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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE COASTAL AND MARINE SECTOR IN THE BRITISH VIRGIN ISLANDS

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NOTES AND EXPLANATIONS OF SYMBOLS:

The following symbols have been used in the present study:

A full stop (.) is used to indicate decimals

n.a. is used to indicate that data are not available

The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.

The word “dollar” refers to United States dollars, unless otherwise specified.

The term “billion” refers to a thousand million.

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Acknowledgement

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EXECUTIVE SUMMARY

Owing to their high vulnerability and low adaptive capacity, Caribbean islands have legitimate concerns about their future, based on observational records, experience with current patterns and consequences of climate variability, and climate model projections. Although emitting less than 1% of global greenhouse gases, islands from the region have already perceived a need to reallocate scarce resources away from economic development and poverty reduction, and towards the implementation of strategies to adapt to the growing threats posed by global warming (Nurse and Moore, 2005).

The objectives of this Report are to conduct economic analyses of the projected impacts of climate change to 2050, within the context of the IPCC A2 and B2 scenarios, on the coastal and marine resources of the British Virgin Islands (BVI). The Report presents a valuation of coastal and marine services; quantitative and qualitative estimates of climate change impacts on the coastal zone; and recommendations of possible adaptation strategies and costs and benefits of adaptation.

A multi-pronged approach is employed in valuing the marine and coastal sector. Direct use and indirect use values are estimated. The amount of economic activity an ecosystem service generates in the local economy underpins estimation of direct use values. Tourism and fisheries are valued using the framework developed by the World Resources Institute. Biodiversity is valued in terms of the ecological functions it provides, such as climate regulation, shoreline protection, water supply erosion control and sediment retention, and biological control, among others.

Estimates of future losses to the coastal zone from climate change are determined by considering: (1) the effect of sea level rise on coastal lands; and (2) the effect of a rise in sea surface temperature (SST) on coastal waters. Discount rates of 1%, 2% and 4% are employed to analyse all loss estimates in present value terms.

The overall value for the coastal and marine sector is USD $1,606 million (mn). This is almost 2% larger than BVI's 2008 GDP. Tourism and recreation comprise almost two-thirds of the value of the sector.

By 2100, the effects of climate change on coastal lands are projected to be $3,988.6 mn, and $2,832.9 mn under the A2 and B2 scenarios respectively. In present value terms, if A2 occurs, losses range from $108.1-$1,596.8 mn and if B2 occurs, losses range from $74.1-$1,094.1 mn, depending on the discount rate used. Estimated costs of a rise in SST in 2050 indicate that they vary between $1,178.0 and $1,884.8 mn. Assuming a discount rate of 4%, losses range from $226.6 mn for the B2 scenario to $363.0 mn for the A2 scenario. If a discount rate of 1% is assumed, estimated losses are much greater, ranging from $775.6-$1,241.0 mn.

Factoring in projected climate change impacts, the net value of the coastal and marine sector suggests that the costs of climate change significantly reduce the value of the sector, particularly under the A2 and B2 climate change scenarios for discount rates of 1% and 2%. In contrast, the sector has a large, positive, though declining trajectory, for all years when a 4% discount rate is employed.

Since the BVI emits minimal greenhouse gases, but will be greatly affected by climate change, the report focuses on adaptation as opposed to mitigation strategies. The options shortlisted are: (1) enhancing monitoring of all coastal waters to provide early warning alerts of bleaching and other marine events; (2) introducing artificial reefs or fish-aggregating devices; (3) introducing alternative tourist attractions; (4) providing retraining for displaced tourism workers; and (5) revising policies related to financing national tourism offices to accommodate the new climatic realities. All adaptation options considered are quite justifiable in national terms; each had benefit-cost ratios greater than 1.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (AR3) noted that small island states, such as those in the Caribbean, share many similarities (e.g., physical size, proneness to natural disasters and climate extremes, extreme openness of their economies, low adaptive capacity) that enhance their vulnerability and reduce their resilience to climate variability and change.

Observational data showed a global mean temperature increase of around 0.6°C during the 20th century. Notably, the rate of increase in air temperature in the Caribbean during the 20th century exceeded the global average. Mean sea level rose by about 2 mm/year, although sea-level trends are complicated by local tectonics and El Niño-Southern Oscillation (ENSO) events, an interaction between pronounced temperature anomalies and sea-level pressure gradients in the equatorial Pacific Ocean, with an average periodicity of 2 to 7 years. The AR3 also found much of the rainfall variability appeared to be closely related to ENSO events, combined with seasonal and decadal changes in the convergence zones.

Owing to their high vulnerability and low adaptive capacity, Caribbean islands have legitimate concerns about their future, based on observational records, experience with current patterns and consequences of climate variability, and climate model projections. Although emitting less than 1% of global greenhouse gases, islands from the region have already perceived a need to reallocate scarce resources away from economic development and poverty alleviation, and towards the implementation of strategies to adapt to the growing threats posed by global warming (Nurse and Moore, 2005).

The TAR reported that sea level is projected to rise at an average rate of about 5.0 mm/year over the 21st century, and concluded that sea-level change of this magnitude would pose great challenges and high risk, especially to low-lying islands that might not be able to adapt (Nurse and others, 2001). Given the sea level and temperature projections for the next 50 to 100 years, coupled with other anthropogenic stresses, the coastal assets of the Caribbean (e.g., coral reefs, mangroves, sea grasses and reef fish), would be at great risk. As the natural resilience of coastal areas may be reduced, the costs of adaptation could be expected to increase. Moreover, anticipated land loss, soil salinisation and low water availability would be likely to threaten the sustainability of island agriculture and food security.

In addition, the AR3 noted that most settlements and infrastructure of island states are located in coastal areas, which are highly vulnerable not only to sea-level rise but also to high energy waves and storm surge. Further, temperature and rainfall changes and loss of coastal amenities could adversely affect the vital tourism industries. Other cultural assets, especially those near the coasts, were also considered to be vulnerable to climate change and sea-level rise. Integrated coastal management was proposed as an effective management framework in small islands for ensuring the sustainability of coastal resources. Such a framework has been adopted in several island states. More recently, the Organisation of Eastern Caribbean States (OECS, 2000) has adopted a framework called ‘Island Systems Management’, which is both an integrated and holistic (rather than sectoral) approach to whole-island management including terrestrial, aquatic and atmospheric environments. Apart from natural and managed system impacts, the AR3 also drew attention to projected human costs. These included an increase in the incidence of vector- and water-borne diseases in many tropical and subtropical islands, which was attributed partly to temperature and rainfall changes, some linked to ENSO.

The AR3 concluded that small islands could focus their efforts on enhancing their resilience and implement appropriate adaptation measures as urgent priorities. Thus, integration of risk reduction strategies into key sectoral activities should be pursued as part of the adaptation planning process for climate change.

Against this background, the objective of this report is to conduct an economic analysis of the projected impacts on the coastal and marine resources associated with climate change in the British Virgin Islands (BVI). Specific objectives are: valuation of coastal and marine services; quantitative and qualitative estimates of impacts on the coastal zone including beaches and fisheries; and recommendation of possible adaptation strategies and costs and benefits of adaptation. First, it assesses recent scientific literature on vulnerability to climate change and sea-level rise, adaptation to their effects, and implications of climate-related policies, including adaptation, for the sustainable development of small islands. Second, it estimates the impacts of climate change on the coastal and marine sectors of the BVI under the A2 and B2 scenarios summarised in the IPCC Special Report on Emissions Scenarios (SRES). A baseline or business as usual (BAU) reference point is also established. Assessment results are presented in a quantitative manner wherever possible. All currency figures in the report are in United States dollars (USD).

II. BACKGROUND

This section provides an overview of the economy of the BVI. It also describes in general terms the physiological characteristics of the BVI within the context of small island states in the Caribbean region. Located

A. ECONOMIC CONTEXT

1. Economic Strengths

The BVI is a British Overseas Territory of 153 square kilometres in size and comprising approximately 60 islands, islets and cays, of which 16 are inhabited, with a population of around 28,000. About two-thirds of the population lives on Tortola (54 square kilometres) and another 15%, on the island of Virgin Gorda (21 square kilometres); the remainder reside on a few of the other larger islands. The economy is closely tied to the larger and more populous US Virgin Islands located to the west of the islands.

Over the past 30 to 40 years, the BVI has evolved from an agriculture/subsistence economy to one based on tourism and then to one based around a combination of tourism and the provision of financial services to the international business community. Tourism and the offshore financial sector both contribute approximately 40% to 45% of GDP, sectors on which the future prosperity of the territory is likely to depend.

Figure 1: Map of the British Virgin Islands

Source: Escape BVI

Tourism Services: Tourism plays a vital role in the economy. The BVI tourism product is reasonably diverse, comprising sailing, cruise ship arrivals, scuba diving and high end resorts. However, government officials indicate that yachting and cruise ship tourist arrivals may be peaking. Nevertheless, the government hopes to increase value added in the sector and to spread arrivals over a longer season, attract higher-spending visitors and encourage the development of smaller, boutique hotels. These actions are not expected to result in large increases in employment.

Stay-over visitors to the islands increased an average of 3% per year over 2000-2005. The total number of visitors to the islands was 820,800 in 2005, of which 337,150 were stay-over visitors. The islands attract the yachting crew drawn by steady trade winds, well-protected anchorages and a year-round balmy climate.

Tourism to the islands experienced a slowdown in the latter part of 2008 as a consequence of the global slowdown. This caused layoffs and cutbacks in the sector but the government is committed to sustaining tourism through initiatives such as maintaining a subsidised transport service to Puerto Rico. Infrastructure projects such as renovation work on the Cruise Ship Pier and the tender dock for cruise ships were also planned.

Financial Services: Commensurate with its small population, the BVI has a small domestic market for financial services. As a general matter, there are no separate regulatory schemes for financial services offered to the domestic market and those restricted to non-residents ("offshore"), although there is for company registration.

The BVI's offshore sector was launched in the mid-1980s, when the government began offering offshore registration to companies wishing to incorporate in the islands. Low registration and licence fees, coupled with an exceptionally efficient registration system and low reputational risk contribute to the significant growth of this sector. As a result, incorporation fees generate substantial revenues for the islands. The adoption of a comprehensive insurance law in late 1994, which provides a blanket of confidentiality with regulated statutory gateways for investigation of criminal offences, makes the BVI attractive to international business. The BVI has made a policy determination of only allowing highly reputable institutions subject to effective consolidated supervision to engage in onshore or offshore banking.

By far, the largest offshore activity is the registration of International Business Centres (IBCs). There is a very limited offshore banking sector, which is insignificant when compared to well-developed offshore centres. IBCs are also used as vehicles for captive insurance companies and for mutual funds. The offshore insurance sector is restricted to captive insurers and to their managers. The offshore securities sector is limited to mutual funds, their managers, and administrators. It is estimated that $50 billion of public and private mutual funds are presently administered in the Territory.

The Financial Services Commission (FSC) and the private sector estimate that there are approximately 350,000 active IBCs registered in the BVI, which is assumed to dominate the world IBC market with an estimated 45% share.

2. Economic Weaknesses

Size Constraints: The BVI is subject to a number of constraints in the development of its economy. There is a limited stock of office and hotel space (including convention facilities) and a relatively small airport that cannot accommodate wide-bodied planes. These limitations are due in part to the physical nature of the islands, which are small, mostly volcanic, and extremely steep, thereby limiting the amount of land suitable for construction of new or improved facilities.

The government has also adopted policies designed to preserve the charm, beauty, and environmental quality of the islands, including size and number restrictions on new construction. This lack of suitable office and hotel space constrains the development of both the tourism and financial services sectors.

In addition, the relatively small population, the lack of superior onshore secondary education facilities, and labour and immigration laws have contributed to a relative dearth of available human capital, especially with respect to sophisticated financial services. Currently, approximately 56% of the labour force comes from outside the territory. Employment by nationality is as follows: BVI nationals – 44%; immigrants from other Caribbean countries – 43%; other non-nationals – 13%.

Decline in International Business: In recent years, the number of IBCs being registered has begun to level off or even decline, while the number of companies being struck from the register (typically due to non-payment of licence fees or, less commonly, formal winding-up) has increased. This appears to be due in part to increased regulatory and anti-money laundering (AML) and combating the financing of terrorism (CFT) standards, as well as to the fact that a title to a significant percentage of personal wealth has already been transferred to IBCs. This has led to concerns on the part of the registered agent community, and an even greater interest in moving beyond what has largely been the "commodity" production of registering companies, toward the provision of more sophisticated (and higher value added) financial services. However, this effort has been hampered by a number of causes, the most important being a lack of sophisticated international banking services and of qualified personnel.

Pockets of Poverty: While the territory has virtually no unemployment and a relatively high level of other social indicators, some small pockets of relative poverty do remain. At present, poverty is low, around 16% of households and 22% of the population, although this is relative poverty and not absolute poverty. Indigence is almost totally absent.[1]

B. General Climate and Weather of the British Virgin Islands

1. General Features

Climate regimes in the Caribbean are quite variable, generally characterised by large seasonal variability in precipitation and by small seasonal temperature differences. Hurricanes cause considerable losses to life and property. The climate of Caribbean islands is broadly characterised by distinct dry and wet seasons with orography and elevation being significant modifiers. The dominant influences are the North Atlantic Sub-tropical High (NAH) and ENSO.

