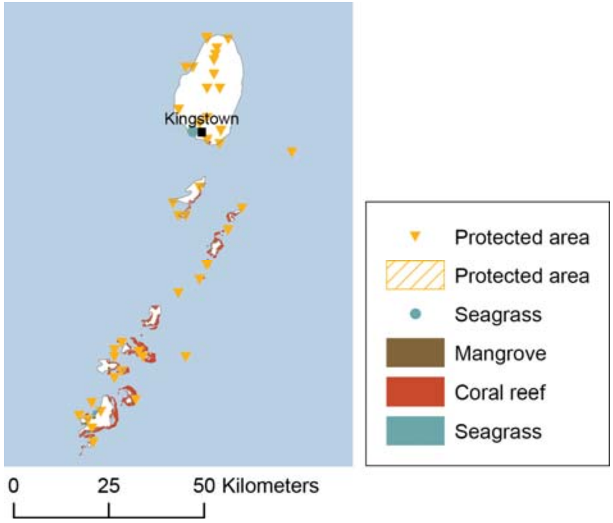
Benthic Class	Hectares
Sand	16,351
Dense seagrass	3,098
Flat gorgonian hardgrounds	2,854
Dense macroalgae on hardground	2,774
Semi-consolidated rubble	2,595
Unconsolidated sand with algae	1,929
Hardcoral framework	1,578
Acropora palmata stumps	574
Sparse seagrass	370
Rugose gorgonian slope	258
Lagoonal mud	165
Algal reef flat	61



Benthic Habitat Classification: Near-shore (less than 30-meter depth) benthic habitat map of St. Kitts and Nevis showing the distribution of 12 benthic habitat classes derived from extensive underwater video sampling and multispectral image classification using high-resolution (2.5 x 2.5-meter) IKONOS and Quickbird satellite imagery.

Saint Vincent and the Grenadines

The country presents the highest number of punctual protected areas (like the Bahamas and Santa Lucia), but information regarding their area extent still needs to be collected. The large number of islands well protected by coral reefs allows for a variety of CCA projects.



Seagrass meadow	0.1%
Mangrove forest	0.0%
Coral reef	1.5%
Inland protected area	2.0%
Marine protected area	1.0%

Reef development on St. Vincent is generally considered poor, whereas the Grenadines possess a larger overall distribution of reef systems with highly variable conditions (Mills 2001). St. Vincent lies in the transition zone to sediment-loaded continental waters and seems to be affected by sedimentation. This questions the suitability for restoration efforts, but further information could not be obtained yet. The Grenadines, harbouring the majority of coral reefs, do not seem to be affected by sedimentation that much.

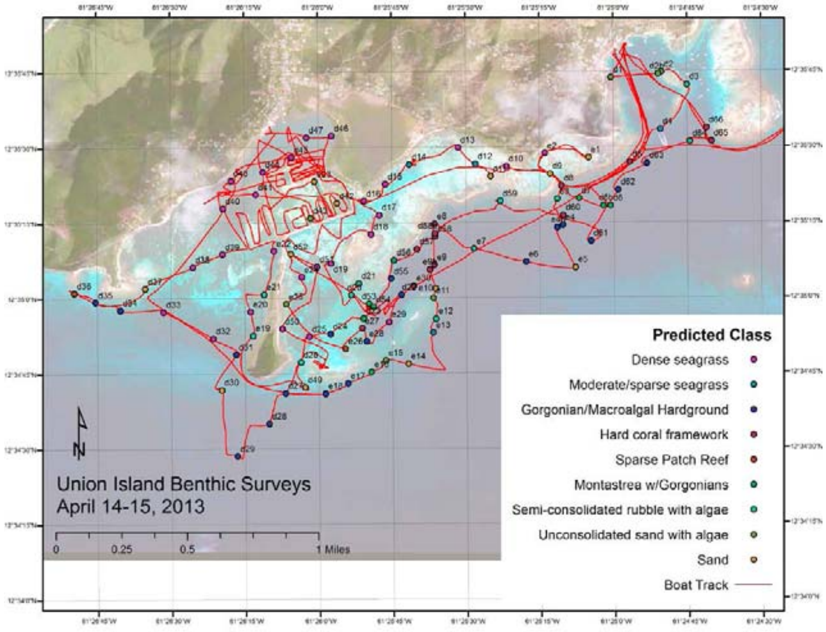
Caribsave'S (2012) projections calculated that only 10 % of major tourist resorts would be impacted by a 1 m SLR. 50 and 100 m beach erosion would impact 38 and 76 % of major tourism resorts.

The Central Water and Sewage authority (CSWA) deals with marine pollution, but activities are mostly limited to the area around Kingstown. Predominant sewage treatment consists of septic tanks for collection and treatment and soak-away systems for disposal of effluent. Offshore outlets do still affect nearby shorelines.

Various departments and divisions share responsibility for coastal zone management, natural resource management, biodiversity and physical infrastructure, often leading to a lack of coordination and integration and therefore inefficient management. Until present, international donor organizations seem most suitable to conserve the environment and coastal livelihoods of the islands (Mills 2001). Luckily, numerous international governmental and non-governmental organizations, try to cooperate with SVG's government, such as the Mayreau Environment Development Organization (MEDO) which created a major eco-tourism initiative with assistance of the EU. One promising example is the management of the Tobago Cays Marine Park, initiated in 1991 (CEP). In the Grenadines particularly, people do prize their environment and are resourceful in their outlook and understanding of environmental issues.

Although the SVG islands do possess large quantities of coral reef ecosystems, and are therefore suitable for coral reef restoration efforts, apparently inefficient management practices may pose a risk to effective and long term restoration efforts. Dr. Gregg Moore (University of New Hampshire, US) is about to publish two manuscripts regarding suitable restoration sites for St. Vincent and the Grenadines.

Union Island in the southern Grenadines, which is particularly interesting for tourism, has recently (04/2013) been surveyed by Steve Schill (TNC) and his team to assess the status of the coastline including marine ecosystems (Schill , Trip report Union island 2013):



"…Compared to Grenville Bay (Grenada), the benthic habitats around Union Island appear to be healthier in general, particularly with respect to coral and fish life, receiving fewer impacts from sedimentation and excessive algal growth. Within the inner areas of Clifton Bay, rubble and unconsolidated sand were mostly observed, largely dominated by macroalgae and seagrass. In the deeper outer parts of this bay (10-15m), coral structure seemed to increase with depth, however, very little actual coral cover was observed. The long narrow inner bay between Ashton and Clifton is a shallow area (1-3m) comprised of large swaths of sandy bottom with inter-connected seagrass patches with sporadic growth of *Porites* coral, particularly on the western side of the bay. Directly in front of this bay, the coral structure and health improves with increasing depth as well as fish abundance. The highest coral cover was observed directly in front of the shallow algal rim areas, exposed to the most wave action. Here, higher fish populations were observed. Beyond this band of healthier reef, in close proximity to the shallow algal rim areas, the reef structure appeared gradually worn down, with increases in rubble, gorgonian/sponge hardground, with occasional patch reef. Higher coral cover percentages and fish abundance were also observed along the outer reef that extends east of Frigate Island.
Within Ashton Harbor area, large expansive seagrass beds extend from near the coast outwards to 10-12m depth just west of Frigate Island with intermittent sandy areas and occasional rubble. The areas near the fingers of the failed marina are dominated by dense seagrass. Fish tend to congregate near the mangrove areas which are continuing to increase into the bay, using the fingers to expand outwards. The satellite imagery shows turbid water and poor flushing/circulation issues within the marina area. Water quality samples collected by Sustainable Grenadines show that the quality decreases rapidly within the harbor. "

Without ground truthing, one (first) exploratory step is to identify potential areas where synergies of multiple ecosystems could emerge. These are, based on satellite imagery:

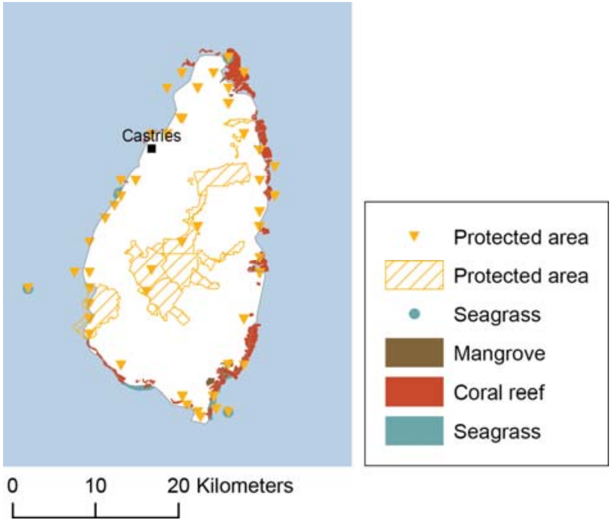
- Union Island; both seagrass meadows and coral reefs present

- Mustique Island; both seagrass meadows and coral reefs present

Concerning the Grenadines, those areas could be of interest for follow-up base line studies, and if evaluated positively, would require further socio-economic assessments. No additional satellite imagery could be obtained for those two islands.

Santa Lucia

This country is ranking first (along with the Bahamas and Saint Vincent & the Grenadines) regarding the number of protected areas. However, the vast majority of these are provided by points, without information regarding area extent and specification of protected areas extent should have priority. The island has potential for CCA projects, although the area extent of environmental features, i.e. ecosystems, is limited.



Seagrass meadow	0.3%
Mangrove forest	0.1%
Coral reef	1.5%
Inland protected area	6.1%
Marine protected area	1.2%

According to Caribsave (2012), Saint Lucia possesses a variety of ecosystems and biological species, including 1,436 vascular plants and 175 species of amphibians, birds, and mammals; furthermore, 333 coral reef and pelagic fish species and 3 species of marine turtles. Coral reefs, especially those along the west coast, have long supported fisheries for Saint Lucian society and economy. Grunts, snappers, parrotfish and groupers are common species extracted from coral reefs and have been valued to between US $520,000 and US $841,000 annually. Over 2,300 fishers and some 120 fish processors are employed in the fisheries sector. Major problems are unsustainable levels of harvest, illegal fishing methods, and habitat degradation. Near shore fisheries are considered overfished while the pelagic fisheries are regarded as under-utilised.

Scuba diving is a popular activity among tourists, mostly occurring along the west coast of the island. A valuation study on coastal capital in Saint Lucia estimated that about 25% of the tourists visit the island for the coral reefs. Approximately 45,000 total dives and 95,000 snorkelers engaged in reef based activities during 2006. The combined direct and indirect expenditures, including MPA user fees and miscellaneous expenditures on reef-related tourism and recreation in that year were estimated to be between US $160 and $194 million. The healthiest reefs are found off the coast of Soufrière which is at high risk to landslides and consequently disposes its reefs are prone to sedimentation. All 90 km of reefs around the island are at risk to human activities. A general trend of declining coral cover and increasing growth of macro-algae is observed.

According to Hawkins *et al.* (2006), St. Lucia’s reserves succeeded in producing significant gains to fish stocks despite a strong decline in coral cover and structural complexity, being a great example how protected no-take areas can create mid-term benefits, even under degrading environmental conditions, if managed effectively. Likewise, these MPAs proved the ability of functional coral reef ecosystems for recovery after natural disturbances such as hurricanes, via the regulation of macroalgae by herbivorous fishes. Overall, the coral reef ecosystems in St. Lucia average as low as elsewhere in the Caribbean (<15% coral cover), and disturbances such as storms and coral diseases do occur regularly (Nugues, 2002). Yet, the management practices in place suggest that the island is strongly committed to maintain its marine ecosystems. The combination of large designated large protected areas and partially well-planned management efforts make St. Lucia a suitable SIDS for coral reef restoration efforts.

The GEF-IWCAM case study “Protecting and Valuing Watershed Services and Developing Management Incentives in the Fond D’Or Watershed Area of Saint Lucia” only partially fulfilled the expectations. Apart from the Water and Sewerage Management authority, which receives wide powers for the protection of watersheds, other management arrangements are weak. According to GEF, this gap has been partially filled by the establishment of the TMR, a multi-disciplinary body with cross-sectoral and community representation and which emerged as an NGO with direct responsibilities for the continued work of IWCAM in the Fond D'Or Watershed.

The people of St. Lucia recognize the importance of biological conservation and there is extensive awareness among the population as evinced by a number of successful community-participation management projects (Caribsave 2012). The Government has also taken steps toward integrating biodiversity issues into the national agenda, with several cross-sectoral communities responsible for the over-sight of environmental agreements. It is evident that the government of Saint Lucia is committed to adapting to climate change. Many policies and plans for action are in place, but financial resource shortages along with limited technical capacities hinder the successful adaptation efforts across most government ministries and other stakeholder groups.

Compared to most other Caribbean SIDS, a projected SLR of 1 m only affects 7 % of all major tourism resorts on the island. Beach erosion of 50 and 100 m would case 2 and 30 % or tourism resorts to be affected, respectively. However, two beaches at Rodney Bay, considered one of the island's main tourist attractions, would be inundated by a 0.5 m SLR, once again, demonstrating the dependence of those islands on functioning ecosystems. Pigeon Island, Pigeon Causeway, Rodney Bay and Soufrière have been identified as some of the most vulnerable areas to SLR and include notable resorts, ports and an airport that all lie within less than 6 m above sea level.

Without ground truthing, one (first) exploratory step is to identify potential areas where synergies of multiple ecosystems could emerge. One example, based on satellite imagery may be:

- South-Eastern St. Lucia (Savannes Bay, Sandy Beach/Vieux Fort); seagrass meadows, mangrove stands and coral reefs present

That area could be of interest for follow-up base line studies, and if evaluated positively, would require further socio-economic assessments: However, most settlements are situated along the western coastline. Additional satellite imagery with regard to past and present coverage of mangroves could be obtained for that area as well (see page 50).

Reef check performed a relatively recent (2000-2012) comprehensive survey on 4 different reef sites around St. Lucia. Partly repeated (n=1-4) surveys were conducted in shallow water areas (depth range between 3 - 12 m). Data were obtained via belt and line-transect methodology and point counts. Transect length was 80 m (5 m width for belt transects). Data displayed here correspond to total observations in case of fish/fauna or percentages of coverage (Mean ± SE).

I. Site description, environmental conditions and hazards

Reef Name	City/Town	Distance to river (km)	Distance to Pop. (km)	Reason for site selection	Visibility	Anthropogenic impact	Siltation	Dynamite Fishing	Poison Fishing	Tourist impact	Sewage pollution
Rachette Point	Soufriere		1	healthy reef	15	moderate	often	none	none	high	low
Malgretoute	Soufriere	2	1.8		20	low	occasionally	none	none	moderate	low
Superman's Flight	Soufriere			very good reef	20	moderate	occasionally	none	none	high	low
Grande Caille	Soufriere		1	healthy reef	15	moderate	often	none	none	high	low

Reef Name	City/Town	Industrial pollution	Commercial fishing	Artisinal/ recreational	Site protected	Enforced protection	Level of poaching	Spear-fishing	Shell collection	Anchoring	Diving	Other (specify)
Rachette Point	Soufriere	none	moderate	high	yes	yes	low	yes	yes	yes	yes	zonation of MPA
Malgretoute	Soufriere	none	low	low	yes	yes	low	yes	yes	yes	yes	zonation in MPA
Superman's Flight	Soufriere	none	moderate	high	yes	yes	low	yes	yes	yes	yes	zonation of MPA
Grande Caille	Soufriere	none	moderate	high	yes	yes	low	yes	yes	yes	yes	zonation of MPA

Result:

Reef check data here show some general differences to data from Jamaica: The anthropogenic impact is categorized as “moderate” or “low” and Industrial pollution is considered absent. Fishing practices seem to be non-destructive (no poisoning or dynamite fishing), yet artisanal and recreational fishing is frequent. Also, the overall impact by tourism is considered “high”. All sites are protected, and protection seems to be enforced. The pressure from tourism and artisanal fisheries on the selected sites seems higher than for most sites on Jamaica. One further difference seems to be the enforcement of protection on those sites.

Part 2 and 3, i.e. benthic community composition and the analysis of marine biodiversity provide additional, helpful information.

II. Benthic community composition

Reef Name	Hard coral (HC)		Macroalgae (NIA)		Others (OT)		Rubble (RB)		Rock (RC)		Recently killed coral (RKC)		Soft coral (SC)		Sand (SD)		Silt (SI)		Sponge (SP)		Transect segments	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	data points	n
Rachette Point	**24.2**	1.2	**5.8**	0.7	5.6	1.4	12.7	1.7	**5.9**	0.6	3.4	0.7	2.3	0.3	**32.8**	1.8	0.0	0.0	7.2	0.7	640	16
Malgretoute	**20.0**	1.8	**7.5**	1.2	2.5	0.7	7.5	0.8	**32.5**	1.9	8.2	1.2	1.8	0.3	**10.7**	1.1	0.0	0.0	9.3	0.5	280	7
Superman's Flight	**24.1**	1.9	**9.4**	1.0	2.8	0.5	4.7	0.8	**39.1**	1.9	0.0	0.0	1.9	0.5	**8.1**	0.7	0.0	0.0	10.0	0.7	320	8
Grande Caille	**17.8**	1.3	**12.2**	1.9	1.6	0.4	20.3	2.9	**9.4**	0.9	0.9	0.4	5.3	1.1	**29.4**	2.1	0.0	0.0	3.1	0.4	320	8

Reef check operates the following categories (See Hodgson protocol 2006):
Hard Coral (HC): Live coral including bleached live coral
Soft Coral (SC): Include zoanthids, but not sea anemones (the latter go into "Other")
Recently Killed Coral (RKC): Coral that has died within the past year (may be standing or broken into pieces). RKC appears fresh and white *or* with corallite structures still recognizable (i.e. their structure is still complete/not yet eroded)
Nutrient Indicator Algae (NIA): The NIA definition was changed to include all algae except coralline, calcareous (such as *Halimeda*) and turf. Turf algae are defined as being shorter than 3 cm. When turf algae are present, record the substrate directly beneath the algae
Sponge (SP): All sponges (but no tunicates) are included
Rock (RC): Any hard substrate whether it is covered in e.g. turf or encrusting coralline algae, barnacles, oysters etc. Rock also includes dead coral that is more than about 1 year old, i.e. corallite structures still visible
Rubble (RB): Includes rocks between 0.5 and 15 cm diameter in the longest direction. If larger, it is rock, if smaller, it is sand
Sand (SD): Particles smaller than 0.5 cm. In the water, sand falls quickly to the bottom after being dropped
Silt/Clay (SI): Sediment that remains in suspension if disturbed
Other (OT): Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrate

III. Coral reef and associated fauna description

Reef location	Gorgonian & Coral diseases				Lionfish (*Pterois volitans*)	Coral Bleaching (% all populations)	Fauna										Gorgonians (spp.)
	Aspergillosis	Black Band	White Band	White Plague			Turtles	Sharks	Parrotfish (Scaridae)	Grouper (*Serranidae*)	Snapper (*Lutjanidae*)	Triton (*Charonia var.*)	Spiny /Slipper Lobster	Black Sea urchin (*Diadema ant.*)	Pencil Urchin (*Eucidaris spp.*)	Collector urchin (*Tripneustes* sp.)	
Rachette Point	n.a	n.a	n.a	n.a	n.a	2.5	n.a	n.a	15.3	10.3	29.0	0.0	0.0	120.0	0.3	1.0	25.0
Malgretoute	n.a	n.a	n.a	n.a	n.a	0.0	n.a	n.a	8.5	0.5	1.0	2.5	1.0	167.5	0.5	7.0	24.0
Superman's Flight	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	9.5	0.5	38.5	0.0	0.0	420.0	0.0	0.0	28.5
Grande Caille	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	n.a.	14.5	3.0	33.0	0.0	0.0	47.5	0.0	0.0	7.5

The abundance of snapper, parrotfish, grouper, Nassau Grouper (not shown, but not present), Black sea urchin and lobster indicate the impact of overfishing for selected areas. The abundance of Pencil urchin and Triton shells indicate the impact of Curio or ornamental trade

Result:

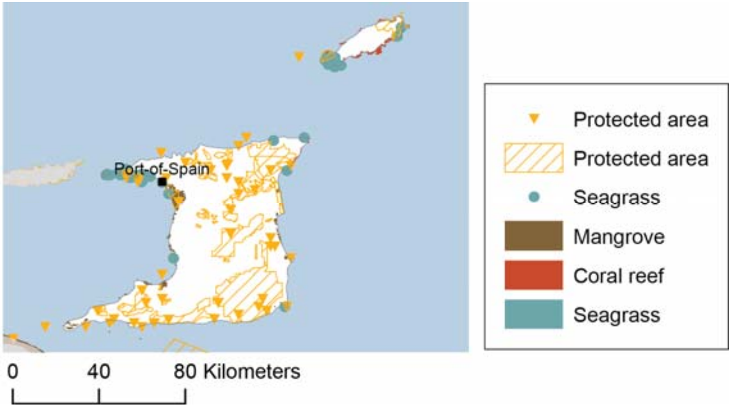
Compared to data on Jamaica, the last table indicated that important fish and invertebrate taxa are more common here. Benthic community data indicate macroalgae are less common, although the primary settlement substrate for macroalgae, i.e. bare substratum, seems predominant. The relative coverage of hard corals is good, at least for Caribbean standards.

Herbivorous fish species and grazers such as sea urchins may thus exert a positive effect on benthic community composition, preventing the increase of macroalgae. These reefs may be good examples how synergistic effects of stressors, i.e. anthropogenic disturbance and overfishing, can be counteracted when the marine biodiversity can respond to such scenarios.

Again, if EbA projects are to be implemented on St. Lucia, a comprehensive analysis of the ecological and socio-economic conditions is recommended.

Trinidad and Tobago

The country is ranking second in terms of land protected areas and has important local potential for CCA projects using seagrass meadows in the region of Port-of-Spain. As they remain recorded as points, their extent still remains to be specified, as well as the extent of marine protected areas.



Seagrass meadow	0.0%
Mangrove forest	0.6%
Coral reef	0.3%
Inland protected area	17.8%
Marine protected area	0.7%

The quality and quantity of available scientific information regarding the ecological assets of Trinidad and Tobago is very limited. Suitable biodiversity studies were presented at regional conferences in 1999 (see Sandy & Faizool: Biological diversity in Trinidad and Tobago: Its management and benefits. 9th Meeting of the Caribbean Foresters; Dominican Republic).