2. Observed Trends

1. Air Temperature

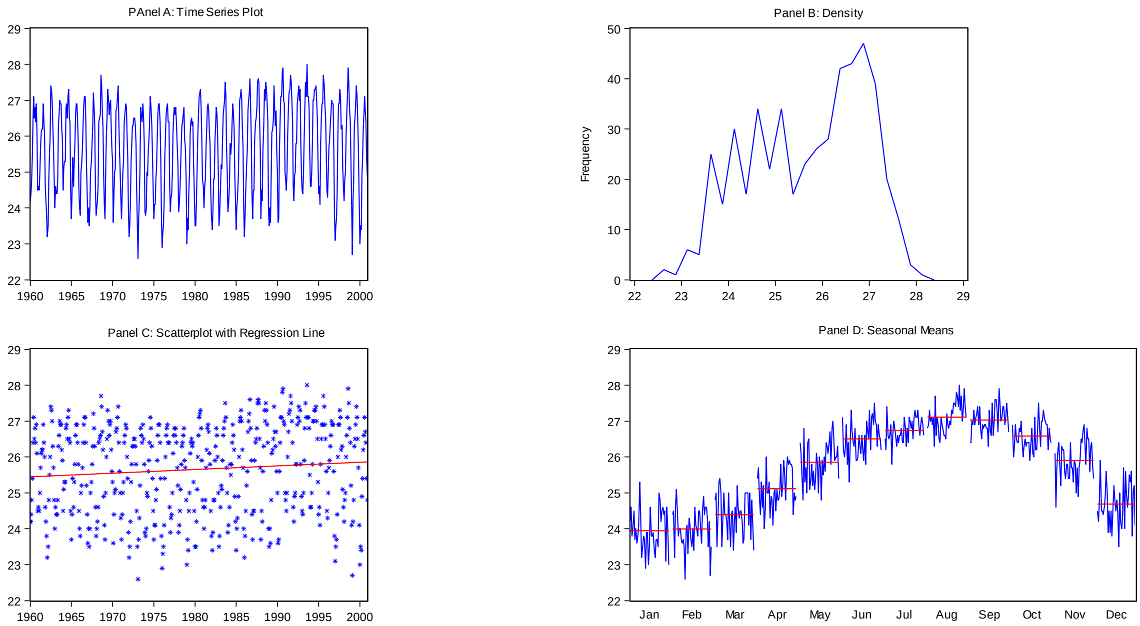
For the Caribbean subregion, analyses show that warming ranged from 0 to 0.5°C per decade for the 1971 to 2004 period (Trenberth and others, 2007). The percentage of days having very warm maximum or minimum temperatures has increased considerably since the 1950s, while the percentage of days with cold temperatures has decreased (Peterson and others, 2002). Malmgren and others (1998), claim that the average air temperature in the Caribbean is influenced primarily by ENSO events.

The BVI, situated just 18° north of the equator, are considered subtropical. Figure 2 presents the historical average trends in air temperature in the BVI from 1960Jan-2000Dec: Panel A shows a time series plot of the series; Panel B shows the density pattern; Panel C shows a scatter plot with a regression line to indicate the long-term trend; and Panel D shows the seasonality in the mean air temperature. Over the review period, air temperature fluctuated between 22°C and 28°C. Temperatures fluctuated slightly between winter (December through April which corresponds to the tourism high season) and summer months. The average temperature in the winter ranged between 24-25°C, dropping a few degrees at night. It gets slightly warmer in the summer months (July-September) with August and September being the hottest; average temperatures were around 27°C during this period.

[1] Caribbean Development Bank (2003).

Over time, there was a gradual upward trend, consistent with overall global trends in air temperature. Temperature rose by 0.3°C relative to the 1960-1990 baseline, which was less than the global average.

Figure 2: Air Temperature in the British Virgin Islands, 1960Jan-2000Dec



Source of Data: Mitchell and others, (2004)

Sea Surface Temperature (SST)

In broad terms, SST started to rise in the Caribbean from the 1970s and in some sites a little cooling occurred before the sustained rise commenced (Sheppard and Rioja-Nieto, 2005). For most areas of the region, the rise generally became marked from about 1980, and continued to increase.

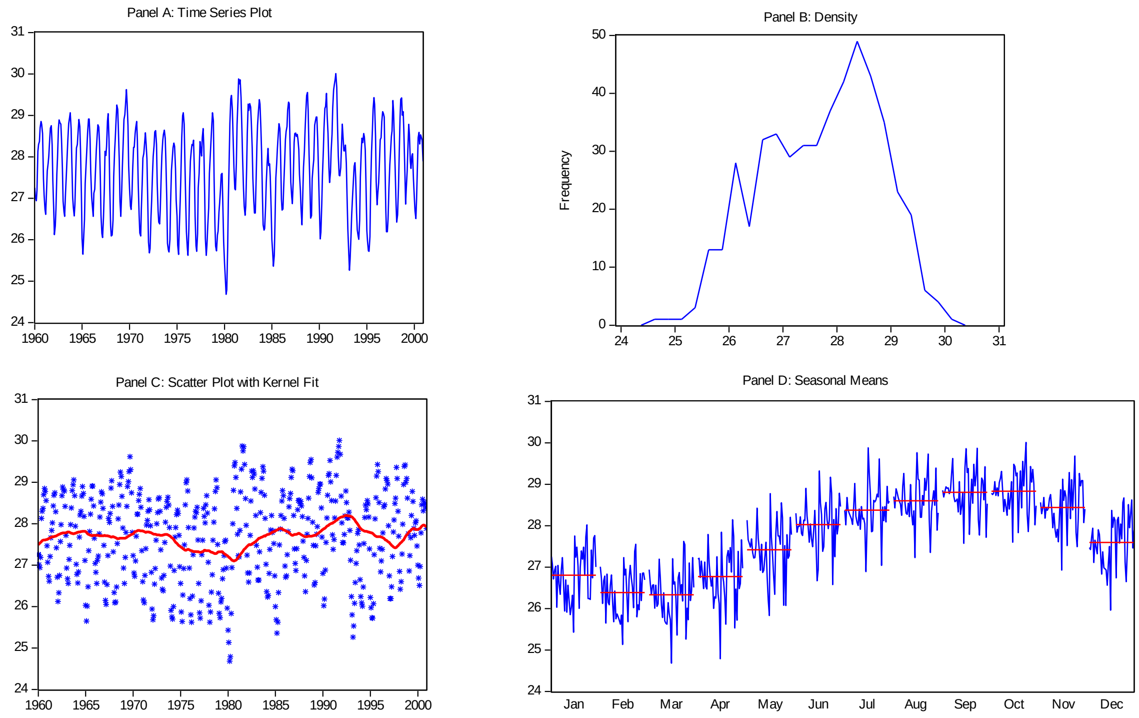
Figure 3 presents the historical average trends in SST in the BVI from 1960Jan-2000Dec: Panel A shows a time series plot of the series; Panel B shows the density pattern; Panel C shows a scatter plot with a kernel fit to indicate the long-term trend; and Panel D shows the seasonality in the mean SST. The rising trace of SST in the BVI is typical of that for the Caribbean subregion as a whole; that is, there is a gradual decline until around 1980 and then a trend upwards thereafter.

2. Precipitation

The maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing in the Caribbean. These changes were found to be similar to the changes reported from global analysis (Trenberth and others, 2007).

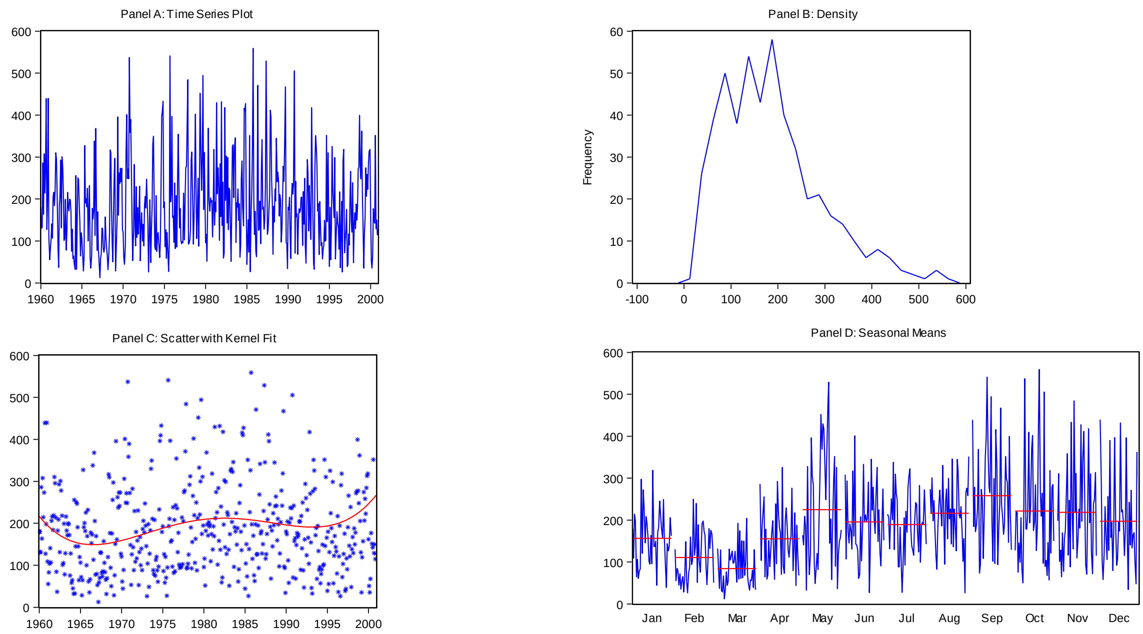
Average annual rainfall in the BVI is approximately 1140 mm (44.88 inches). Figure 4 presents the historical average trends in precipitation in the BVI from 1960Jan-2000Dec.

Figure 3: Sea Surface Temperature in the Waters of the British Virgin Islands, 1960Jan-2000Dec



Source of Data: Sheppard and Rioja-Nieto (2005)

Figure 4: Precipitation in the British Virgin Islands, 1960Jan-2000Dec



Source of Data: Mitchell and others (2004)

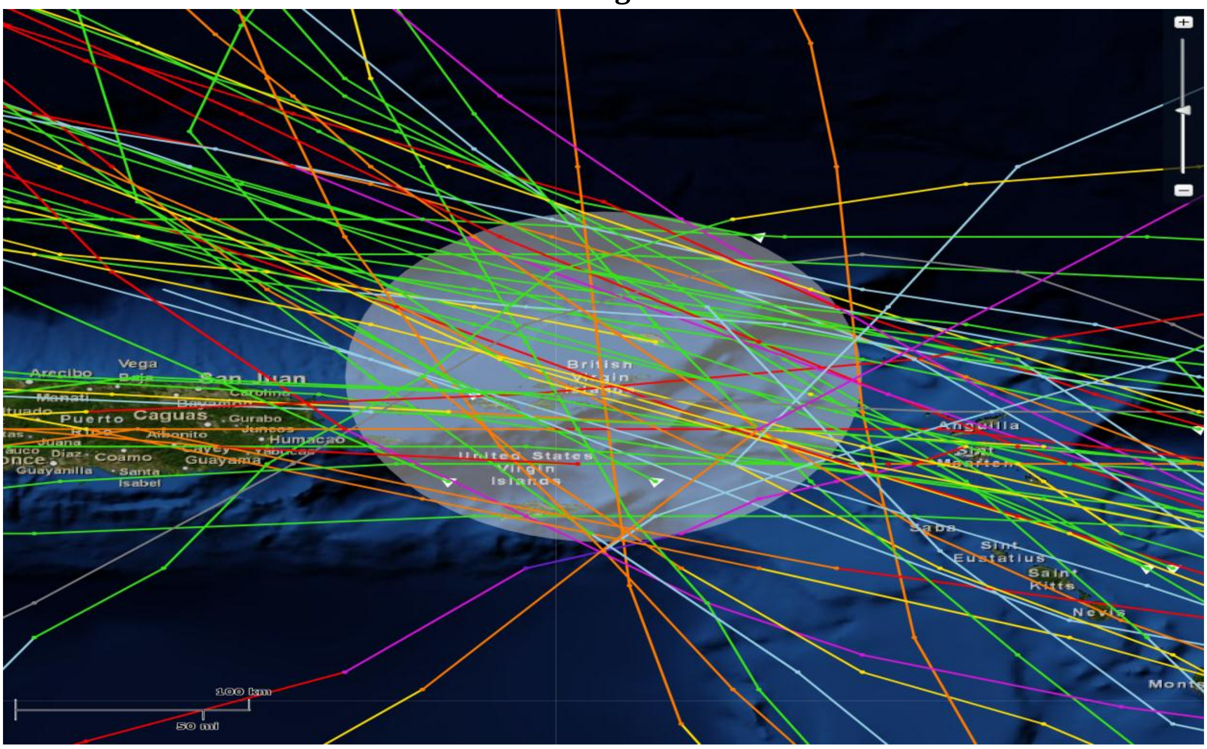
There was wide variation in precipitation in the BVI for the review period. The minimum monthly level of precipitation recorded was 12 mm and the highest 559 mm. Relative to the baseline period, 1960-1990, average precipitation fell by 18.2 mm/month (0.72 inches/month) or 218 mm/year (8.58 inches/year). There is a high degree of seasonality; precipitation levels were highest in the third quarter of the year, which corresponds to the hurricane season and lowest in the first quarter. September is the wettest month and March the driest month. There appears to be a cyclical pattern in precipitation levels; roughly every 15 years, the trend changes from a gradual decline to gradual increase and vice versa.

3. Hurricanes and Storms

The hurricane season in the Caribbean is officially between June and November with the majority of storm activity taking place in September. In the Caribbean, hurricane activity was greater from the 1930s to the 1960s, in comparison with the 1970s and 1980s and the first half of the 1990s. Beginning with 1995, all but two Atlantic hurricane seasons have been above normal. The exceptions were the two El Niño years of 1997 and 2002; El Niño acts to reduce activity and La Niña acts to increase activity in the North Atlantic. The increase contrasts sharply with the generally below-normal seasons observed during the previous 25-year period, 1975 to 1994.

The location of the BVI at the North Eastern tip of the Caribbean chain places it in the direct path of tropical cyclones that develop in the Atlantic Tropical cyclone basin. Since 1852, the islands have been affected by many tropical systems including hurricanes and tropical (see Figure 5). Historically, most hurricanes and tropical storms affecting the country have occurred mainly in September; August is second in terms of frequency.

Figure 5: Hurricane/Storm Tracks of Tropical Systems Passing within 60 Nautical Miles of the British Virgin Islands 1852-2010

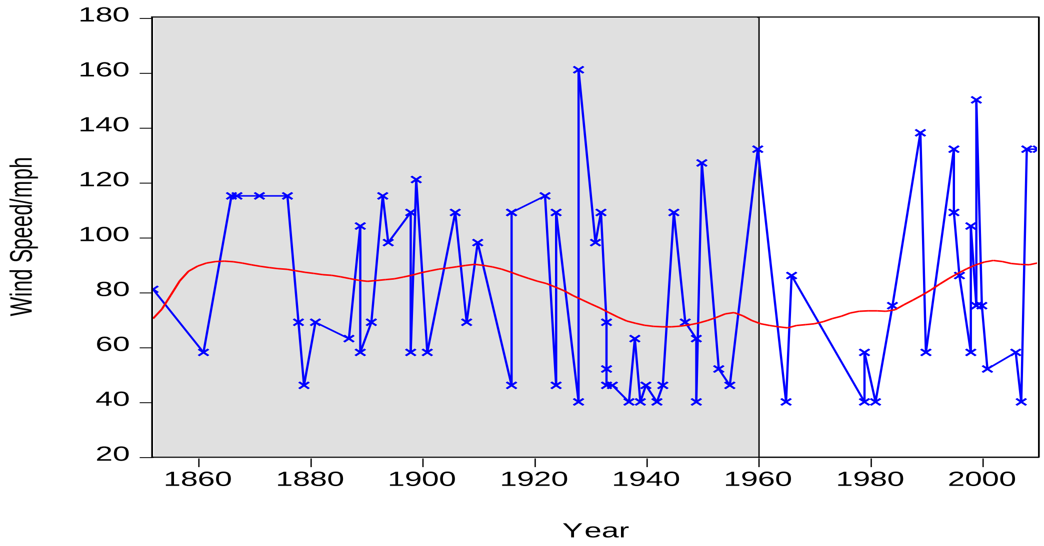


Source: National Oceanic and Atmospheric Administration (NOAA)

From 1852-2010, 71 hurricanes and tropical storms passed within 60 nautical miles of the BVI. Over this period, there has been general cyclicality in the average intensity of the systems (see Figure 6).

The general trend in system intensity from 1852-1959 (area shaded grey) was downward; average intensity was 78.5 mph. There were 49 systems, during this sub-period of 108 years; at least one system occurred 37% of the years under review. Of these 49 systems, 21 reached hurricane strength: 1 category one; 11 category two; 8 category three; and 1 category five.

Figure 6: Intensity of Tropical Systems Passing within 60 Nautical Miles of the BVI 1852-2010



Source: Observations obtained from the Caribbean Hurricane Network

In the remaining sub-period, 1960-2010 (41 years), there has been a generally increasing trend in intensity of hurricanes and storms (see un-shaded area in Figure 6); average intensity was 85 mph, 6.5 mph higher than in the former sub-period. There were 22 systems (13 reached hurricane strength; 5 were category one; 2 category two; and 6 category four). At least one system affected the BVI in 44% of the years in the current sub-period, 7 percentage points higher than in the former sub-period. Taken together, these trends imply that a system of hurricane intensity will affect the BVI roughly once every 2 years. Available damage estimates for a sample of hurricanes are provided in Table 1.

Table 1: Damage Estimates from Hurricanes in the British Virgin Islands

Wind Speed/mph	Category	Name	Damage/$ mn
138	4	Hugo	40
132	4	Luis }	10
109	2	Marilyn }	
86	1	Bertha	2
104	2	Georges	12
75	1	Jose	5
150	4	Lenny	29
75	1	Debby	2

Sources: Caribbean Hurricane Network and DDM (2002)
Note: The damage estimate for Luis and Marilyn is for both hurricanes jointly.

4. Flooding and Landslides

The BVI is susceptible to flooding in heavy rain events due to the combination of steep slopes and shallow soils (Earle, 1997, cited in Burnett Penn and George, 2011). Landslides are another hazard associated with flood events as the most susceptible landslide zones are located in and along the natural waterways (known locally as ghuts). These flood and landslide events have resulted in significant losses. For example, the November 2003 flood, in which an average of 20 inches of rain fell in 5 days, resulted in total losses (response/relief costs, rehabilitation costs, and reconstruction costs) estimated at $19,147,898.00 (DDM, 2003).

C. Coastal and Marine Biodiversity in the British Virgin Islands

1. Geographic Pattern of Species Richness

Coral Reefs

The Caribbean contains the greatest concentration of marine species in the Atlantic Ocean and is a global-scale hot spot of marine biodiversity (Roberts and others, 2002). The most characteristic ecosystems in the Caribbean are coral reefs covering about 26,000 square kilometres (Burke and Maidens, 2004), seagrass beds with an area of about 66,000 square kilometres (Jackson, 1997), and mangroves at nearly 11,560 square kilometres (FAO, 2003).

Coral reefs play a critical role in fostering the productivity of the tropical oceans and are often compared with tropical rainforests in terms of their importance as habitat and the biological diversity they harbour. Live coral cover has already declined by as much as 80% in many areas of Caribbean reefs over the last two decades because of various human activities and environmental changes (Gardner and others, 2003; Wilkinson, 2004).

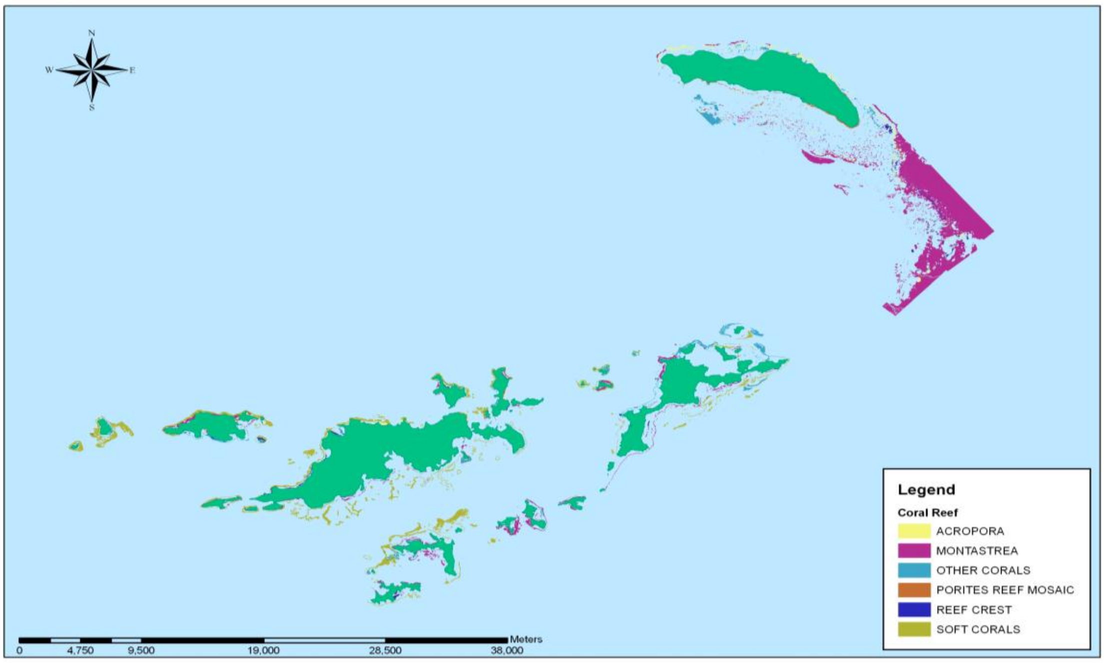
Table 2: Coral Reefs in the British Virgin Islands

Type of Coral	Area (square kilometres)
Live Coral	**40.23**
➢ Acropora	3.24
➢ Montastrea	7.28
➢ Porites Reef	1.26
➢ Reef Crest	1.75
➢ Soft Coral	19.02
➢ Other Corals	7.68
Dead Coral	**13.54**
➢ Coral Rock	4.24
➢ Dead Acropora	9.30

Source: Conservation and Fisheries Department, British Virgin Islands

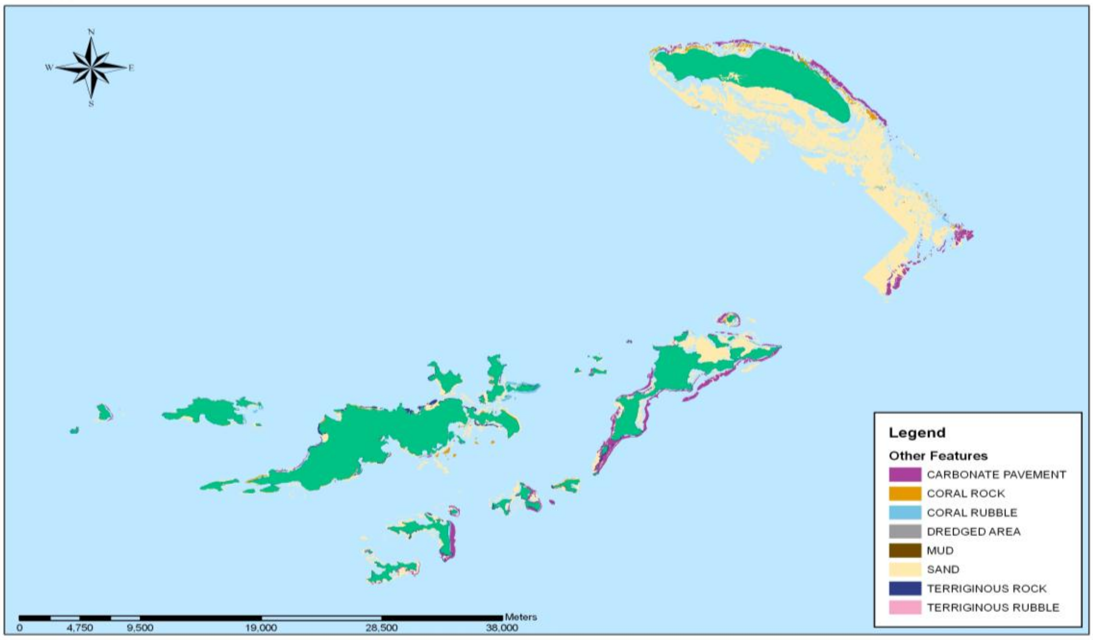
Geographic Information Systems (GIS) estimates of the coral reef in the BVI by the Conservation and Fisheries Department, BVI, indicate an area of 53.77 square kilometres. Of this total, 40.23 square kilometres, or 74.8% is live coral (see Table 2); Figures 7 and 8 indicate the location and extent of the varieties of coral and other marine substrata respectively.

Figure 7: Coral Reefs of the British Virgin Islands



Source: Conservation and Fisheries Department, British Virgin Islands

Figure 8: Other Marine Substrata of the British Virgin Islands



Source: Conservation and Fisheries Department, British Virgin Islands

Seagrass Beds

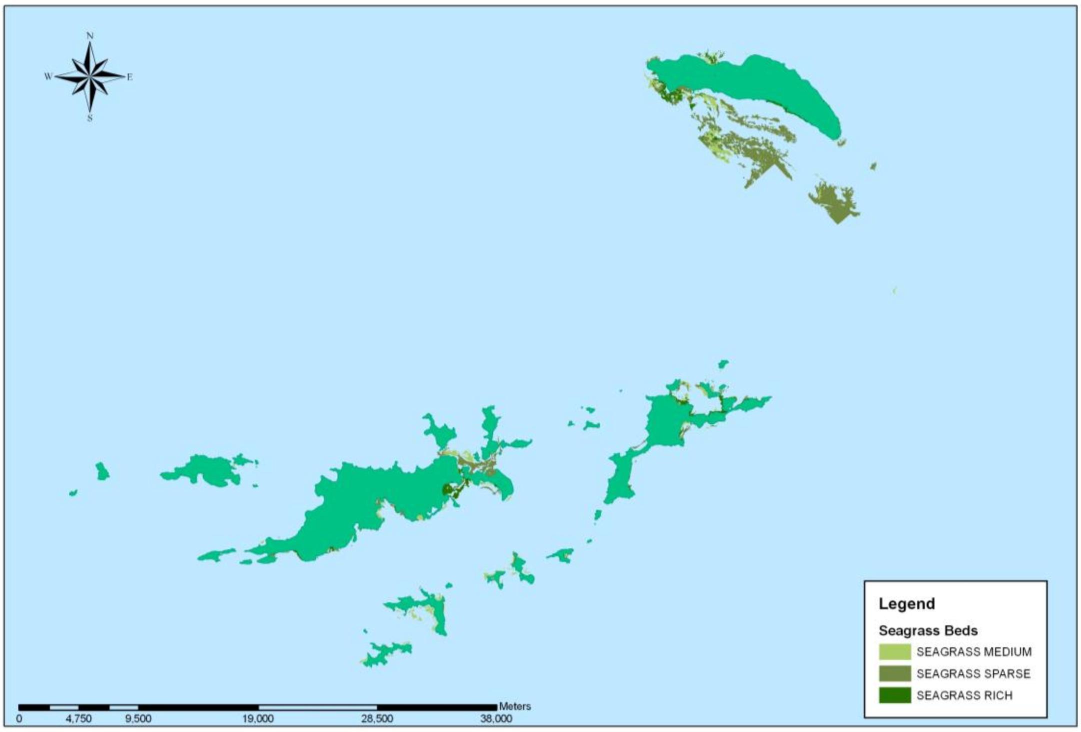
Seagrasses are grass-like flowering plants that live completely submerged in marine and estuarine waters. Seagrasses perform many significant functions: they help maintain water clarity by trapping fine sediments and particles with their leaves; they stabilise the bottom with their roots and rhizomes; they provide shelter for fishes, crustaceans and shellfish; and they and the organisms that grow on them are food for many marine animals and water birds. Three types of seagrasses are found in the BVI (see Figure 9), covering approximately 40 square kilometres (see Table 3). Dense beds can be found around the northern and south-western coasts of Anegada, the north-eastern, southern and western coasts of Anegada, north-eastern and southern coasts of Virgin Gorda, and Ginger Island, Cooper Island, Salt Island, Peter Island and Norman Island.