Rawlins *et al* (2007) determined the level of understanding of the issues of climate change/variability by populations of Trinidad and Tobago (and St. Kitts, see above). 55% of respondents showed some understanding of the concept of climate change (CC) and distinguished this from climate variability (CV). 50% of people attributed CC to green houses gases, holes in the ozone layer burning of vegetation and vehicular exhaust gases. 31% people did not answer this question.

Adaptive and community-based resource management can bring resilience into both human and ecological systems and is an effective way to cope with environmental change characterized by future surprises or unknowable risks. Tompkins (2004) demonstrates, by evaluating present-day collective action for community-based coastal management in Trinidad and Tobago, that community-based management enhances adaptive capacity in two ways: by building networks that are important for coping with extreme events and by retaining the resilience of the underpinning resources and ecological systems.

According to the CEP‘s report for wastewater management, sewage pollution comes from both point and non-point sources. The former is caused mainly by inadequately treated effluent from sewerage treatment plants, the latter from a wide range of agricultural, animal husbandry, and urban land use activities. Several coastal areas indicate the presence of sewage-associated bacteria. Even seafood marketability is affected, including the risk of contracting typhoid and cholera from consuming shellfish contaminated from contact with sewage, which has even led to bans on the harvesting of shellfish in the past. The porous nature of the coralline limestone in which the septic tank/soakaway systems are constructed, allows contaminants to constantly enter the coastal waters via ground water. Chronic sewage pollution results in eutrophication, causing algal growth and red tides that impact coral reefs and have caused massive fish kills.

Lapointe (2010) assessed the chemical and ecological impacts of sewage pollution in Tobago’s Buccoo Reef Marine Park (BRMP) and on surrounding fringing reefs, including a water quality and coral reef monitoring project. Results identified land-based nitrogen runoff to cause eutrophication of Tobago’s fringing reefs. Importantly, the creation of the BRMP has not protected the coastal zone from water quality and subsequent ecosystem degradation, despite large populations of herbivorous fishes to potentially balance out the macroalgal proliferation. Trinidad and Tobago can be considered a good example how reef ecosystems within marine protected areas continue to degrade due to anthropogenically-derived insufficiently treated sewage.

Tourism expenditure through time

Figure 10 represents the evolution of international tourism expenditure through time (World Bank, World Development indicators) for the five pre-selected countries. Graph (a) highlights the large differences in tourism expenditures between countries, and graph (b) allows the comparison of their respective trends (by normalization to respective expenditures in the year 1995). Figure 10.c represents the share of the SIDSs' international tourism expenditures with regard to national GDPs.

St. Lucia, Grenada and SVG have significantly lower tourism expenditures than Jamaica and the Bahamas (a). Yet, they showed the highest increase in relative expenditures from 1995 – 2010 (b), highlighting the enormous importance of tourism for these countries, even when compared to other Caribbean SIDS. All countries show an increase of relative tourism expenditures until 2007, and a subsequent decline afterwards, except for Saint Lucia (b). With regard to their national GDPs (Graph c), the Bahamas and St. Lucia show a relatively higher contribution of tourism expenditures than the other 3 countries. However, the relative contribution of tourism expenditures of all countries is steadily decreasing since 1995 - with the exception of the Bahamas, showing a temporary increase after 2000. Comparing 1995 and 2010 values, only the Bahamas experienced a decrease by 2 % from 7 to 5 % over the last 15 years, whereas tourism remains to provide more less steady contributions for the economic development in the other countries.

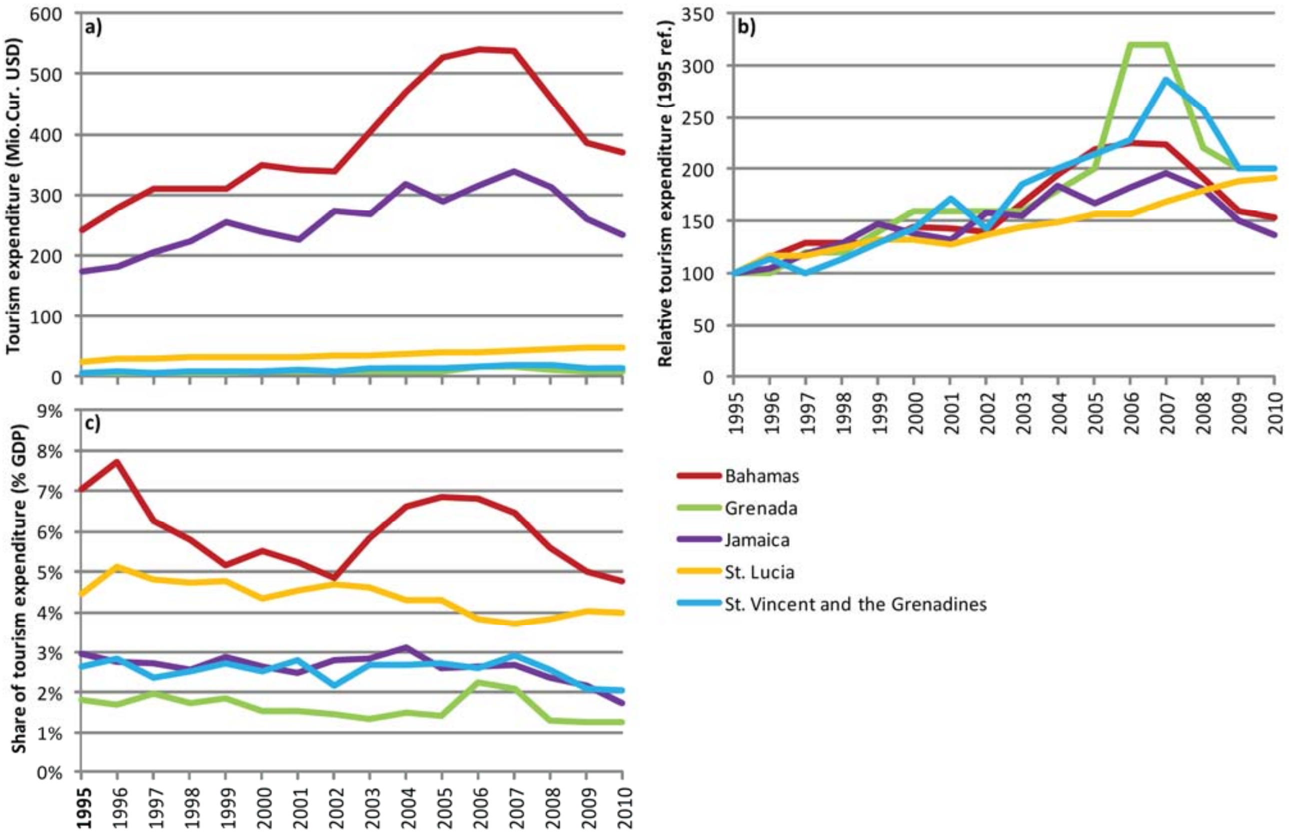


Figure 10: Tourism expenditure through time (source: World Bank)

Today's (2010) values regarding the share of tourism expenditures remain significant and around 5 and 4% for the Bahamas and Saint Lucia, respectively, and around 2% for the other countries.

Fish capture through time

Evaluating the evolution of the state of fish stocks in the national waters through time is not an easy task and consequently has to be done through a proxy such as fishery captures available at national scale (FAO FISHSTAT database, http://www.fao.org/fishery/statistics/software/fishstat/en). These figures are based on reports by monitoring agencies and do not include untargeted species thrown overboard, artisanal, sport or illegal catches (Pauly, 1997), the real values are therefore expected to be higher. The Sea Around Us Project (http://seaaroundus.org/) attempts to fill these gaps and is today the most accurate and detailed global database on fisheries with strong components on ecosystems and biodiversity. The database uses the Exclusive Economic Zone (EEZ) of each country as geographic unit, and provides information for species, ecosystem, fishing country, and type of gear.

Figure 11 displays the “catches by fishing country” divided by the surface of EEZ to calculate a fish capture density through time. Graph (a) comprises the complete period of the database (1950 – 2006), showing total (national plus foreign countries) fish capture densities in national waters, while graph (b) focuses on national captures (both graphs are greyed to ease comparisons). All countries, except for Grenada, had a period during which captures of foreign countries had a much higher influence on fish stock than national captures. These periods ended between the end of the 1970s and the beginning of the 1990s when new national regulations were implemented.

Figure 11.b shows the strong fluctuations in national fish capture densities of Jamaica, Grenada and St. Lucia during the examined period, and an increase in national fish capture densities when comparing 1995 to 2010. Both the Bahamas and SVG show a steady increase in national captures over the same period.

Graph (c) allows the comparison of respective trends in national fish capture densities (by normalization to respective densities in the year 1995). Two distinct groups emerge here: The Bahamas, Saint Vincent and the Grenadines and St. Lucia experienced periodical increases in national fish captures from 1995-2005, however, always followed by quick declines afterwards. Overall capture densities are slightly higher in 2005 than in 1995. Jamaica and Grenada experienced pronounced declines in capture densities from 1995 to 2000. Since 2001, it appears as if both countries recover and display steadily increasing national fish capture densities again.