Table 3: Seagrass Beds of the British Virgin Islands

Type of Seagrass	Area (square kilometres)
Seagrass	**39.91**
➢ Seagrass Medium	8.04
➢ Seagrass Rich	5.85
➢ Seagrass Sparse	26.03

Source: Conservation and Fisheries Department, British Virgin Islands

Figure 9: Seagrass Beds of the British Virgin Islands



Source: Conservation and Fisheries Department, British Virgin Islands

Salt Ponds

Salt ponds are enclosed or mostly enclosed water bodies that occur within coastal mangrove wetlands. They are usually hypersaline (Hammer, 1986). Salt ponds and their surrounding mangrove forests are the predominant type of coastal wetland in the Caribbean (Bacon, 1994). These wetlands provide important ecological services, including storm protection and flood mitigation, shoreline stabilization, erosion control, and retention of nutrients and sediments (Marshal, 1994; Rivera-Monroy and Twilley, 1996; Tam and Wong, 1999). They also provide critical habitat and food resources for resident and migratory birds in the Caribbean (Scott and Carbonell, 1986).

There are approximately 60 salt ponds in the BVI (Jarecki and Walkey, 2006). The largest is the lagoon complex at the west end of Anegada, comprising Flamingo Pond, Bones Bight Pond and Red Pond. This area is protected as the Flamingo Pond Bird Sanctuary. It is one of the largest, relatively undisturbed saline lagoons in the Lesser Antilles (Jarecki and Walkey, 2006).

Mangroves

Mangroves are found along sheltered coastlines in the tropics and sub-tropics where they fulfil important functions in terms of providing wood and non-wood forest products, coastal protection, conservation of biological diversity and provision of habitat, spawning grounds and nutrients for a variety of fish and shellfish. Other functions include: filtering runoff from land; and protecting boats from the strength of the waves.

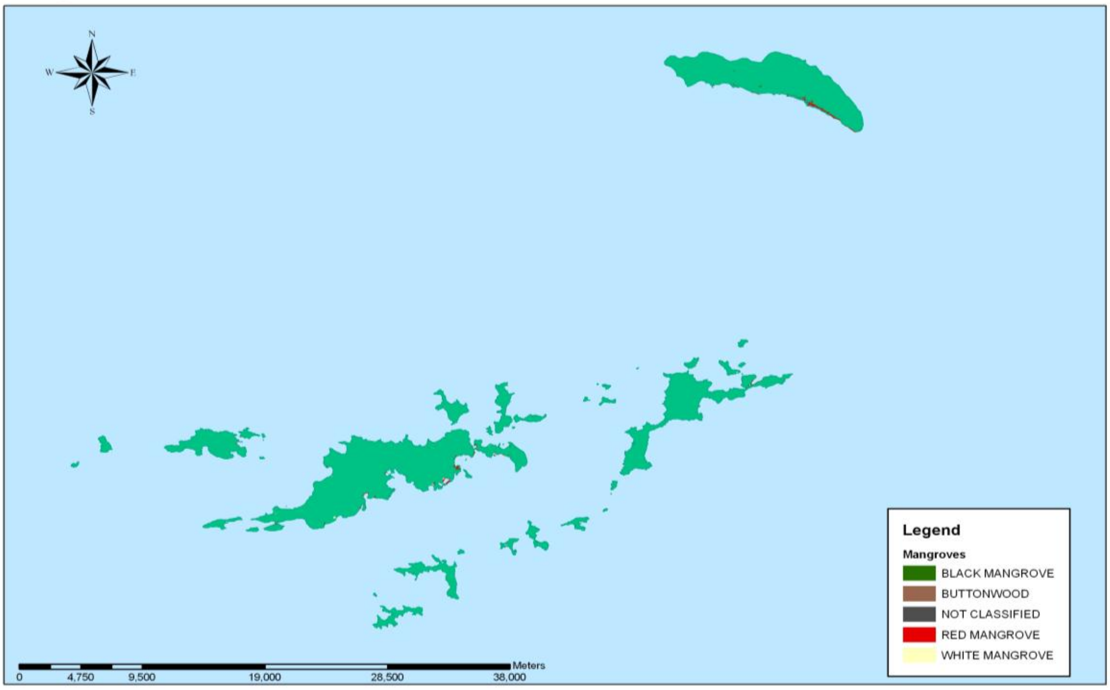
There are 4 species of mangrove in the BVI: red mangrove; black mangrove; white mangrove; and buttonwood. Table 4 shows the extent of each species.

Table 4: Mangroves of the British Virgin Islands

Type of Mangrove	Area (square kilometres)
Mangroves	**0.61**
➢ Red Mangrove	0.34
➢ Black Mangrove	0.12
➢ White Mangrove	0.13
➢ Buttonwood	0.01

Source: Conservation and Fisheries Department, British Virgin Islands

Figure 10: Mangrove Sites of the British Virgin Islands



Source: Conservation and Fisheries Department, British Virgin Islands

Mangroves are scattered throughout the islands (Beef Island, Anegada, Jost Van Dyke, Tortola and Virgin Gorda), mostly as scrubby fringe communities (FAO, 2005). The coastlines are generally rocky and mangroves are mainly found on the northern coasts of the islands, where the frequence of sandy beaches is higher. Fringing mangroves and lagoons occur on the south coasts (see Figure 10). Some of the most significant are: Tortola—Paraquita Bay, Hodges Creek, Sea Cow's Bay, Belmont Pond, Dubois Point Pond, Wickhams Cay, Pockwood Pond, Chapel Hill, Slaney Point; Virgin Gorda—Deep Bay; Anegada—Flamingo Pond; Beef Island—Beef Island Channel north and south, Hans Creek, Trellis Bay Pond; and Jost Van Dyke—East End.

Beaches

Beaches play a very important role. They create a barrier between the land and sea; provide access to the ocean; buffer coastal areas from storm energy; and support a number of life forms such as molluscs, algae, plants and shorebirds, among other things (Gore and others, 2008).

There are more than 150 "sandy" beaches in the BVI and approximately 100 "gravelly" beaches made up of volcanic cobble and coral rubble (Gore and others, 2008). Sandy beaches have an area of 2.82 square kilometres (see Table 5).

Table 5: Beaches of the British Virgin Islands

Type of Beach	Area (square kilometres)
Beaches	**2.82**
➢ Sandy Beach	2.60
➢ Rock Shore	0.22

Source: Conservation and Fisheries Department, British Virgin Islands

Coastal and Marine Wildlife

There are 3 species of turtles that nest in the BVI: The Green turtle, the Hawsbill turtle, and the Leatherback. Green turtle nesting has been reported from the following islands: Anegada, Beef Island, Cooper Island, Camanoe, Great Tobago, Great Thatch Island, Guana Island, Mosquito Island, Norman Island, Peter Island, Jost van Dyke, Prickly Pear, Sandy Spit, Sandy Cay, Tortola, Virgin Gorda, Necker Island and Scrub Island (Groombridge and Luxmoore, 1989). Foraging turtles have been reported from Anegada, Tortola, Virgin Gorda, and Norman's Island (Groombridge and Luxmoore, 1989). Hawksbill turtle nesting is reported to occur on the same islands as the green turtle (Groombridge and Luxmoore, 1989). Foraging areas for this species include East End on Tortola, the north-east end of Virgin Gorda, and the east and west coasts of Anegada. The Leatherback turtle is an annual visitor (Gore and others, 2008). There have also been occasional reports of the Loggerhead turtle foraging around the BVI (Gore and others, 2008; Overing 1992).

Humpback whales are reported to migrate off the BVI (Gricks, 1994). Other species which may occasionally be encountered include sei whales and sperm whales.

"FishBase" by Froese and Pauly (2010)[2] indicates that there are 476 species of fish in BVI waters; 342 are reef-associated; and 17 species are threatened.

[2] See http://www.fishbase.org.

2. Threats to Marine Biodiversity and Conservation of Marine Life

Rising population densities and associated coastal development, increasing fishing pressure, agricultural and industrial activities, increased river sediment loading, introduction of alien species, and climate change are among the major identified sources of anthropogenic pressure in the BVI (Burnett Penn and George, 2011; Burke and Maidens, 2004).

BVI's coral reefs are already degraded. This degradation is due to a combination of impacts, including damage by hurricanes, diseases, bleaching, pollution, sediment runoff, climate change, as well as more directly through boat anchoring, setting of fish traps, and groundings of ships. These changes have induced alterations in the community structure, reduced species diversity and live coral cover, and increased bio-erosion (Fabricius, 2005).

Other threats to the coral reefs in the BVI are diseases caused by among other things, elevated sea surface temperature. Appendix A lists the diseases that have afflicted coral reefs in the BVI (since the 1980s) respectively.

D. FISHERIES

Fishing has long been an important part of the culture of the BVI dating back thousands of years (Gore and others, 2008). The main types of fishing are artisanal, pelagic and recreational fishing.

Artisanal fishing takes place on the shallow, near-shore shelf surrounding the BVI; fishermen use small boats and traditional fishing methods, such as fish traps, hook and line, and fishing nets. Pelagic fishing ("deep sea fishing") occurs within the Exclusive Economic Zone (EEZ). Recreational fishing includes pleasure and sport fishing: pleasure fishing is aimed at small fishes such as tarpon and bonefish, as well as many other fish found on the reefs; and sport fishing is primarily catch-and-release aimed at billfish.

The fisheries industry is important for food and recreation for both local residents and visitors (Gore and others, 2008). The tourism industry relies upon fisheries for supplying hotels and restaurants with fresh local fish, as well as for the dive and charter boat industries. Within this context, while the fisheries sector contributes a small share of GDP in the BVI (0.49% in 2008), the socio-economic implications of the impact of climate change on fisheries are likely to be dire.

2.5 HUMAN SETTLEMENT AND INFRASTRUCTURE

Coastal urbanisation and land-use controls have traditionally not been viewed as critical issues in the Caribbean, so lands have been inefficiently utilised under the freehold[3] and leasehold[4] land-use allocation system. This has led to many sensitive areas being developed, particularly those lands with high environmental values such as offering watershed protection

[3] Freehold system: land ownership with no legal stipulations on land use controls associated with the development of the land.

[4] Leasehold system: land tenure by lease and with legal stipulation on land use and development.

or possessing high biodiversity. Most of the coastal open space that could easily be developed has long since been built upon, and the continued growth of the population has contributed to encroachment in hazard-prone areas such as coastal flood plains or steep slopes for settlements.

Figure 11: An Example of Coastal Development in Tortola

Source: Google Earth

The small size of the BVI limits the different types of land use. A majority of the population centres, ports and other major sites for industrial and commercial activity are located in the coastal zone. However, the needs of tourism compete with the needs of housing, agriculture, industry, roads, and ports. Trends in coastal lands have been skewed towards tourism sites close to the water's edge, which have increased the competitiveness of tourism with other activities for coastal land. As tourism growth has fuelled intensive development, coastal infrastructure such as roads, by necessity has expanded into more vulnerable areas. The result has been a ribbon growth pattern of development along the coast and the associated infrastructure requirements such as transport links (Caribbean Environment Programme (CEP), 1997). An example of such development is provided in Figure 11 which illustrates the density in coastal development on Tortola.

Because most of the country's activities are concentrated in the coastal zone, much of the infrastructure is vulnerable to extreme weather events such as hurricanes, and rising seas that are predicted to result from climate change (CEP, 1997). Moreover, the development of the necessary tourism infrastructure has led to coastal degradation, through increased siltation from land reclamation, dredging and construction, and pollution from sewage outfalls. In addition, anchor damage has been implicated in reef degradation, and large numbers of divers are believed to be responsible for damage to corals at BVI dive sites (Smith and others, 1999).

III. LITERATURE REVIEW

This section provides key general insights into the ways in which coastal and marine systems are presently changing, as a context for assessing the economic impacts of, and early effects attributable to, climate change in the BVI.

A. NATURAL COASTAL SYSTEMS

Coasts are dynamic systems, undergoing adjustments of form and process at different time and space scales in response to geomorphological and oceanographical factors (Cowell and others, 2003). Human activity exerts additional pressures that may dominate natural processes. Often models of coastal behaviour are based on palaeo-environmental reconstructions at millennial scales and/or process studies at sub-annual scales (Stolper and others, 2005). Adapting to global climate change, however, requires insight into processes at decadal to century scales, at which understanding is least developed (Donnelly and others, 2004).

Climate-related ocean-atmosphere oscillations can lead to coastal changes (Viles and Goudie, 2003). One of the most prominent is the ENSO phenomenon. Coral bleaching and mortality appear related to the frequency and intensity of ENSO events, which may alter as a component of climate change, becoming more widespread because of global warming (Stone and othres, 1999).

B. EXTERNAL TERRESTRIAL AND MARINE INFLUENCES

External terrestrial influences have led to substantial environmental stresses on coastal and near-shore marine habitats (Sahagian, 2000). As a consequence of activities outside the coastal zone, natural ecosystems (particularly within the catchments draining to the coast) have been fragmented and the downstream flow of water, sediment and nutrients has been disrupted (Nilsson and others, 2005). Land-use change, particularly deforestation, and hydrological modifications have had downstream impacts, in addition to localised development on the coast. Erosion in catchments has increased river sediment load. In contrast, damming and channelisation have greatly reduced the supply of sediments to the coast on other rivers through retention of sediment in dams (Syvitski and others2005).

Coasts can be affected by external marine influences. Waves generated by storms over the oceans reach the coast as swell; there are also more extreme, but infrequent, high-energy swells generated remotely (Vassie and others, 2004). Ocean currents modify coastal environments through their influence on heat transfer, with both ecological and geomorphological consequences. Other external influences include atmospheric inputs, such as dust (Shinn and others, 2000), and invasive species.

C. OBSERVED EFFECTS OF CLIMATE CHANGE ON COASTAL SYSTEMS

Trenberth and others (2007) and Bindoff and others (2007) observed a number of important climate change-related effects relevant to coastal zones. Rising CO_2 concentrations have lowered ocean surface pH by 0.1 units since 1750, although to date, no significant impacts on coastal ecosystems have been identified. Recent trend analyses indicate that tropical cyclones have increased in intensity. Global sea levels rose at 1.7 ± 0.5 mm/year through the 20th century, while global mean sea surface temperatures have risen about 0.6°C since 1950, with associated atmospheric warming in coastal areas (Bindoff and others, 2007).

Many coasts are experiencing erosion and ecosystem losses, but few studies have unambiguously quantified the relationships between observed coastal land loss and the rate of sea-level rise (Zhang and others, 2004). Coastal erosion is observed on many shorelines around the world, but it usually remains unclear to what extent these losses are associated with relative sea-level rise due to subsidence, and other human drivers of land loss, and to what extent they result from global warming (Hansom, 2001; Jackson and others, 2002). Long-term ecological studies of rocky shore communities indicate adjustments apparently coinciding with climatic trends (Hawkins and others, 2003). However, for mid-latitudinal coastal systems it is often difficult to discriminate the extent to which such changes are a part of natural variability; and the clearest evidence of the impact of climate change on coasts over the past few decades comes from high and low latitudes, particularly polar coasts and tropical reefs.

Global warming poses a threat to coral reefs, particularly any increase in SST. The synergistic effects of various other pressures, particularly human impacts such as over-fishing, appear to be exacerbating the thermal stresses on reef systems and, at least on a local scale, exceeding the thresholds beyond which coral is replaced by other organisms (Buddemeier and others, 2004).

D. CLIMATE CHANGE AND FISHERIES

Temperature and other variations resulting from climate change are expected to have a strong impact on fisheries. Since most marine species used for human consumption are poikilothermic, any changes in habitat temperatures can significantly influence their metabolism, growth rate, productivity, seasonal reproduction, and susceptibility to diseases and toxins. Research has shown that while fish may take refuge from rough conditions through minor changes in distribution, most fish species have a fairly narrow range of optimum temperatures related both to the species basic metabolism and the availability of food organisms that have their own optimum temperature ranges (NOAA, n.d.). While species, particularly those with shorter life spans, will change the timing of their life cycle, some plankton species will bloom earlier, resulting in mismatches between the early life stages of fish and their prey, and therefore cause declines in abundance. Studies have also shown that there is a similar decline in the abundance of seabirds which rely upon the fish as prey and this overall decline of fish species correlated to the decline in zooplankton abundance.

Increased temperatures will not only affect the productivity of some marine areas but will also have a negative impact on associated marine ecosystems such as coral reefs (Murray, 2005). However, there are significant local and regional variations in the scale and type of threats to coral reefs especially in small-island situations. It is difficult to measure direct impacts of climate change as against other elements such as misuse or overuse of coral reefs or other habitats. Ocean acidification on the marine biosphere can add stress to coral reefs as progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms and their dependent species (IPCC, 2007).

There is an association between rains, the transport of sediments in rivers and the supply of nutrients as a source of food for fish. This applies mainly to "surface" fishing. A key example is the influence of the Orinoco plume across the entire Eastern Caribbean. This plume is affected mainly by winds and currents. Increased precipitation, in addition to intensification of the typical seasonal pattern of winds could lead to the Orinoco River discharge reaching east of the Eastern Caribbean during periods when the westerly winds are relaxed (Mahon, 2002).

E. CLIMATE CHANGE AND MARINE DISEASES

Large-scale ''mass'' bleaching events (the loss of symbiotic algae from coral colonies over large reef tracts) have been associated most commonly with abnormally elevated water temperatures (Jokiel 2004). Higher prevalence of coral-mortality-causing diseases have also been correlated with warmer temperatures (e.g., Gil-Agudelo and Garzon-Ferreira, 2001; Kuta and Richardson, 2002; Boyett and others, 2007; Bruno and others, 2007), which may increase pathogen virulence or decrease host disease resistance (Harvell and others, 2002). It is not surprising, therefore, that mass bleaching events and disease outbreaks have been linked temporally during thermal anomalies (Jones and others, 2004; Miller and others, 2006). For example, in summer and fall of 2005, a thermally induced mass bleaching event affected coral populations of the north and north-eastern Caribbean region (Donner and others, 2007). This event was followed by outbreaks of coral disease that had devastating impacts in many parts of this region (Miller and others, 2006; Wilkinson and Souter, 2008).

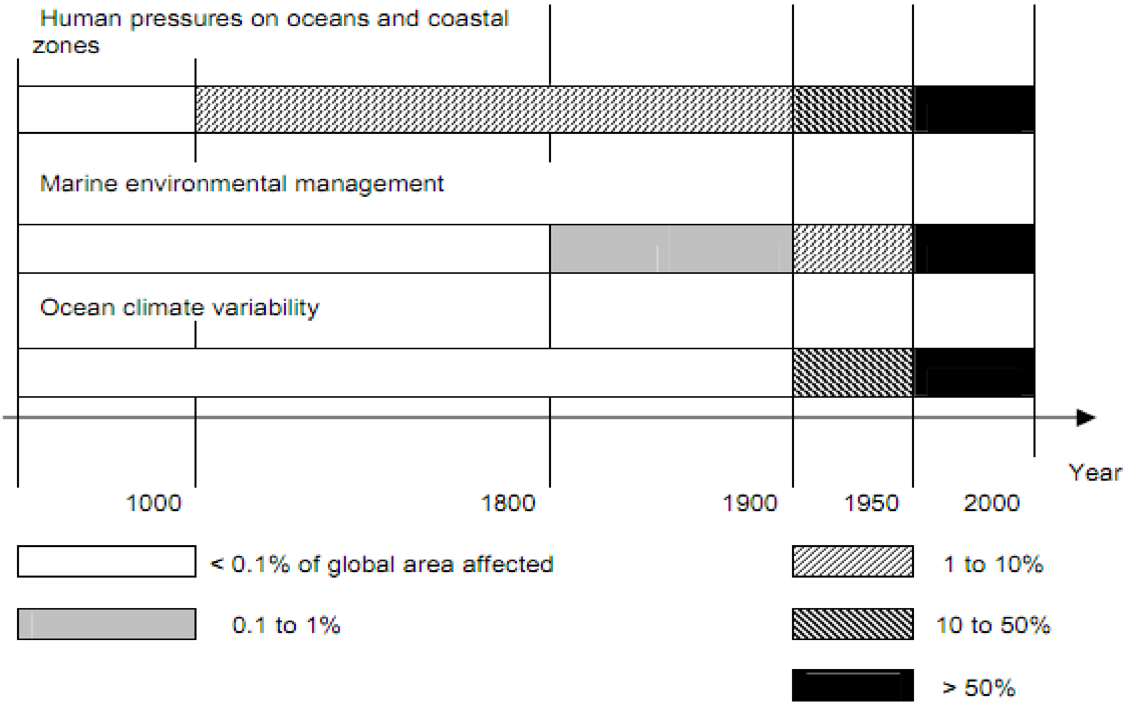
Climate warming may also favour disease in sea turtles. Green turtle fibropapilloma tumours are hypothesised to grow more rapidly in warm water and the prevalence of this disease has increased since the 1980s (Herbst, 1994). Reports of diseases of sea turtles have increased greatly over the last three decades (Ward and Lafferty, 2004), consistent with the evidence that warming is associated with this disease.

F. HUMAN ENGAGEMENT WITH THE COASTAL ZONE

Human activities in the coastal zone are many and varied. These effects can be both beneficial and detrimental. For example, consider the construction of a seawall. Benefits include the protection of properties at risk of erosion or recession hazard. Detrimental effects may include the loss of beach sand through interference with the sediment budget, more limited access to the beach and reduced recreational amenity.

Our understanding of climate changes caused by the growing population and anthropogenic interventions in the marine environment are still incomplete and frequently underestimated. However, studies reveal that direct human impacts have already affected marine and coastal ecosystems much faster than climate change (Salomons and others, 1999). Figure 12 reflects an historical perspective of changes caused by natural and human-generated factors and attempts to manage coastal and ocean resources within this historical perspective. It demonstrates that presently human pressures and interventions in the marine and coastal environment affect over 50% of the global ocean ecosystems. Human activities inflict harsh and often irreversible damage on the coastal and marine environment and their resources.

Figure 12: Occurrences of Major Human Pressures on the Coastal Zone at the Global Scale and Related Environmental Management



Source: Adapted from Crutzen and Stroemer (2000)

Because of intensifying use of these resources environmental deterioration and resulting climate changes are inevitable. The question is where, when and to what extent these changes will affect coastal societies and their economies in the following decades?

Rapid urbanisation and industrialisation of the coastal zones are linked to the increasing density of population. This is caused more by migration of people to the coast than by the natural increase of the coastal population. Incentives to move to coastal areas include more favourable economic opportunities, better living standards and a more favourable climate. In many countries these incentives are stronger than the risks of moving to the coastal areas, even if they are exacerbated by storms, hurricanes and tsunamis.

IV. IMPACT SCENARIOS FOR COASTAL AND MARINE SECTOR

This section presents the different climate change scenarios which are investigated in this study and lays out possible impact scenarios for the marine and coastal sector as a result of climate change.

A. IPCC EMISSIONS SCENARIOS

Global scenarios describe variations in greenhouse gas emissions. Their output projects climate changes averaged over the entire Earth. Regional and local changes are affected by global events, and could be more intense and variable than expressed by the global net effect.

In addition, it does not matter where greenhouse gases are released into the atmosphere.[5] They mix well, so local concentrations will not vary significantly from global concentrations.

The two IPCC scenarios summarised by Nakicenovic and others (2000) for which economic impacts are estimated are the A2 and B2 scenarios:

- **A2** assumes *regional* resiliency and adaptation. The underlying theme of A2 is self-reliance and preserving local identities, with economic development being moderate and focused within regions. Compared to other scenarios,[6] global population is expected to increase at a high rate in A2. Energy consumption is high and changes in land use are moderately high. Resources are becoming scarce and technological change is fragmented and slower than in other scenarios.
- **B2** assumes *local* resiliency and adaptation. It emphasises environmental preservation and social equity with local solutions to economic, social and environmental sustainability. Global population is expected to increase continuously, yet more slowly than in scenario A2. B2 has a moderate level of economic development (like A2), but requires less energy and less change in land use than A2. Resources are more abundant and technological change is more diverse than in A2.

A2 is at the higher end of the SRES emissions scenarios, but is not the highest; emissions under A2 can be considered medium high. B2 is at the lower end of the SRES emissions scenarios, but is not the lowest; emissions under B2 can be considered medium-low. As such, then, the A2 and B2 scenarios are not extremes. Yet they are quite different in what they anticipate the Earth might be like by the end of the 21st century. Compared with scenario B2, scenario A2 anticipates: higher CO_2 concentrations; a larger human population; greater energy consumption; more change in land use; scarcer resources; and less diverse applications of technology.

B. Potential Impact Scenarios for the British Virgin Islands

Use of the A2 and B2 scenarios is based on the fact that their output data are widely available. In addition, they are the most widely modelled and have received the most scientific peer review.

Under the A2 and B2 scenarios, many of the goods and services produced by the BVI will be threatened by climate change and variability arising especially from sea-level rise, increases in SST, and possible increases in extreme weather events. Key impacts will almost certainly include accelerated coastal erosion resulting in loss of beaches, saline intrusion into

[5] The main sources of greenhouse gases due to human activity are: burning of fossil fuels and deforestation leading to higher carbon dioxide concentrations in the air. Land use change (mainly deforestation in the tropics) account for up to one third of total anthropogenic CO_2 emissions; livestock enteric fermentation and manure management; paddy rice farming, land use and wetland changes, pipeline losses, and covered vented landfill emissions leading to higher methane atmospheric concentrations; use of chlorofluorocarbons (CFCs) in refrigeration systems, and use of CFCs and halons in fire suppression systems and manufacturing processes; and agricultural activities, including the use of fertilisers, that lead to higher nitrous oxide concentrations.

[6] The other scenario families are: **A1 -** a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies; and **B1** - a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

freshwater lenses, increased flooding from the sea, and loss of coastal structures, both natural and man-made. Reduction in biological diversity and possible wildlife extinctions is likely to occur; for example, sea-level rise is projected to cause a decrease in turtle nesting habitat by up to 35% (Fish and others, 2005) if the sea rises by 0.5 metres. It is also possible that mangroves may migrate landward in response to sea level rise.