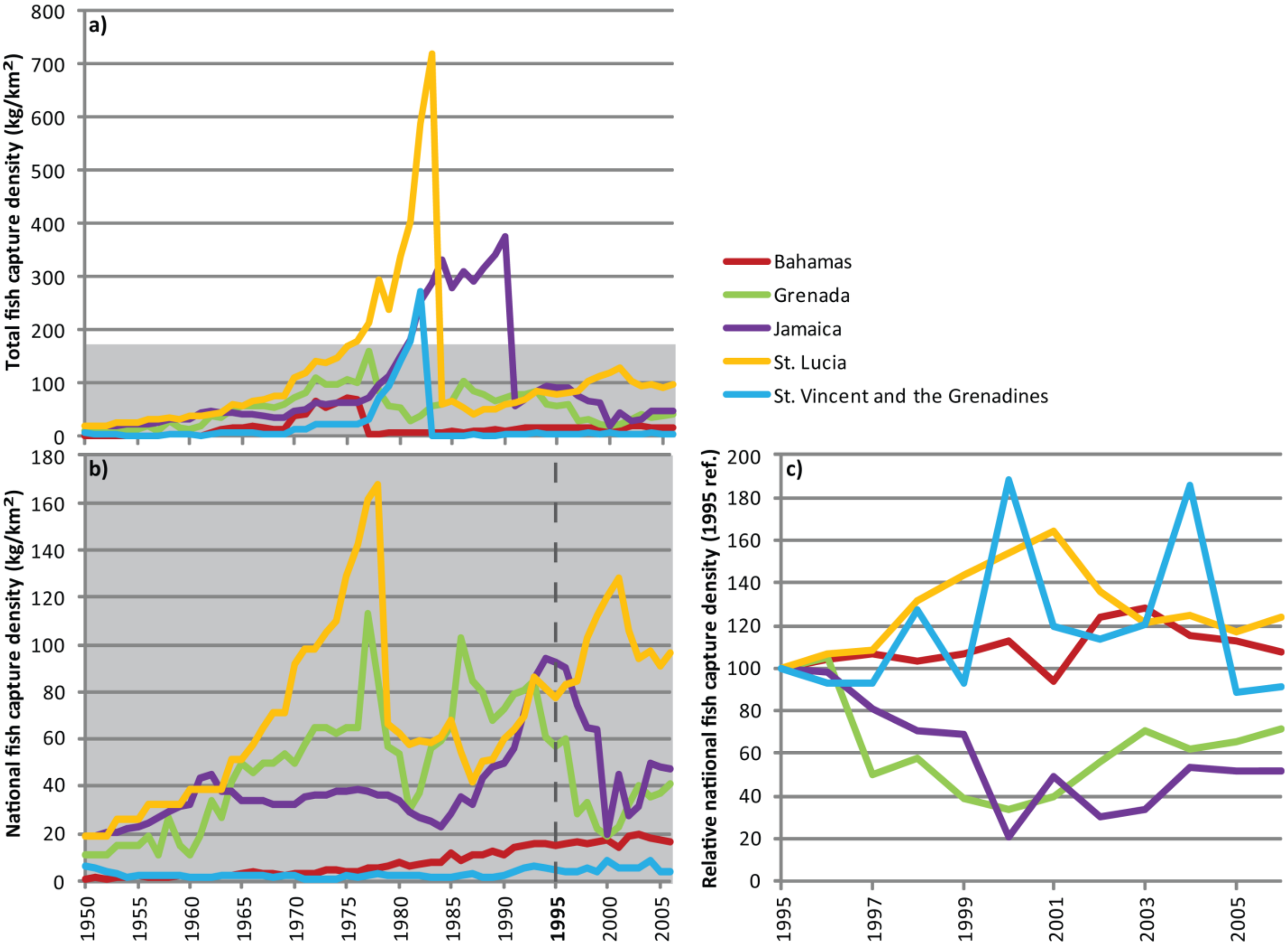


Figure 11: Fish capture density through time (source: Sea around us project)

Unfortunately the Sea round us project database stops in 2006 and as it cannot be compared directly with the FAO database, more recent values could not be estimated.

Mangrove coverage through time – demo sites

This chapter presents the detection of mangrove distribution using remote sensing techniques. We obtained free satellite images for selection of sites in Grenada, Jamaica and Saint Lucia. Underwater ecosystems were not treated. This is feasible, but would request high resolution satellite imagery with deep blue band. These were not freely available.

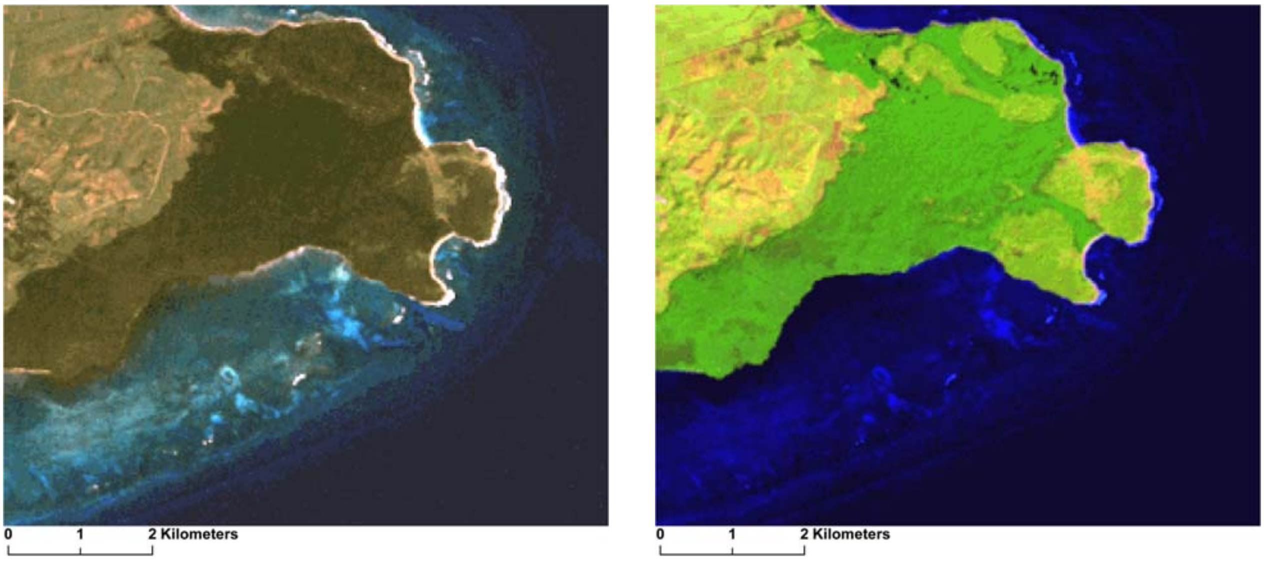
Two types of satellite imagery products are commonly used for the monitoring of mangrove ecosystems using remote sensing. The most widely available – and over a long time period – ones are based on medium resolution sensors (Landsat, Aster, IRS, SPOT), the second type are high resolution sensors (IKONOS, Quickbird, Earthview).These are more recent and consequently no images are available for the pre-2000 era. Scientific literature indicates that for an "assessment of reforestation and conservation success", project medium resolution imagery is the most appropriate (Kuenzer et al., 2011). We used mostly medium resolution images, at the exception of the recent image of Vieux Fort in Grenada, which was the only image we could get for this site.

Site selection was performed using the historical imagery tool of Google Earth combined with the latest global dataset on mangrove coverage provided by the WCMC Ocean Data Viewer (http://data.unep-wcmc.org/datasets, Global Distribution of Mangroves USGS 2011).

Nine sites were preselected, for which free imagery (Landsat 5/7 archives) with cloud-free or low cloud coverage - were available for long time periods (1985-1986 and 2010).

The extraction of mangrove coverage was performed through the Spring 5.2.2 software developed by the Brazil's National Institute for Space Research / Image Processing Division (INPE/DPI) and distributed as freeware (Camara et al., 1996). Within its large panel of possibilities, the segmentation tool was the key functionality in the selection of this software.

Segmentation is a recent remote sensing method to ease image classification. It creates uniforms regions of similar pixels which are then used for the classification on the base of their spectral signature and texture. Mangrove ecosystems differ from adjacent dense forests by the wetness of its environment, which is highlighted in remote sensing through the Infrared band. Consequently the band combination retained after a set of test is 541 (respectively shortwave infrared, near infrared and blue) which sharply delineates land from ocean and differentiates "dry forest" from "wet mangrove" (see Figure 12, mangrove cover in dark green).



LS5 TM 9 January 1986 (Golden Grove) - BGR

Bands 5, 4 and 1

Figure 12: Band color combination comparison

To reliably differentiate forest from mangrove, satellite imagery needs to be acquired at (or just after) high tide, before the terrains gets drained. As the availability of free satellite imagery remains limited, a majority of images cannot be used due to significant cloud cover. For this reason, it is impossible to apply a common methodology on each site.

We therefore had to use different classification methods. In absence of ground trusting for calibration, non-supervised methods were generally used. However, we also calibrated our classification using the preliminary source of mangrove locations available (Global Distribution of Mangroves USGS 2011). It was primarily used for a visual estimation of the mangrove extent before to start the remote sensing analysis. After the classification phase, mangrove regions where manually extracted from the classified layer and merged in a single mangrove layer in the GIS project provided with this report.

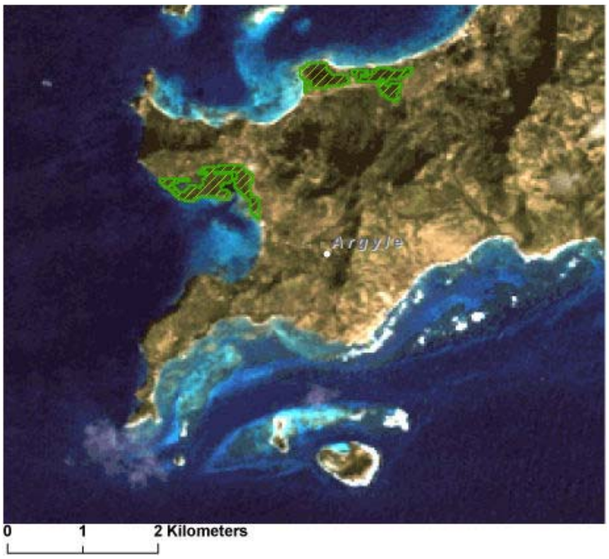
The results of the analysis of the five demo sites used are briefly presented below. Due to the limitations mentioned above, the extents and the values have to be interpreted cautiously, as their accuracy was not estimated and probably very low for the aforementioned reasons.

Table 4 synthesizes the variety of satellite images, methods and parameters applied, used on each site and date. The taxonomy used in the "Segment" column corresponds to the bands used, "Similarity limit" and "minimum size of the region" (in pixel) were separated by "-". The taxonomy of the "Classif" column corresponds to the methodology and the parameter applied.

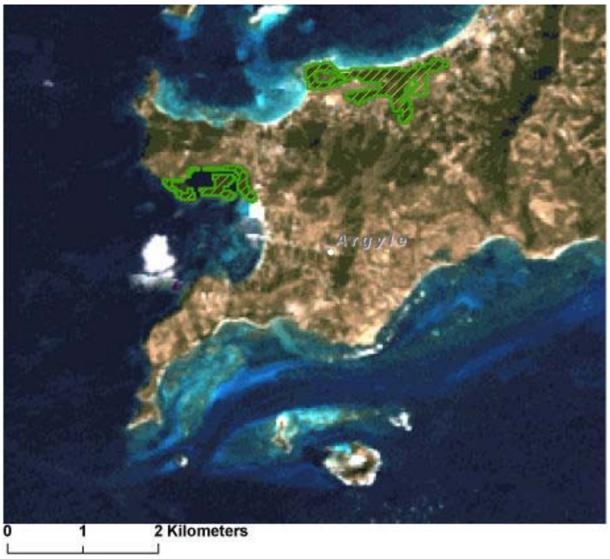
Country	AOI_Name	Sensor	Res.	Segment.	Classif.
Grenada	Argyle	LS5 TM	30 m	145_10_5	Iso_95
Grenada	Argyle	LS7 ETM+	30 m	145_10_5	Iso_95
Jamaica	Savanna la mar	LS5 TM	30 m	145_10_5	Arq_10
Jamaica	Savanna la mar	LS5 TM	30 m	145_10_5	Arq_10
Jamaica	Golden grove	LS5 TM	30 m	145_10_5	Arq_10
Jamaica	Golden grove	LS5TM	30 m	145_10_5	Bhat_95
Jamaica	Annoto bay	LS5TM	30 m	145_10_5	Iso_95
Jamaica	Annoto bay	LS5TM	30 m	145_10_5	Iso_95
Saint_Lucia	Vieux Fort	LS5TM	30 m	145_10_5	Iso_95
Saint_Lucia	Vieux Fort	WorldView	~ 2m	5_500	Manual