There will likely be detectable influences on marine and terrestrial pathogens, such as coral diseases linked to ENSO events (Harvell and others, 2002). These changes are in addition to coral bleaching, which could become an annual or biannual event in the next 30 to 50 years or sooner without an increase in thermal tolerance of 0.2-1.0°C (Donner and others, 2005; Sheppard, 2003). Seagrass decline will likely accelerate if climate change alters environmental conditions in coastal waters. Changes in salinity and temperature and increased sea level, atmospheric CO_2, storm activity and ultraviolet irradiance alter sea grass distribution, productivity and community composition (Short and Neckles, 1999).

Climate change is predicted to drive fish species toward the more cold waters (Parmesan and Yohe, 2003) potentially resulting in widespread extinctions where dispersal capabilities are limited or suitable habitat is unavailable (Thomas and others, 2004). Climate change may strongly influence fish distribution and abundance (Wood and McDonald, 1997) through changes in growth, survival, reproduction, or responses to changes at other trophic levels. Furthermore, coral reefs and other coastal ecosystems severely affected by climate change will also have an impact on fisheries (Graham and others, 2006). These changes may have impacts on the nature and value of commercial fisheries. Changing fish distributions and abundances will undoubtedly affect the populations who harvest these stocks in the BVI.

Caribbean coastal waters periodically experience extensive blooms of algae that impact living resources, local economies and public health. Impacts of harmful algal blooms include human illness and death from ingesting contaminated shellfishes or fish, mass mortalities of wild and farmed fish, and alterations of marine food chains through adverse effects on eggs, young, and adult marine invertebrates (e.g., corals, sponges), sea turtles, seabirds, and mammals.

In general, literature on seabirds and coastal waterfowl, and possible impacts of climate change do not focus on the Caribbean. Based on a report by DEFRA (2005), it is expected that climate change will generally have the following effects on seabirds and coastal waterfowl in the BVI: the shifting of bird seasonal responses; changes in egg laying dates; changes in migratory timing (increased frequency of storms in the Caribbean already appears to be reducing the number of some birds reaching their breeding grounds (DEFRA, 2005); mortality from wind, rain and flooding; geographic displacement by winds (commonly documented in seabirds blown inland); mismatches between behaviour and environment; loss of habitat, particularly wetlands; and vulnerability of long distance migrants.

One of the greatest threats to marine mammals perhaps comes from changes in their food resources, as a result of climate change. Many prey species such as fish and plankton appear to rely on, and are influenced by, particular sets of environmental conditions (Harwood, 2001). Any changes in the geographic distribution of these oceanographic conditions as a result of climate change will affect the abundance and distribution of prey species (DEFRA, 2005). Apart from species residing within the region, it appears that other long ranging migratory species may depend on the region for food supply.

V. METHODOLOGY

In this section, the methods that will be employed to estimate the economic costs of climate change on the marine and coastal sector of the BVI are explained. First, frameworks to estimate the value of the services provided by this sector in terms of what they are worth in 2008 are described. Second, techniques for measuring the economic costs of climate change on the coastal and marine sectors of the BVI up to the year 2050, based on the A2 and B2 scenarios are described.

A. VALUATION OF COASTAL AND MARINE SECTOR

This section estimates the economic value of the coastal and marine sector in the BVI in terms of their contribution to tourism and recreation, fisheries, and biodiversity. Estimates of the current value of goods and services are presented in terms of gross benefits.

There are many different methods for estimating the economic value of natural resources. The commonly used Total Economic Value (TEV) framework divides the value of ecosystem goods and services into use and non-use values. Use values are further broken into direct use, indirect use and option values. Direct use values include consumptive uses—such as food—and non-consumptive uses, such as tourism and recreation. Indirect use values include ecosystem services such as shoreline protection. Option values estimate the value of preserving the use of ecosystem goods and services for the future, including "bequest value," where the value is for future generations. Non-use values typically refer to existence value; i.e., the value humans place on the knowledge that a resource exists, even if they never visit or use it. Non-use and option values are frequently the most controversial elements of TEV; they are the most difficult to quantitatively measure, and have the greatest uncertainty attached to them.

A more basic approach is to examine the amount of economic activity an ecosystem service generates in the local economy (Pendleton, 2008). This involves looking at the revenues, taxes, and jobs generated by an activity—information that is especially useful for national and local decision-makers who are faced with questions around restricting development or investing in efforts to protect a threatened resource. This approach is employed to value two critical goods and services provided by these resources: tourism and fisheries. The framework employed for valuing tourism and fisheries was developed by the *World Resources Institute* (WRI, 2009). These services were chosen because they can be assessed using publicly available data.

The value of the services provided by coastal and marine ecosystems, or biodiversity, are also considered. This is determined in terms of the ecological functions they provide, such as the control of coastal erosion. A study by Costanza and others (1997) forms the basis for arriving at an estimate for coastal and marine biodiversity.

These valuations do not take into account whether these resources are being used at a sustainable level, and do not address the damage that overcrowding, inadequate waste treatment, and fishing at current levels, among other things, may be doing to the beaches, rocky shores, mangroves and reefs. In addition, the accuracy of the valuation analysis is limited by the quality and availability of data, and of course, the assumptions that were made.

1. Direct Use

Coral Reef- and Mangrove-Associated Tourism
The value of coral reef-and mangrove-associated tourism was calculated using the *WRI* (2009) methodology. This method estimates gross revenues and taxes from marine recreation as well as revenues from accommodation and other tourist spending on days spent using coralline beaches, reefs, or mangroves. Indirect impacts from tourism expenditure associated with the coral reefs and mangroves and consumer surplus (the additional welfare a consumer enjoys beyond what he or she has paid for the service) of reefs and mangroves are also estimated. The focus though is the combined value of reef- and mangrove-associated tourism, rather than the independent contribution of each habitat.

The most difficult step in the tourism analysis is determining what portion of total "tourist days" should be attributed to use of mangroves and coral reefs. Published tourism statistics by the *Caribbean Tourism Organisation* (CTO, 2007) indicating the purpose of visit to each country by tourists, are employed. For example, it is estimated that 96% of tourists visit beaches, reefs or coastal mangroves in the BVI since 96% of visitors to the BVI go there for holiday. Accommodation and other spending by tourists on reef- and mangrove-associated days are calculated using published room and occupancy rates. Where exact rates were unavailable, average rates for the Caribbean are used. For a discussion of the data and assumptions for all of the tourism components, see Appendix B.

Coral Reef- and Mangrove-Associated Fisheries
The value of coral reef- and mangrove-associated fisheries was calculated by estimating gross revenues from commercial fishing and processing activities. Coral reef health impacts fisheries productivity and by extension total fisheries revenue. Reef productivity for the BVI was determined based on a reef threat index and associated estimates of reef productivity by Burke and Maidens (2004). In the Caribbean, productivity of the reefs lies in the range of 1-5 metric tonnes per square kilometre (Burke and Maidens, 2004). On this basis, it is assumed reef productivity for the BVI varied between, 2-5 metric tonnes per square kilometre.

In addition to fish production, or catch, the value added through fish processing is estimated. This study examines the economic benefits accruing to the BVI respectively, so it does not count any revenues earned by people fishing in their waters, but landing and selling their catch in neighbouring or other countries. As such, the estimate will undervalue fisheries in the BVI. For a discussion of the data and assumptions for the various fisheries components, see Appendix B.

2. Indirect Use

Valuing biodiversity has proven both difficult and controversial (Christie and others, 2006). A significant amount of literature has been published on the valuation of biodiversity (see, for example, Barbier and others, 1994; Patterson and Cole, 1999; Tacchoni, 2000; Kettunen and Brink, 2006). Valuing marine biodiversity suffers the added complication that the marine environment is extremely diverse. In addition the marine environment is difficult to sample and monitor (Ray and Grassle, 1991).

Valuing Coastal and Marine Biodiversity
This study estimates the value of coastal and marine biodiversity using the results from Costanza and others (1997) for estimation of the global value of the world's ecosystem services. Briefly, the global valuation study estimated the value per unit area of 17 ecosystem services: gas regulation; climate regulation; disturbance regulation; water regulation; water supply erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; pollination; biological control; habitat; food production; raw materials; genetic resources; recreation; and cultural values.

The indirect coastal and marine services provided by coral reefs, the shelf up to 30 metre depth, seagrass beds and mangroves as a value of coastal and marine biodiversity *a la* Beaumont and others (2008) are considered. Food production or recreation services are not considered since these can be considered direct use values. Of the services described by Costanza and others (1997) for each ecosystem, the services for: coral reefs, are disturbance regulation, waste treatment, biological control, habitat, raw materials, and cultural values; the coastal shelf, are nutrient recycling, biological control, raw materials and cultural values; seagrass beds, are nutrient recycling and raw materials; and mangroves, are disturbance regulation, nutrient recycling, habitat and raw materials. These services and their functions are described in Table 6.

Table 6: Ecosystem Services and Functions used in Valuation of Biodiversity

Ecosystem Service	Ecosystem Function	Example
Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure
Nutrient recycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation, and other elemental or nutrient cycles
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Waste treatment, pollution control, detoxification
Biological control	Trophic-dynamic regulations of populations	Keystone predator control of prey species, reduction of berbivory by top predators
Habitat	Habitat for resident and transient populations	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds
Raw materials	That portion of gross primary production extractable as raw materials	The production of fuel, fodder, and other extracts
Cultural	Providing opportunities for non-commercial uses	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems

Source: Adapted from Costanza and others (1997)

The annual global values were estimated in 1994 USD on a per hectare (ha) basis. The values per ha were: $2,847 for coral reefs; $1,542 for the coastal shelf; $19,004 for seagrass beds; and $8,866 for mangroves. To arrive at values of the BVI's coastal and marine environment in 2008 dollars, the 1994 values are converted to 2008 values by price inflating the original values through to 2008 using annual US consumer price inflation (1995-2008). This resulted in 2008 indirect use values of: $4,136/ha for coral reefs; $2,240/ha for the coastal shelf; $27,609/ha for sea grass beds; and $12,881/ha for mangroves. For the calculations, please see Appendix B.

This simple approach rests upon the core assumption that the annual ecosystem service values per hectare for the BVI are similar to the average global values and have the same worth in today's dollars. In actuality these values are likely to be different. This method has been criticised, notably due to inaccuracies relating to benefit transfer, aggregation and extrapolation to a global scale (Balmford and others, 2002). It is important to reiterate that there are severe limits to the economic valorisation of biodiversity. In using the global valuation methodology, the estimates should be taken as useful starting points for establishing a value for coastal and marine biodiversity of the BVI.

B. Economic Losses of Climate Change on Coastal and Marine Sector

UNEP loosely defines the coastal zone as the area of land subject to marine influences and the area of the sea subject to land influences. More specifically, they divide the coastal zone into three main components: the sea, the beach, and the land behind the beach. The sea, or offshore area, extends from the low water mark seaward. This area covers the shallow marine habitats of the coast, such as seagrasses, and the coral reefs among others. The beach zone extends from the low water mark to the seaward edge of the coastal vegetation. The last component of the coastal zone is the adjoining coastal land. This zone extends landward for some distance from the end of the beach.

To provide an estimate of coastal zone losses from climate change, the potential losses of the impact of climate change on beaches, the land behind the beach, coral reefs, sea grass beds and the coastal shelf to 30 metre depth are taken into account. The "beach" and "land behind the beach" components are referred to as "coastal lands", while the "sea" component is referred to as "coastal waters". Although interactions between impacts of climate change may be important, they are ignored; this reflects the underlying literature.

It was not possible to obtain sufficiently long continuous time series on key coastal and marine descriptors, such as coral reef cover, mangrove cover, seagrass bed cover, beach width and fish stocks for the BVI, which would have been critical for making inferences about the impact of climate variables, especially with regard to sea surface temperature and sea level rise. This eliminates econometric techniques from our methodological approach for estimating the costs of climate change.

1. Cost of Climate Change on Coastal Lands

This study seeks to estimate the long-term costs of coastal inundation as a result of climate-induced SLR in the BVI. Various studies predict SLR in the region of 1-2 mm/year (Church and others, 2001; Miller and Douglas, 2004). Other estimates have put SLR at 4 mm/year (Cazenave and Nerem, 2004; Leuliette and others, 2004). Rahmstorf (2007) predicts that seas in the region will rise by 0.5-1.4 metres by 2100 (5-14 mm/year).

IPCC (2007, p. 8) presents projected global SLR by the end of the 21st century for the 6 SRES marker scenarios. Under the A2 scenario, SLR by 2100 is predicted to be in the range 0.23-0.51 m, and under the B2 scenario, 0.20-0.43 m. However, these projections exclude future dynamical changes in ice flow.

According to Simpson and others (2010), recent studies accounting for observations of rapid ice sheet melt (Greenland and Antarctic) have led to more accurate estimates of SLR than in the IPCC projections. A growing consensus suggests that by the end of the 21st century SLR will be between 1-2 m above present levels (Simpson and others, 2010). Moreover, the Caribbean is projected to experience greater SLR than most areas of the world due to its closer proximity to the equator and related gravitational and geophysical factors (Simpson and others, 2010).

Based on the revised SLR projections by Simpson and others (2010) which take into account melting of the ice sheets, it is assumed that by 2100 SLR will be 2 metres above 2000 levels under the high impact scenario, A2. To model the low impact scenario, B2, it is assumed that SLR will be 1 metre above 2000 levels.

Using GIS software, SLR assumptions under A2 and B2 are modelled to determine the area of land that will be inundated on the four main islands (Tortola, Virgin Gorda, Jost Van Dyke, and Anegada).[7] Together, these islands make up 80% of the total land mass in the BVI. The land loss from SLR in 2100 is then valued. A current (2011) estimate of the value of land in the BVI, obtained from a local real estate agent, indicated a value of $150,000-300,000/acre. The median value, $225,000, is used as a representative estimate and projected to 2100 by assuming the value of land appreciates at a rate of 1%/year; this gives us a value of $545,487/acre.[8] It is important to note that this approach will produce a conservative estimate for the losses associated with SLR, since it does not consider the cost of relocation/rebuilding.

2. Cost of Climate Change on Coastal Waters

Gradual and consistent increases in SST have yielded increasingly frequent bleaching events (1993, 1998, 2005), the latest of which caused wide-scale bleaching throughout the Caribbean region. The extended coral mortality caused during these events is only partially recovered over time, provided that no subsequent bleaching takes place. More than one bleaching event over a short timeframe can be devastating. Under conditions anticipated by the IPCC, SST in the Caribbean during the current century may reach threshold values that would lead to a collapse of the coral biome (Christensen and others, 2007). Increasing SST is also expected to have similar adverse effects on seagrass beds and the coastal shelf.

Vergara and others (2009) estimate expected coral loss in the Caribbean to be almost 100% by 2050 as a result of increases in SST under the top IPCC emissions scenario, A1F1. Adjusting Vergara and others estimates for the SRES markers employed in this study, the assumption is made that losses of 80% under A2 and 50% under B2 will occur by 2050, to the services provided by coral reefs, sea grass beds and the coastal shelf.

In this analysis losses associated with degradation in the biomes (coral reefs, sea grass beds and the coastal shelf) in the coastal waters of the BVI are estimated. The negative impact of rising SST is obtained using the following formula:

$$\sum_{biome} Expected\ Loss * Current\ Biome\ Cover * Unit\ Value\ of\ \ Biome\ in\ 2050 \qquad (1)$$

The value of services provided by coral reefs, seagrass beds and the coastal shelf in 2050 are estimated using the values in Costanza and others (1997) projected to 2050 by using

[7] The GIS estimates were obtained from the Conservation and Fisheries Department, British Virgin Islands.

[8] This the value of land in the BVI is likely to appreciate at a faster rate.

average US consumer price inflation (from 2004-2008) of 3.2%. For the calculations, see Appendix C.

C. ECONOMIC LOSSES FROM EXTREME EVENTS

The data available on the costs of extreme events in the BVI is limited to the direct physical impacts or to losses in fixed capital and inventories associated with hurricanes; indirect and secondary effects on economic activity such as changes in fiscal policy and the consequences of the long-term reassigning of resources are excluded from existing estimates. Costs associated with other extreme events such as floods are not available. Consequently, this section focuses on the increased losses which can occur due to the impact of climate change on hurricane intensity.

IPCC (2007) reports that there is no clear evidence of an increasing frequency of cyclones and tropical storms that can be associated with climate change, at least up to the end of the 1990s, but there is evidence of an association with their intensity. Estimates indicate that the world's oceans have absorbed approximately 20 times more heat than the atmosphere during the past half century, producing higher temperatures in both shallow and deep water (Barnett and others, 2005; Levitus and others, 2005). Both factors contributed to the greater intensity of tropical cyclones over ocean waters (Hansen, 2005). This conjecture is supported by studies that identify a positive relationship between the intensity of tropical cyclones and SST (Emanuel, 2007; Henderson-Sellers and others, 1998).

Henderson-Sellers and others (1998) have estimated that if the 1990 level of emissions were to double by 2080, the intensity potential of hurricanes could increase within a range of 10-20%. Knutson and others (2001) calculated that an increase in SST of between 2.3 and 2.8°C due to CO_2 emissions, would lead to an increase of 3-10% in wind intensities. Lennart Bengtsson and others (2007) have estimated that the maximum wind velocity could increase in a range of 6-8% in this century if emissions rise 1% per year for the next 80 years.

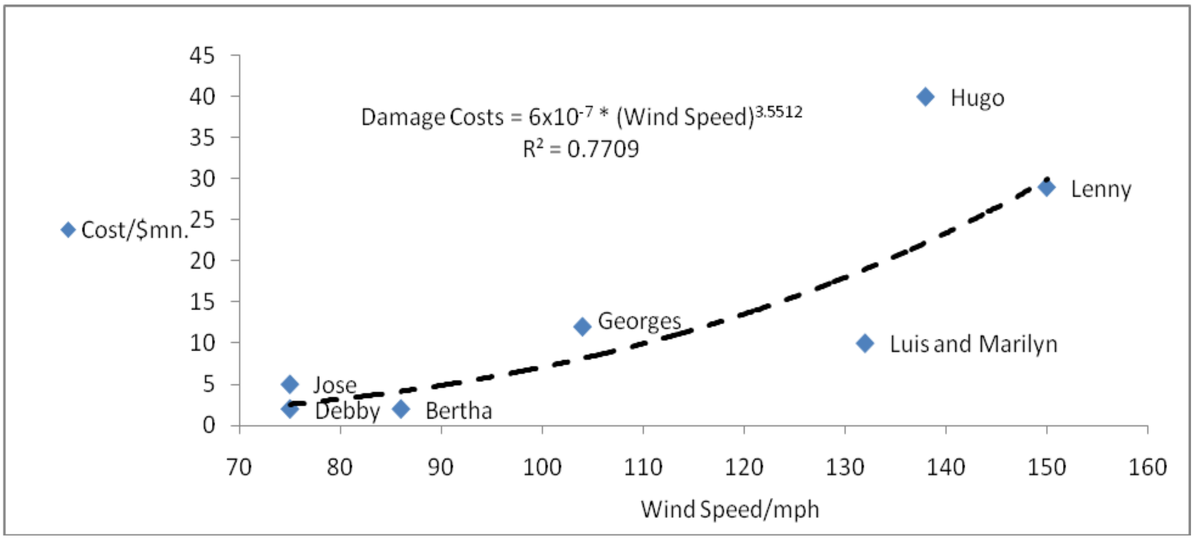
The patterns observed in the available information for the BVI (see Table 1) indicate an upward trend in costs associated with hurricanes, consistent with the hypothesis that costs are positively associated with the intensity of extreme events (see Figure 13). The best fit curve indicates that damage costs increase at an increasing rate with respect to wind intensity. Therefore, this study assumes that greater wind intensity (derived from an increase in SST), translates into higher costs. For the BVI, damage costs as a function of wind speed can be expressed as:

$$Cost = 6\mathbf{x}10^{-7} * (Wind\ Speed)^{3.5512} \quad (2)$$

Using Equation (2), costs for the 17 hurricanes and storms from 1960-2000 (41 years), the baseline period are estimated. Next, costs for hurricanes and storms which are more intense as a result of increasing SST for 2009-2050 (42 years), are calculated. Most studies describe scenarios with increases of 4-12% in hurricane intensity. The present analysis considers increases of 5% as the lower limit (assigned to the B2 scenario) and 10% (assigned to the A2 scenario) as the upper limit. These scenarios are applied to the tropical systems in the baseline period to calculate the increase in costs due to climate change (rise in SST). For the calculations, see Appendix C.

It is important to note that determining the real impact of hurricanes, and other extreme events, on the BVI, including direct and indirect costs and implications for the country's development path, requires further long-term analysis. More and better data are needed, along with improved forecasting capacity and more precise vulnerability studies with which to formulate dynamic risk assessments.

Figure 13: Relationship between Damage Costs and Hurricane Intensity in the British Virgin Islands



Source: Data obtained from DDM (2002)

D. DISCOUNTING

Discounting is used by economists to compare economic impacts occurring at different times (Arrow and others, 1995).[9] Because of the long periods involved in climate change decisions, the choice of discount rate critically affects the net present value of alternative policies, and thus the policy recommendations that emerge. As a result, the discount rate is one of the most contentious issues in the debate about the extent of climate change. The prescriptive approach tends to generate relatively low discount rates and thus favours relatively more spending on climate change mitigation. The descriptive approach tends to generate relatively higher discount rates and thus favours relative less spending on climate change mitigation.

The implicit discount rate used for climate change damages in the Stern Review is approximately 1.4% (Dietz, 2008).[10] This relatively low rate is consistent with the view that the welfare of future generations is as important as that of the current generation. Critics of

[9] There are four main reasons commonly proposed by economists for placing a lower value on consumption occurring in the future rather than in the present: future consumption should be discounted simply because it takes place in the future and people generally prefer the present to the future (inherent discounting); consumption levels will be higher in the future, so the marginal utility of additional consumption will be lower; future consumption levels are uncertain; and improved technology of the future will make it easier to address global warming concerns.

[10] The Stern Review on the Economics of Climate Change is a report released for the British government on October 30, 2006 by economist Nicholas Stern, which discusses the effect of global warming on the world economy.

the Stern Review, for example, Nordhaus (2007), suggest that a discount rate of 4% or higher should be employed, to be consistent with the observed real rate of return in the stock market. However, supporters of the Stern Review counter that a rate as high as 4%, implies that the welfare of future generations is much less important than that of the current generation; essentially this would mean that nothing should be done now to combat climate change.[11] Further, they argue that the 1.4% rate of discount used in the Stern Review is consistent with the real rate of return in the bond market. If supporters of the Review are correct, then discount rates of approximately 1-2% are more applicable for discounting climate change losses.

Notwithstanding the highly charged debate about the appropriate rate of discount that should be employed, the previous discussion provides us with a range of discount rates to employ in this study to assess predicted losses in today's dollars. Rates of 1%, 2% and 4% are used. This allows for examination of the sensitivity of loss estimates to different choices of discount rate.

E. BUSINESS AS USUAL"

This study also developed a baseline or "business as usual" (BAU) trajectory for the value of the coastal and marine sector "without climate change" up to 2050. BAU is a concept that is difficult to pin down because it critically depends on what assumptions are made about structural change.

To accomplish this task, the value of each component which comprised the total value of the coastal and marine sector is projected up to 2050 based on their individual underlying growth rates and then the component values for the respective years are added to get the total value for each year.[12] Once this baseline is established, the difference between the trajectory "without climate change" and the cost of climate change is assessed. This study estimated the change in the value of the sector from SLR and rise in SST.

VI. RESULTS

A. COSTS OF CLIMATE CHANGE ON COASTAL AND MARINE SECTOR

It is important to stress that the estimates that appear in this section are only indicative and not definitive. Building multiyear scenarios is an extremely complicated endeavour involving a high degree of uncertainty. However, it is possible to identify various trends.

1. Value of Coastal and Marine Sector

The results for valuation of the services provided by the coastal and marine sector in the BVI are presented in Table 7. Calculations indicate that the sector is valued at approximately $1,606.9 million (mn). The largest contributor to the overall valuation is the tourism and

[11] For a more thorough discussion of the controversy surrounding the discount rate see Quiggin (2006).

[12] The underlying rates for the tourism and recreation (0.31%) and fisheries (-6.2%) were determined from the average growth rates of these sectors from 2003-2008. The underlying growth rate for biodiversity is 3.2% for reasons explained in Section 5.2.2.

recreation component, making up almost 63% of the total. In comparison to 2008 GDP of approximately $991.85 mn, all component values with the exception of fisheries are very large. In particular, the value of tourism and recreation is 1.9% larger than 2008 GDP. Overall, the value of the sector is 62% larger than baseline GDP.

Table 7: Value of Coastal and Marine Sector 2008

	Value ($mn)	Share of Total Value (%)	Share of 2008 GDP (%)
Tourism and Recreation	1,010.2	62.9	101.9
Fisheries	2.1	0.1	0.2
Biodiversity	594.7	37.0	60.0
Total	$1,606.9 mn	100	162.0

2. Value of Losses to Coastal Lands

In this section estimates of the economic impacts of SLR on coastal lands under the A2 (2 metre rise) and B2 (1 metre rise) scenarios are calculated. Figures 14-17 show the extent of the areas that will be inundated and the critical infrastructure affected as a result.