Table 4: Synthesis of the satellite imagery used

Grenada

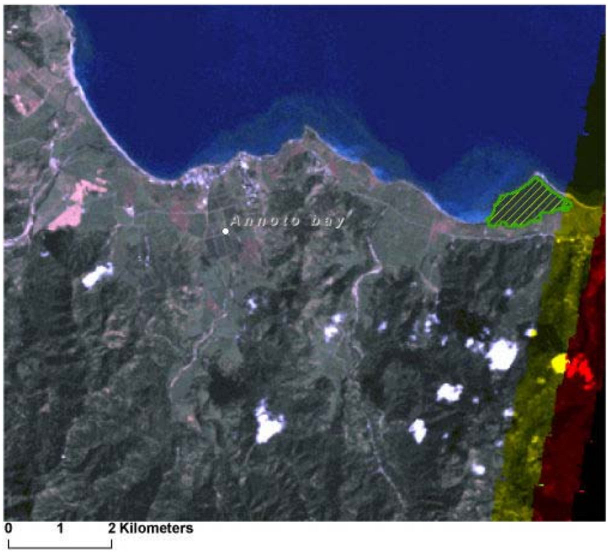


LS5 TM 19 January 1986

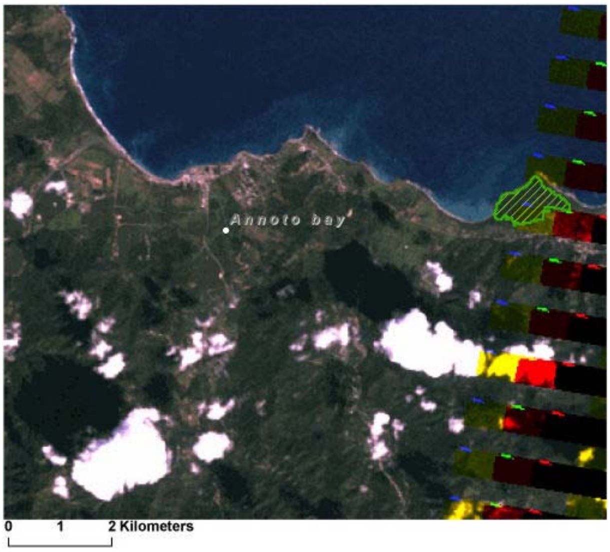


LS7 ETM+ 29 January 2010

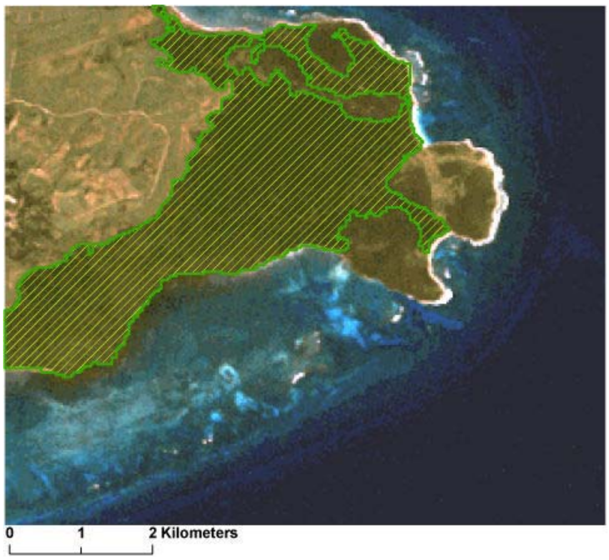
Jamaica



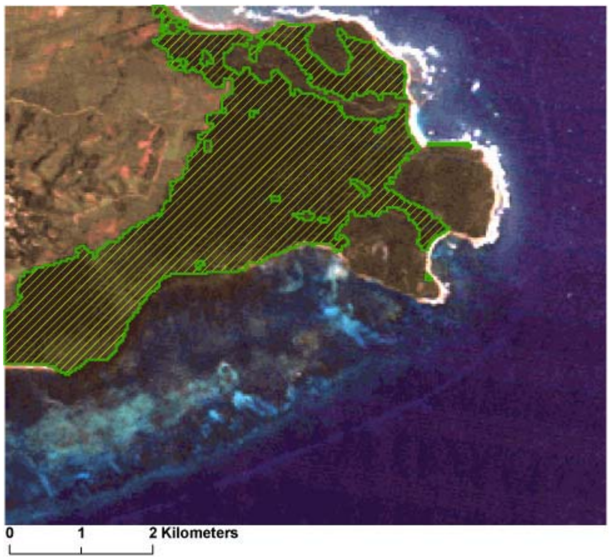
LS5 TM 29 January 1985



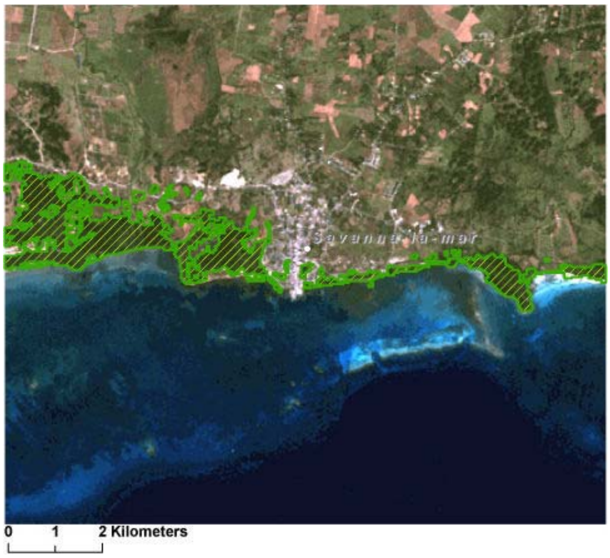
LS5 TM 18 January 2010



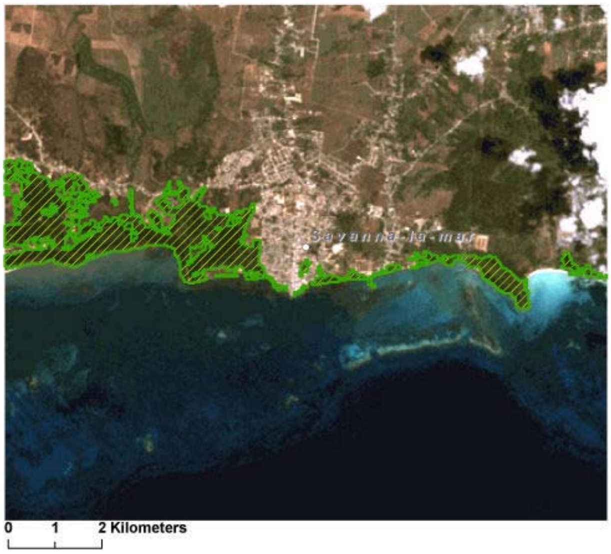
LS5 TM 9 January 1986 (Golden Grove)



LS5 11 January 2010

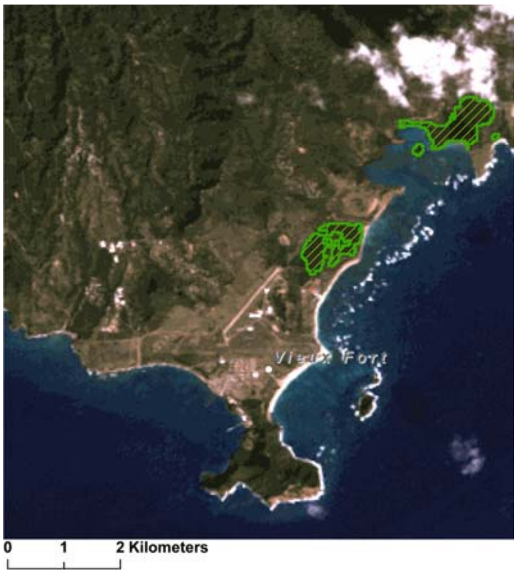


LS5 TM 17 February 1986

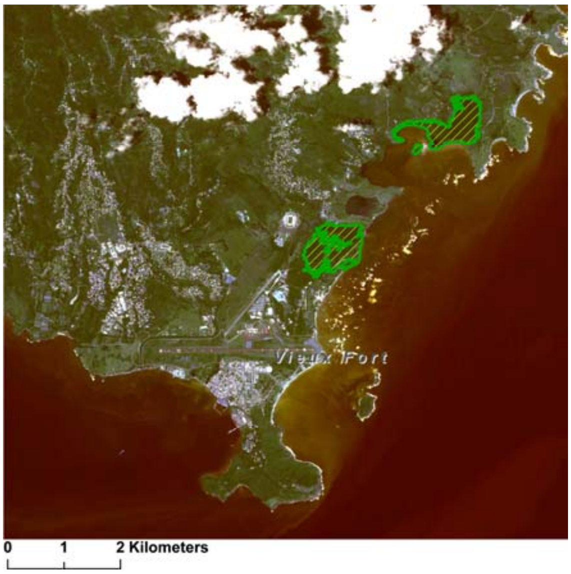


LS5 TM 11 April 2011

Saint Lucia



LS5 TM 3 January 1986



WorldView 15 September 2010

		Area (ha)		Change
Country	**AOI**	**1980s**	**2010s**	**%**
Grenada	Argyle	63.9	76.3	19.4%
Jamaica	Annoto bay	86.4	74.9	-13.3%
Jamaica	Golden Grove	1223.4	1178.4	-3.7%
Jamaica	Savanna la mar	768.1	780.0	1.5%
St-Lucia	Vieux Fort	119.3	126.8	6.3%

Table 5: Summary of mangrove area of demo sites

As can be seen in Table 5, a large range of areas was covered by the demo sites, and trends differ greatly from place to place. According to our results, mangrove coverage remains steady or increases except in Jamaica “Annoto bay” site (-19.4%). Note that this is representing the situation after 1985 and ground truthing would be needed to validate the results.

This chapter highlights the high dependency of the quality of mangrove classification on the time of acquisition of the image (no clouds in the area of interest, wetness of the terrain), as well as the input from the field in order to be able to perform supervised classification and/or output validation. Consequently, the next step of the project, in synergy with implementing partners of respective countries, will be to precisely define the area of interest, best date and time for image acquisition (which probably will have to be paid to increase the choice), and to validate the output in the field.

Monitoring efforts & indicative list of Local Adaptation Measures (modified from KfW's Aide memoire_EBACC)

A distinct goal of the EbA project will be the establishment of one or more long-term monitoring programs with repeated efforts by the local government, authorities and communities. First steps will include the:

1) selection of the institute to collect and gather that data

2) selection of project sites suitable for repeated, long term monitoring

3) development of a monitoring protocol

4) definition of objectives and deriving from the monitoring data

The following table presents local adaptation measures, and their respective impact on coastline protection, fish stocks and tourism.

Potentially selected coastal areas will often involve different stakeholders with a multitude of interests. Therefore, improved management efforts should include the set up of multi-use marine zoning plans, as exquisitely done by Baldwin (Grenadines island report 2012)). Zoning plans provide clear objectives and are a very useful visualization tool for stakeholders in terms of benefits and underlying requirements. In case of monitoring activities in the Grenadines islands, it is strongly recommended to refer to already existing zonation plans like derived from the MARSIS -Project (2006-2012), in order to optimize efforts.

Measures	Main impact on		
The impact of LAMs is estimated by [+, ++, +++] to display the general importance. When informative, detailed measures received a valuation of the LAM as well ().	Reduction of coastal erosion	Fish stocks	Attraction for tourists
A) Measures related to the protection and sustainable management of ecosystems relevant for adaptation			
1) Improved management of protected areas, e.g.	++	+++	++
- Infrastructure (offices, visitor centers, IT)			
- Boats and other equipment for guards (e.g. radios)			
- Demarcation (buoys)			
- Update of management plans			
- Creation of multi-use marine zonation plans	(+)	(+++)	
2) Reduction of land-based stressors on coastal marine ecosystems (in and outside MPAs), e.g.	+++	+++	+++
- Reduction of nutrient/pollutant inputs from small point sources (e.g. sewers)			
- Reduction of sedimentation from land based erosion (e.g. reforestation, slope stabilization)			
3) Measures to reduce physical damage to ecosystems, e.g.	++	++	
- Mooring-buoys for minimizing damages of coral reefs by anchors			
- Demarcation and signaling of relevant ecosystems			
- Board walks for the protection of beach vegetation			

4) Measures to reduce pressure on ecosystems (in & outside protected areas), e.g.	+++		
· Alternative fuel wood sources, where mangroves are used			
· Aquaculture (questionable)			
· Assessment and regulation of fisheries		(+++)	
· Creation of multi-use marine zonation plans	(+)	(+++)	
B) Measures related to the rehabilitation or substitution of ecosystems relevant for adaptation			
5) Rehabilitation of natural ecosystems	+++	+++	+++
· Mangrove reforestation	(+++)	(++)	
· Coral reef restoration (where circumstances allow for), e. g. with more temperature-resilient species	(+++)	(+++)	(+++)
· Sea grass rehabilitation	(++)	(+++)	
· Rehabilitation of beach vegetation	(+++)		
6) Installation of artificial reefs (in combination with coral transplanting)	(+)	(++)	(++)
C) Measures related to the monitoring of coastal ecosystems	+++	+++	
7) Elaboration of a joint monitoring concept (applicable to and acceptable for the 4 countries), on the basis of information needs of decision makers and including the establishment of harmonized monitoring and information management protocols; including stressors on ecosystems			
8) Harmonization of monitoring methods (including capacity development)			
9) Implementation of the monitoring system			
· Support to countries for investments to implement the monitoring			
· Support to establish (possibly, joint) information management system			

Whereas costs for infrastructure and capacity building can be easily drawn from ongoing projects, the costs for ecosystem restoration are specifically determined by location and extent of the respective measure. Consequently, costs should only be estimated upon the results of baseline studies and site determination. An indication of costs for coral reef restoration has recently been given by Caribsave’s Owen Day, upon initial request of KfW’s Dr. Haider. Costs for an estimated increase in live coral cover by 20% in a 1 km^2 area (1,000.000 m^2) were estimated to range between 6-10 million USD. It is important to note that the suggested scope (1 km^2) is beyond the realistic or advisable scope for restoration efforts, since adequate ecological conditions, the prerequisite of any restoration measure, are likely not to be met.

Costs for sea built like structures as protection measures range between approximately US$3,000 - 5,000 per meter, according to Smith Warner Ltd.’s David Smith. Whereas armor stone revetments can be built at the lower end of this range, concrete retaining walls would be at the upper end. The creation of beach area in order to provide a coastal buffer against climate change impacts would be, depending on sources of sand material, in the order of US$2,000 - $4,000 per meter of created beach. It is important to note, however, that none of the described sea built intervention measures would classify as ecosystem-based adaptation measure.

Below, a list depicting sea built structures across CARICOM SIDS, where Smith Warner Ltd. has been involved as company or has knowledge about the project. Note that this summary of structures may not be comprehensive:

Barbados
Accra Beach – offshore breakwater
Bridgetown to Accra – sea defence revetment and boardwalk
Holetown to Heron Bay – sea defence revetment and boardwalk
Speightstown (Port St Charles and Port Ferdinand) – offshore protective breakwaters
St Lucia
Gros Islet - shoreline protection - breakwater
Soufriere - sea defence
Dennery Fishing Village - sea defence, offshore breakwaters and river training works
Grenada
Gouyave – sea defence works to protect a critical stretch of roadway
True Blue Bay – offshore breakwater to provide protection to a marina and land areas in its lee
St Vincent and the Grenadines
Darkview – sea defence works and shoreline enhancement
Sandy Bay – sea defence works
Georgetown – sea defence works
Dominica
Pointe Michel – sea defence works
Roseau – sea defence
Portsmouth/Canbrits – sea defence
Jamaica
Palisadoes Road – sea defence works for a main coastal road linking the city of Kingston to the south international airport

Conclusion and recommendations

We first analyzed and ranked the different ecosystems of all Caribbean SIDS according to their potential risk for climate related impacts, distribution and respective sizes, including the existence of protected areas. Subsequently, ecological information has been evaluated where available to complement the overall understanding of the countries' ecosystems. Since, especially for coral reef ecosystems, a differentiation according to the quality of the ecosystem is not advisable (for above mentioned reasons), we used information on current environmental conditions and the existence & efficiency of coastal zone management to complement the information.

- Grenada and St. Lucia could both be considered suitable due to the future importance of their (coral reef) ecosystems and the overall not too heavily degraded ecological conditions. Under changing climatic conditions, the services provided by those ecosystems will strongly contribute to the island states' socio-economical and ecological well-being. Furthermore, these small SIDS both received substantial "start-off" management help, e.g. via the IWCAM projects, which raised their awareness and tested their commitment to time consuming projects. Apparently, the local authorities and, for St. Lucia, also the communities showed the motivation to improve the environmental conditions.
- Jamaica could be considered a suitable SIDS effort due to its economically and ecologically valuable and large ecosystems. Likewise, St. Vincent & Grenadines, due to large areas of coral reef ecosystems and the strong dependence on its natural resources. Especially St. Vincent and the Grenadines currently receive valuable contributions from NGOs and the University of the West Indies in terms of capacity building and marine resource management. These recent improvements make SVG particularly attractive for upcoming EbA projects.
- The Bahamas could be considered as suitable SIDS#5, since they exhibit considerable ecological assets and the potential risk under climate change scenarios is very high. Also, they appear to have promising governmental programmes running already.

One essential factor to the success of this project will be to identify governmental departments and organizations which actively contribute to the advancement of project goals. Fortunately, the collaboration, i.e. data generation and provision, was sufficient for the selected SIDS. However, data provision was insufficient for other SIDS. We recommend that 5Cs, being the crucial organization for this project, establishes good working relationships with the respective departments of all Caribbean SIDS for optimized communication, and to facilitate the working efficiency for any implementing organization or institute.

Socio-economic assessments should investigate the vulnerability of coastal communities in selected areas, including the identification of all relevant tourism and fisheries activities. Also, the vulnerability of coastlines to erosion and storms has to be analyzed. Finally, data should be incorporated into model scenarios to create a vulnerability index and define the resilience capacity of coastal communities and ecosystems.

Factors ignored, limitations & additional information

- Exact amount of people who are directly depending on the marine resources/ecosystems.
- Discrepancy between the overall amounts of people potentially impacted by climate change under different scenarios, per SIDS (e.g. Jamaica vs. Montserrat)
- Specific contribution of single stressors (tourism impact, agriculture, run-off)
- Specific conditions of distinct coral reefs, since not available to allow qualitate comparisons. However, the assessment of specific conditions will be relevant in the subsequent site determination (EbA projects).

The scale of the information necessary to model the potential impact of climate change on small islands differs from the one used with larger continental units as generally they are too coarse compared to the size of the elements to study. Consequently they need to be downscaled with local data to be acquired if not available through the use of proxies, creating a potential problem of data heterogeneity between countries of a given region.

Local information is generally heterogeneously available within the region studied, meaning the present analysis is data driven. The pre-selection was performed on existing data, meaning the more data on protected areas, the more potential. This may introduce a bias in favour of countries which are the most pro-active. At the same time, the project is also looking for countries which are taking initiatives for their environment. Still, there is a need to complete the compilation of data for all countries and to insure a proper assessment of least developed countries in the CARICOM region.

Acronyms

CCA	Climate Change Adaptation
CARICOM	Caribbean Community
MarSIS	Marine Resource and Space-use Information System
CERMES	Centre for Resource Management and Environmental Studies
SIDS	Small Island Developing States
SIOBMPA	Sandy Island Oyster Bed Marine Protected Area
SusGren	Sustainable Grenadines Project / Sustainable Grenadines, Inc.
SVG	St. Vincent and the Grenadines
TNC	The Nature Conservancy

References

Alongi, D. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76, 1–13 (2008).

Anthony, E. J. & Gratiot, N. Coastal engineering and large-scale mangrove destruction in Guyana, South America: Averting an environmental catastrophe in the making. Ecol. Eng. 47, 268–273 (2012).

Aronson, R. B., Precht, W. F., Macintyre, I. G. & Toth, L. T. Catastrophe and the life span of coral reefs. Ecology 93, 303–313 (2012).

Augustin, L. N., Irish, J. L. & Lynett, P. Laboratory and numerical studies of wave damping by emergent and near-emergent wetland vegetation. Coast. Eng. 56, 332–340 (2009).

Baastel. Disaster Risk Management Strategy and Plan of Action for the Tourism Sector in the Caribbean - Part 1. Requested by CDERA, (2009). http://www.onecaribbean.org/resources/hurricaneinfo/drmproject.aspx

Baldwin K. (2012). Developing a framework for a comprehensive marine multi-use zoning plan for the Grenadine islands. Final report. University of West Indies, Barbados. www.grenadinesmarsis.com

Bamber, J. L., Riva, R. E. M., Vermeersen, B. L. A. & LeBrocq, A. M. Reassessment of the Potential Sea-Level Rise from a Collapse of the West Antarctic Ice Sheet. Science 324, 901–903 (2009).

Bender, M. A., Knutson, T. R., Tuleya, R. E., Sirutis, J. J., Vecchi, G. A., Garner, S. T. & Held, I. M. Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes. Science 327, 454–458 (2010).

Bruckner, A. W. & Borneman, E. H. Implications of coral harvest and transplantation on reefs in northwestern Dominica. Rev. Biol. Trop. 58, 111–127 (2010).

Bruno JF, Sweatman H, Precht WF, Selig ER, Schutte VGW (2009) Assessing evidence of phase shifts from coral to macroalgal dominance on coral reefs. Ecology 90:1478-1484

Burke, L. M. & Maidens, J. Reefs at risk in the Caribbean. (World Resources Institute: Washington, D.C., 2004).

Burke, L. M., Reytar, K., Spalding, M. & Perry, A. Reefs at risk revisited. (World Resources Institute Washington, DC, USA: 2011).

Camara, G., Souza, R.C.M., Freitas, U.M., Garrido, J. (1996). SPRING: Integrating remote sensing and GIS by object-oriented data modelling. Computers & Graphics, 20: (3) 395-403.

Caribbean Regional Fund for Wastewater Management. Gap analysis and regional best practices in wastewater management. CEP technical report 64 (Draft, 2010).

Caribbean Regional Fund for Wastewater Management. Situational Analysis: Regional sectoral overview of wastewater management in the wider caribbean region. CEP technical report 66 (2010)

Carpenter, K. E., Abrar, M., Aeby, G., Aronson, R. B., Banks, S., Bruckner, A., Chiriboga, A., Cortés, J., Delbeek, J. C., DeVantier, L. & others One-third of reef-building corals face elevated extinction risk from climate change and local impacts. Science 321, 560–563 (2008).

Cazenave, A., Lombard, A. & Llovel, W. Present-day sea level rise: A synthesis. Comptes Rendus Geoscience 340, 761–770 (2008).

Chapman, D. D., Babcock, E. A., Gruber, S. H., Dibattista, J. D., Franks, B. R., Kessel, S. A., Guttridge, T., Pikitch, E. K. & Feldheim, K. A. Long-term natal site-fidelity by immature lemon sharks (Negaprion brevirostris) at a subtropical island. Mol. Ecol. 18, 3500–3507 (2009).

Chatenoux, B. and Peduzzi, P. Analysis on the Role of Bathymetry and other Environmental Parameters in the Impacts from the 2004 Indian Ocean Tsunami, UNEP/GRID-Europe, United Nations Environment Programme, Geneva, (2005).

Chatenoux, B. and Peduzzi, P. Impacts from the 2004 Indian Ocean tsunami: analysing the potential protecting role of environmental features. Natural Hazards 40, 289–304, (2007).

Christianen MJA, van Belzen J, Herman PMJ, van Katwijk MM, Lamers LPM, et al. (2013) Low-Canopy Seagrass Beds Still Provide Important Coastal Protection Services. PLoS ONE 8(5): e62413. doi:10.1371/journal.pone.0062413

Cloern, J. E. Our evolving conceptual model of the coastal eutrophication problem. Mar. Ecol.-Prog. Ser. 210, 223–253 (2001).

CTO. Caribbean tourism – State of the Industry. (2011) http://www.onecaribbean.org/statistics/annualoverview/

Das, S. The role of natural ecosystems and socio-economic factors in the vulnerability of coastal villages to cyclone and storm surge. Nat. Hazards 64, 531–546 (2012).

Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D. & Yan, J. The impact of sea level rise on developing countries: a comparative analysis. Climatic Change 93, 379–388 (2009).

DeGeorges, A., Goreau, T. J. & Reilly, B. Land-sourced pollution with an emphasis on domestic sewage: Lessons from the Caribbean and implications for coastal development on Indian Ocean and Pacific coral reefs. Sustainability 2, 2919–2949 (2010).

Diedrich, A. The impacts of tourism on coral reef conservation awareness and support in coastal communities in Belize. Coral Reefs 26, 985–996 (2007).

Doney, S.C., Fabry, V.J., Feely, R.A., Kleypas, J.A. (2009) Ocean Acidification: the other CO2 problem, *Annu. Rev. Mar. Sci.*, **1**, 169–92.

Doropoulos, C., Ward, S., Diaz-Pulido, G., Hoegh-Guldberg, O., Mumby, P.J. Ocean acidification reduces coral recruitment by disrupting intimate larval-algal settlement interactions. Ecol Lett 15:338-346 (2012).

Duarte, C. The future of seagrass meadows. Environmental Conservation. 29, 192–206 (2002).

Dubi, A.M., Torum A. Wave damping by kelp vegetation, Proceedings of 24th International Conference on Coastal (1994)

Duke, N. C., Meynecke, J.-O., Dittmann, S., Ellison, A. M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K. C., Field, C. D., Koedam, N., Lee, S. Y., Marchand, C., Nordhaus, I. & Dahdouh-Guebas, F. A world without mangroves? Science 317, 41–42 (2007).

Dulvy NK, Freckleton RP, Polunin NVC (2004) Coral reef cascades and the indirect effects of predator removal by exploitation. Ecol Lett 7:410-416Engineering, Kobe, Japan, vol. 1, ASCE, 142-156.

Eakin, C. M. *et al.* Caribbean Corals in Crisis: Record Thermal Stress, Bleaching, and Mortality in 2005. PLoS One 5, (2010).

Elginoz, N., Kabdasli, M. S. & Tanik, A. Effects of Posidonia Oceanica Seagrass Meadows on Storm Waves. J. Coast. Res. 373–377 (2011).

Elsner, J. B., Kossin, J. P. & Jagger, T. H. The increasing intensity of the strongest tropical cyclones. Nature 455, 92–95 (2008).

Fabricius; K.E. Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. Marine Pollution Bulletin 50:125-146 (2005).

Fazey, I., Fazey, J. A. & Fazey, D. M. A. Learning more effectively from experience. Ecology and Society 10, (2005).

Feller I.C., Lovelock C.E., Mckee K.L. Nutrient addition differentially affects ecological processes of Avicennia germinans in nitrogen versus phosphorus limited mangrove ecosystems. Ecosystems. Vol.: 10 Issue: 3 Pages: 347-359 (2007).

Fonseca, M.S. The role of seagrasses in nearshore sedimentary processes a review. In Estuarine shores: Evolution environments and human alterations, K. F. Nordstrom and C. T. Roman, ed., John Wiley and Sons Ltd., pp. 261-286 (1996).

Forster, J., Schuhmann, P. W., Lake, I. R., Watkinson, A. R. & Gill, J. A. The influence of hurricane risk on tourist destination choice in the Caribbean. Clim. Change 114, 745–768 (2012).

Fossette, S., Kelle, L., Girondot, M., Goverse, E., Hilterman, M. L., Verhage, B., De Thoisy, B. & Georges, J.-Y. The world's largest leatherback rookeries: A review of conservation-oriented research in French Guiana/Suriname and Gabon. J. Exp. Mar. Biol. Ecol. 356, 69–82 (2008).

Gambi, M., Nowell, A. & Jumars, P. Flume Observations on Flow Dynamics in Zostera-Marina (eelgrass) Beds. Mar. Ecol.-Prog. Ser. 61, 159–169 (1990).

GESAMP. Protecting the Oceans from Land-based Activities - Land-based Sources and Activities Affecting the Quality and Uses of the Marine, Coastal and Associated Freshwater Environment, GESAMP Reports and Studies 71 (2001).

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J. & Duke, N. Status and distribution of mangrove forests of the world using earth observation satellite data. Glob. Ecol. Biogeogr. 20, 154–159 (2011).

Gledhill, D. K., Wanninkhof, R., Millero, F. J. & Eakin, M. Ocean acidification of the Greater Caribbean Region 1996-2006. J. Geophys. Res.-Oceans 113, (2008).

Grant, S. & Berkes, F. Fisher knowledge as expert system: A case from the longline fishery of Grenada, the Eastern Caribbean. Fish Res. 84, 162–170 (2007).

Grinsted, A., Moore, J. C. & Jevrejeva, S. Reconstructing sea level from paleo and projected temperatures 200 to 2100 ad. Clim. Dyn. 34, 461–472 (2010).

Hawkins, J. P., Roberts, C. M., Dytham, C., Schelten, C. & Nugues, M. M. Effects of habitat characteristics and sedimentation on performance of marine reserves in St. Lucia. Biol. Conserv. 127, 487–499 (2006).

Hodgson G, Hill J, Kiene W, Maun L (2006). Instruction manual: a guide to coral reef monitoring. Reef Check Foundation, Pacific Palisades, USA.

Hoegh-Guldberg, O. Coral reef ecosystems and anthropogenic climate change. Reg. Envir. Chang. 11, S215–S227 (2011).

Hughes T. P. (1994) Catastophes, Phase-Shifts, and large-scale Degradation of a Caribbean Coral Reef. Science 265:1547-1551

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nystrom, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B. & Roughgarden, J. Climate change, human impacts, and the resilience of coral reefs. Science 301, 929–933 (2003).

IFRC, Mangrove planting saves lives and money in Vietnam, World Disaster Report 2002, International Federation of Red Cross and Red Crescent Societies (IFRC), 2002.

IISD, Review of Current and Planned Adaptation Action: The Caribbean (2011). International Institute for Sustainable Development (IISD). Medeiros, D. et al. 2011.

IPCC, Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 2007).

Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, et al. (2001) Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629-638

Jennings D.E., DiBattista J.D., Stump K.L., Hussey N.E., Franks P.R., Grubbs R.D., Gruber S.H. Assessment of the aquatic biodiversity of a threatened coastal lagoon at Bimini, Bahamas, J Coast Conserv, 16: 405–428 (2012).

Knutson, T. R., McBride, J. L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J. P., Srivastava, A. K. & Sugi, M. Tropical cyclones and climate change. Nat. Geosci. 3, 157–163 (2010).

Komar, P.D. Beach Processes and Sedimentation (2nd Edition). Prentice Hall, N.J. USA. 544 pp. (1998)

Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T. V., & Dech, S. (2011). Remote sensing of mangrove ecosystems: A review. Remote Sensing, 3(5), 878–928.

Kushner, B., Waite, R., Jungwiwattanaporn, M., Burke, L. Influence of Coastal Economic Valuations in the Caribbean: Enabling Conditions and Lessons Learned. Working Paper. Washington, DC: World Resources Institute (2012).

Lapointe, B.E., Barile, P.J., Matzie, W.R. Anthropogenic nutrient enrichment of seagrass and coral reef communities in the Lower Florida Keys: discrimination of local versus regional nitrogen sources. J Exp Mar Biol Ecol 308:23-58 (2004).

Lapointe, B. E., Langton, R., Bedford, B. J., Potts, A. C., Day, O. & Hu, C. Land-based nutrient enrichment of the Buccoo Reef Complex and fringing coral reefs of Tobago, West Indies. Mar. Pollut. Bull. 60, 334–343 (2010).

Leitch, C. & Harbor, J. Impacts of land use change on freshwater runoff into the near-coastal zone, Holetown Watershed, Barbados: Comparisons of long-term to single-storm effects. J. Soil Water Conserv. 54, 584–592 (1999). Lombard, A., Garric, G., Penduff, T. & Molines, J.M. Regional variability of sea level change using a global ocean model at 1/4 resolution, Ocean Dynamics 3, 433-449 (2009)

Macintyre, I. G., Glynn, P. W. & Toscano, M. A. The demise of a major Acropora palmata bank-barrier reef off the southeast coast of Barbados, West Indies. Coral Reefs 26, 765–773 (2007). McConney P, Mahon R (1998) Introducing fishery management planning to Barbados. Ocean & Coastal Management 39, 189-195.

McConney, P. & Baldeo, R. Lessons in co-management from beach seine and lobster fisheries in Grenada. Fish Res. 87, 77–85 (2007).

Meier, M. F., Dyurgerov, M. B., Rick, U. K., O'Neel, S., Pfeffer, W. T., Anderson, R. S., Anderson, S. P. & Glazovsky, A. F. Glaciers dominate Eustatic sea-level rise in the 21st century. Science 317, 1064–1067 (2007).

Mendez, F. J. & Losada, I. J. An empirical model to estimate the propagation of random breaking and nonbreaking waves over vegetation fields. Coast. Eng. 51, 103–118 (2004).

Mills, A. P. St. Vincent and the Grenadines. Mar. Pollut. Bull. 42, 1208–1220 (2001).

MDE : Programme Changements Climatiques République d'Haïti. Port-au-Prince (2006). Ministère de l'Environnement. http://unfccc.int/resource/docs/napa/hti01f.pdf

Mumby PJ, Edwards AJ, Arias-Gonzalez JE, Lindeman KC, Blackwell PG, Gall A, Gorczynska MI, Harborne AR, Pescod CL, Renken H, Wabnitz CCC, Llewellyn G (2004) Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427:533-536

Nagelkerken I, van der Velde G, Gorissen MW, Meijer GJ, van't Hof T, den Hartog C (2000) Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuarine Coastal and Shelf Science 51:31-44

Nicholls, R. J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Chateau, J., Muir-Wood, R. Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates. Environment Working Papers No. 1 (Organization for Economic Co-Operation and Development, Paris, 2008).

Nicholls, R. J. & Cazenave, A. Sea-Level Rise and Its Impact on Coastal Zones. Science 328, 1517–1520 (2010).

Oxenford, H. A., Roach, R., Brathwaite, A., Nurse, L., Goodridge, R., Hinds, F., Baldwin, K. & Finney, C. Quantitative observations of a major coral bleaching event in Barbados, Southeastern Caribbean. Clim. Change 87, 435–449 (2008). Palanisamy, H., Becker, M., Meyssignac, B., Henry, O. & Cazenave, A. Regional sea level change and variability in the Caribbean sea since 1950. Journal of Geodetic Science 2, 125–133 (2012).

Pandolfi, J. M. & Jackson, J. B. C. Ecological persistence interrupted in Caribbean coral reefs. Ecol. Lett. 9, 818–826 (2006).

Pauly, D (1997). The Sea Around Us Project: Documenting and communicating global fisheries impacts on marine ecosystems. Ambio 36, 290–295.

Pfeffer, W. T., Harper, J. T. & O'Neel, S. Kinematic constraints on glacier contributions to 21st-century sea-level rise. Science 321, 1340–1343 (2008).

Peduzzi, P., Chatenoux, B., Dao, H., De Bono, A., Herold, C., Kossin, J., Mouton, F. & Nordbeck, O. Global trends in tropical cyclone risk. Nat. Clim. Chang. 2, 289–294 (2012).

Peduzzi, P., Velegrakis, A., Chatenoux, B., Quantifying the role of marine ecosystems in reducing coastal erosion: the RiVAMP study in Negril Jamaica, (in prep.)

Peduzzi, P., Estrella, M., Chatenoux, B., Velegrakis, A., Integrating the role of ecosystems in disaster risk and vulnerability assessments: Lessons from the Risk and Vulnerability Assessment Methodology Project (RiVAMP) in Negril, Jamaica, in The role of ecosystems in disaster risk reduction, Renaud FG, Sudmeier-Rieux K and Estrella M, eds, UNU press, (in press).

Quinn, N. J. & Kojis, B. L. The recent collapse of a rapid phase-shift reversal on a Jamaican north coast coral reef after the 2005 bleaching event. Rev. Biol. Trop. 56, 149–159 (2008).

Rahmstorf, S. A new view on sea level rise. Nature Reports Climate Change 44–45 (2010). doi:10.1038/climate.2010.29

Rau, G.H., McLeod, E.L., Hoegh-Guldberg, O. The need for new ocean conservation strategies in a high-carbon dioxide world. Nature Climate Change 2:720-724 (2012).

Rawlins, S. C., Chen, A., Rawlins, J. M., Chadee, D. D. & Legall, G. A knowledge, attitude and practices study of the issues of climate change/variability impacts and public health in Trinidad and Tobago, and St Kitts and Nevis. West Ind. Med. J. 56, 115–121 (2007).

Roff, G. & Mumby, P. J. Global disparity in the resilience of coral reefs. Trends Ecol. Evol. 27, 404–413 (2012).

Sabine, C. L., Feely, R. A., Gruber, N., Key, R. M., Lee, K., Bullister, J. L., Wanninkhof, R., Wong, C. S., Wallace, D. W. R., Tilbrook, B., Millero, F. J., Peng, T. H., Kozyr, A., Ono, T. & Rios, A. F. The oceanic sink for anthropogenic CO(2). Science 305, 367–371 (2004).

Schill SR, Knowles JE, Rowlands G, Margles S, Agostini V, Blyther R (2011) Coastal Benthic Habitat Mapping to Support Marine Resource Planning and Management in St. Kitts and Nevis. Geography Compass 5:898-917

Schill SR (2013) Trip Report: Bathymetric and Benthic Habitat Surveys for Union Island. The Nature Conservancy

Schill SR (2013) Trip Report: Bathymetric and Benthic Habitat Surveys for Grenville Bay, Grenada. The Nature Conservancy

Sea around us project (2013). Global Mariculture Database. http://seaaroundus.org/

Sealey, K. S. Large-scale ecological impacts of development on tropical islands systems: comparison of developed and undeveloped islands in the central Bahamas. Bull. Mar. Sci. 75, 295–320 (2004).

Short, F. T. & Wyllie-Echeverria, S. Natural and human-induced disturbance of seagrasses. Environ. Conserv. 23, 17–27 (1996).

Short, F. T. *et al.* Extinction risk assessment of the world's seagrass species. Biological Conservation 144, 1961 – 1971 (2011).

Simpson, M. C., Scott, D., New, M., Sim, R., Smith, D., Harrison, M., Eakin, C. M., Warrick, R., Strong, A. E., Kouwenhoven, P. & others An overview of modelling climate change impacts in the Caribbean Region with contribution from the Pacific Islands. (United Nations Development Programme (UNDP), 2009).

Simpson, M.C., Scott, D., Harrison, M., Silver, N., O'Keeffe, E., Sim, R., Harrison, S., Taylor, M., Lizcano, G., Rutty, M., Stager, H., Oldham, J., Wilson, M., New, M., Clarke, J., Day, O.J., Fields, N., Georges, J., Waithe, R., McSharry, P. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean (Summary Document), United Nations Development Programme (UNDP), Barbados, West Indies (2010).

Smith, V.H. Eutrophication of freshwater and coastal marine ecosystems - A global problem. Environmental Science and Pollution Research 10:126-139 (2003).

Smith, T. M., Reynolds, R. W., Peterson, T. C. & Lawrimore, J. Improvements to NOAA's Historical Merged Land–Ocean Surface Temperature Analysis (1880–2006). Journal of Climate 21, 2283–2296 (2008).

Steffensen, J. P. *et al.* High-resolution Greenland Ice Core data show abrupt climate change happens in few years. Science 321, 680–684 (2008).

Steig, E. J., Schneider, D. P., Rutherford, S. D., Mann, M. E., Comiso, J. C. & Shindell, D. T. Warming of the Antarctic ice-sheet surface since the 1957 International Geophysical Year. Nature 457, 459–U4 (2009).

Stoffle, R. & Minnis, J. Marine protected areas and the coral reefs of traditional settlements in the Exumas, Bahamas. Coral Reefs 26, 1023–1032 (2007).

TNC MER-SUD – Coastal-marine conservation towards the sustainable development of the south department: Habitat and fisheries baseline assessment. The Nature Conservancy. Silva, E., Pardo, M. (2012)

Tompkins, E. L. & Adger, W. N. Does adaptive management of natural resources enhance resilience to climate change? Ecol. Soc. 9, (2004).

Torres, R. R. & Tsimplis, M. N. Seasonal sea level cycle in the Caribbean Sea. Journal of Geophysical Research 117, (2012).

UNEP. Linking Ecosystems to Risk and Vulnerability Reduction: The Case of Jamaica. Risk and Vulnerability. Assessment Methodology Development Project (RiVAMP) Pilot Assessment Report. Geneva: United Nations Environment Programme, UNEP Post-Conlict and Disaster Management Branch/GRID-Europe, 2nd edition (2010).

UNEP & Gems Water Programme. Water Quality for Ecosystem and Human Health, Ontario Canada (2006).

Vaslet, A., Phillips, D. L., France, C., Feller, I. C. & Baldwin, C. C. The relative importance of mangroves and seagrass beds as feeding areas for resident and transient fishes among different mangrove habitats in Florida and Belize: Evidence from dietary and stable-isotope analyses. J. Exp. Mar. Biol. Ecol. 434, 81–93 (2012).

Velegrakis, A., Chatenoux, B., Peduzzi, P., Kluser, S. & Estrella, M. The RiVAMP Pilot study at Negril beach (Jamaica), (in press).

Vo-Luong, P. & Massel, S. Energy dissipation in non-uniform mangrove forests of arbitrary depth. J. Mar. Syst. 74, 603–622 (2008).

Waycott, M., Duarte, C. M., Carruthers, T. J. B., Orth, R. J., Dennison, W. C., Olyarnik, S., Calladine, A., Fourqurean, J. W., Heck, K. L., Hughes, A. R., Kendrick, G. A., Kenworthy, W. J., Short, F. T. & Williams, S. L. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proc. Natl. Acad. Sci. U. S. A. 106, 12377–12381 (2009).

Witze, A. Climate change: Losing greenland. Nature 452, 798–802 (2008).

Wood, S., Sebastian, K. L., Scherr, S. J., Batjes, N. H. & World Resources Institute Pilot analysis of global ecosystems : agroecosystems. (World Resources Institute, 2000).

World Bank (2008). A year marked by innovation and results in the Bank's partnership with Latin America and the Caribbean. (2008) http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/LACEXT/0,,contentMDK:21858173~pagePK:146736~piPK:146830~theSitePK:258554,00.html

World bank (2013). World Development Indicators. http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators#

WTTC. Travel and tourism, Economic impact 2012, Caribbean. (2012) http://www.wttc.org/research/economic-impact-research/regional-reports/caribbean/

Xue, Y., Smith, T. M. & Reynolds, R. W. Interdecadal changes of 30-yr SST normals during 1871-2000. J. Clim. 16, 1601–1612 (2003).

Weblinks

AVISO Sea Level: http://www.aviso.oceanobs.com/en/applications/ocean/mean-sea-level-greenhouse-effect/regional-trends.html

Caribbean Environment Programme : http://www.cep.unep.org, http://www.cep.unep.org/publications-and-resources/technical-reports/technical-reports

CARIBSAVE: http://caribsave.org, http://www.caribsave.org/index.php?id=235

Climate Investment Funds: https://climateinvestmentfunds.org/cif/

ERSST.v3b: http://www.ncdc.noaa.gov/ersst/

GISS Surface Temperature: http://data.giss.nasa.gov/gistemp/maps/

Global Coral Reef Alliance: http://globalcoral.org/

Organisation of American States, Atlas of Probable Storm Effects in the Caribbean Sea: http://www.oas.org/cdmp/document/reglstrm/index.htm

UNEP (2010) Environmental consequences of ocean acidification: a threat to food security, *UNEP emerging issues*, United Nations Environment Programme, 9 pp.

UNEP/GRID-Geneva: Tropical cyclones: http://preview.grid.unep.ch/index.php?preview=map&lang=eng&lyr=oceans World Lakes cy_buffers cy_tracks satellite &extent=-180.23 180.23 -89.9 83.63

WCMC – Ocean Data Viewer: http://data.unep-wcmc.org

World Resources Institutes – Reefs at Risk revisited: http://www.wri.org/publication/reefs-at-risk-revisited