Figure 14: Impact of Sea Level Rise in Tortola

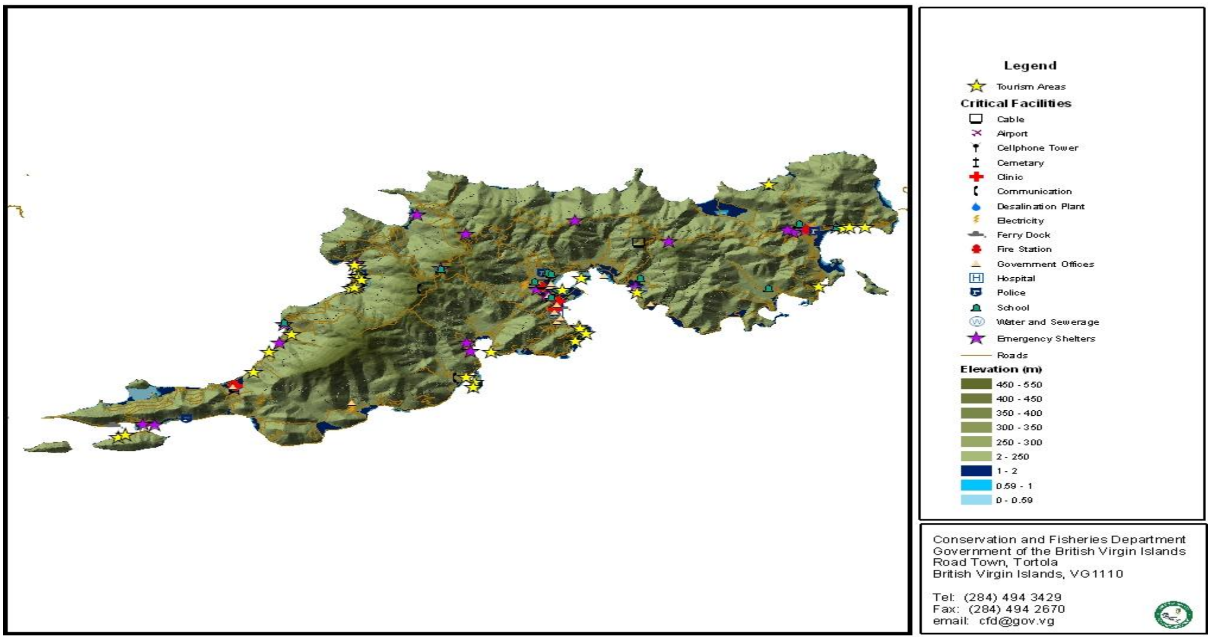


Figure 15: Impact of Sea Level Rise in Virgin Gorda

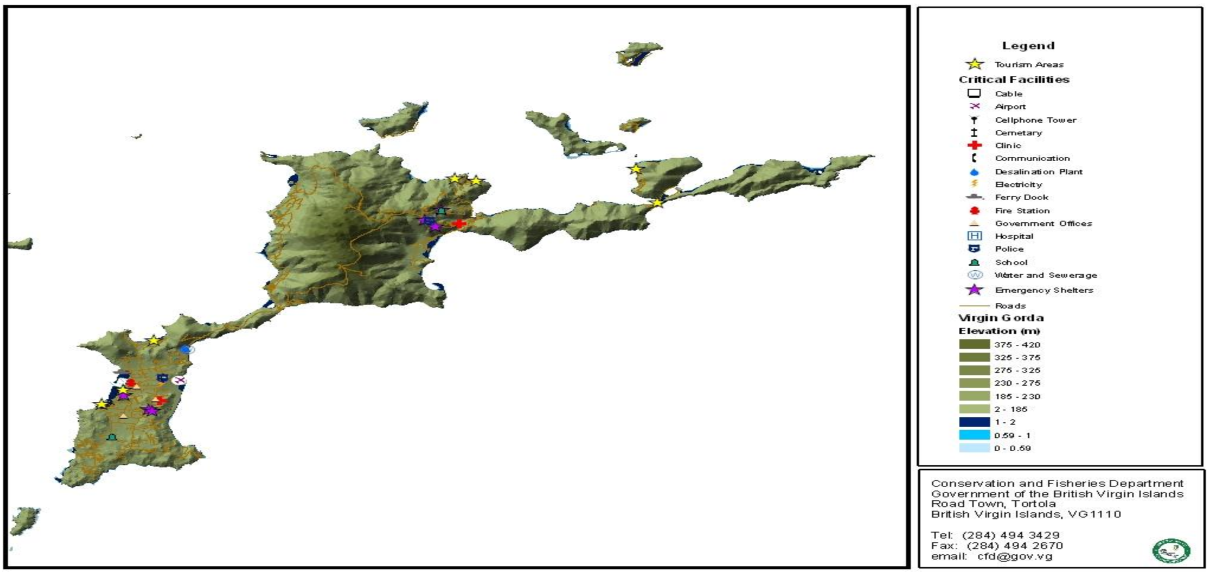


Figure 16: Impact of Sea Level Rise in Anegada

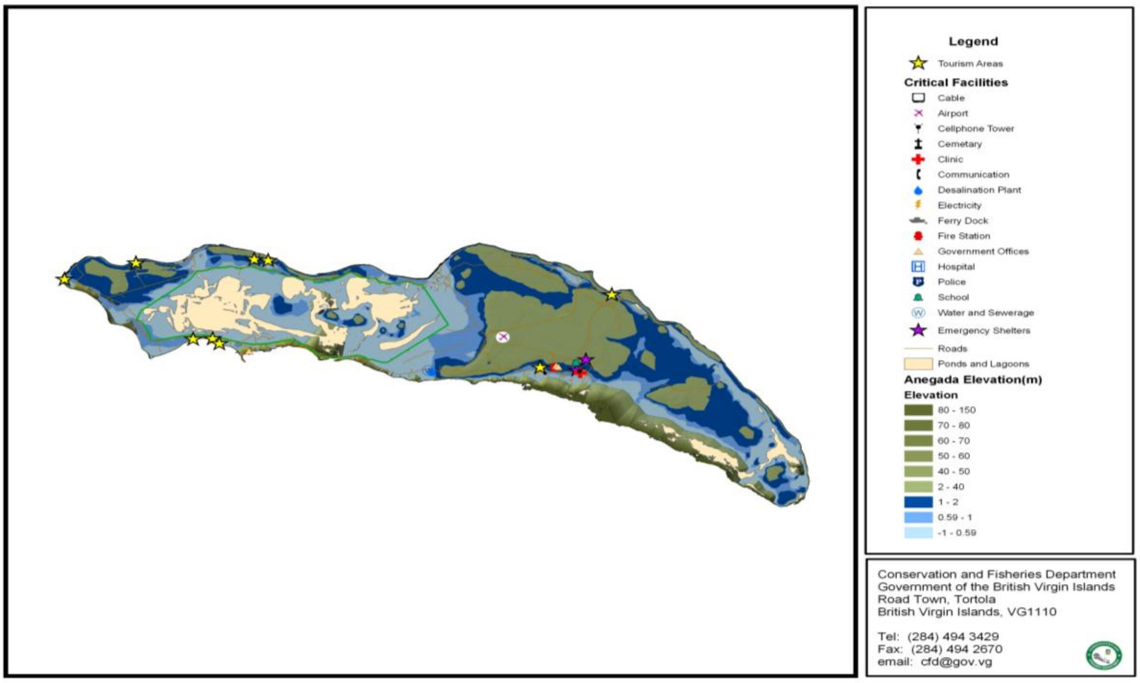
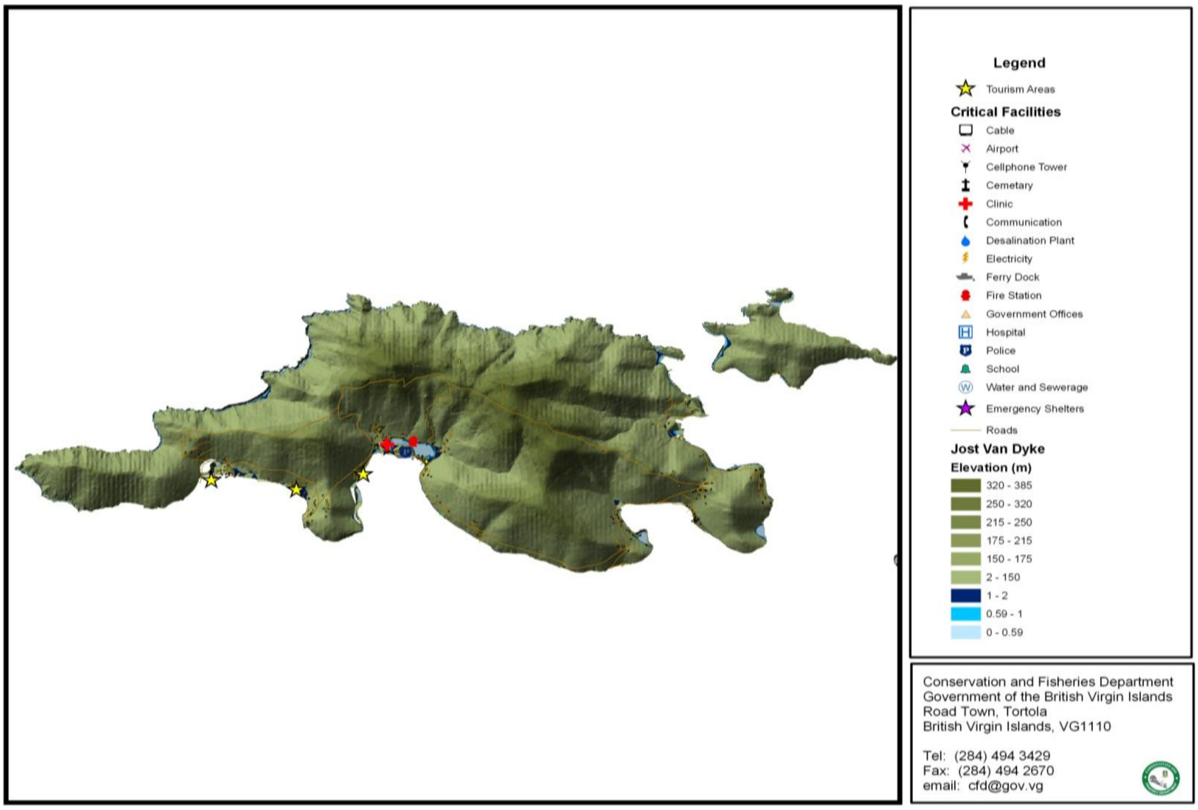


Figure 17: Impact of Sea Level Rise in Jost Van Dyke



A list of some of the critical infrastructure and tourism properties on the four main islands vulnerable to the various sea level rise scenarios is presented in Table 8. The coastal road network is also highly vulnerable to SLR as large segments are low-lying and directly adjacent to or very near the sea (Burnett Penn and George, 2011).

Table 8: Infrastructure Vulnerable to Sea Level Rise in the British Virgin Islands

Island	Tourism Infrastructure	Critical Infrastructure
TORTOLA	Sugar Mill Hotel	Cane Garden Bay Health Clinic
	Coconut Point Vacation Villas	Capoon's Bay Health Clinic
	Shans Bungalow	Road Town Fire and Rescue Station
	Jip's Place	Capoons Bay Fire and Rescue Station
	Rhymers Beach Hotel	Royal Virgin Islands Police Force Headquarters
	Elm's Beach Suites	Royal Virgin Islands Police Force Marine Base
	Myetts Enterprises	House of Assembly
	Indigo House	Government Central Administration Complex
	Bayside House	Government Offices
	Cane Garden Bay Cottages	Cane Garden Bay Cemetery
	Columbus Sunset Vacation	Cane Garden Bay Post Office
	Lambert Beach Resort	Isabella Morris Primary School
	Prospect Reef Hotel	Ivan Dawson Primary School
	Sebastian's on the Beach	Cane Garden Bay public restrooms
	Maria's by the Sea	Cane Garden Bay Sewerage Treatment Plant
	Nanny Cay Hotel	Capoon's Bay Water Desalination Plant
	Frenchman's Cay Marina	Ocean Conversion Desalination Plant
	Sophers Hole Wharf	BVI Ports Authority
	Penn's Landing/Round Rock	West End Ferry Dock
	Harbour View Marina	Road Town Ferry Dock
	Hodge's Creek Marina	ZBVI Radio Station
	The Moorings	ZROD Radio Station
	Village Cay Marina	
	TMM Charters	
	Conch Charters	
	Nanny Cay Marina	
	Peter Island Ferry Dock	
VIRGIN GORDA	Virgin Gorda Yacht Harbour	
	Leverick Bay Marina	
	North Sound Jetty	
	Bitter End Yacht Club	
	Fischer's Cove	
	Little Dix Bay Hotel	
	Biras Creek Resort	
ANEGADA	Anegada Beach Club	Health Clinic
	Anegada Reef Hotel	Fire and Rescue Station
	Cow Wreck Beach Resort	Government Administration Building
	Anegada Seaside Villas	Water and Sewerage Department
	Anegada Seaside Villas	Water Desalination Plant
	Neptune's Treasure	Electricity Corporation
	Whistling Pine	Cable and Wireless substation
	Ocean Range Hotel	Cell Phone Tower
	Loblolly Beach Cottages	
JOST VAN DYKE	Great Harbour Jetty	Fire and Rescue Station
	Mahoney's Water Sports	
	Ivans Camp Ground	

Source: Burnett Penn and George (2011)

Note: Government offices include Conservation and Fisheries Department, Training Division, Government Information Services, Audit Department, Department of Information Technology, Department of Youth Affairs and Sports, Ministry of Finance Procurement Office, Immigration and Labour Department, Civil Registry, Social Security Building, Water and Sewerage Department, and Department of Disaster Management.

The value of land loss by 2100 for each main island is presented in Table 9. The island with the largest area of land loss is Anegada, in both absolute terms (4,673 acres under B2 and 6,250 acres under A2) and relative terms (48.5% under B2 and 64.9% under A2). Tortola is next with 269 acres inundated under the B2 scenario and 840 acres under the A2 scenario. Overall, 5010 acres are lost under B2 and 7,312 acres lost under A2. As percentages of the total land mass of these 4 islands, land loss will vary between 16-24%. In dollar terms, coastal land loss by 2100 is valued at $2,732.9 mn under B2 and $3,988.6 mn under A2.

Table 9: Coastal Area Inundated by Sea Level Rise by 2100

	Anegada	Jost Van Dyke	Tortola	Virgin Gorda	Total
Area Inundated with 1m Rise (acres)	4,673	19	269	50	5010
% of Island's Area	48.5	0.9	2.0	1.0	16.5
Value of Land Loss ($mn)	2,549.1	10.4	146.7	27.3	2,732.9
Area Inundated with 2m Rise (acres)	6,250	49	840	173	7.312
% of Island's Area	64.9	2.2	6.3	3.3	24.1
Value of Land Loss ($mn)	3,409.3	26.7	458.2	94.4	3,988.6

The value of these losses in present value terms is presented in Table 10. In present value terms, if A2 occurs, losses range from $108.1-$1,596.8 mn, and if B2 occurs, losses range from $74.1-$1,094.1 mn, depending on the discount rate. These estimates imply that the cost to coastal lands due to sea level rise may have a lower bound as high as 7.5% of 2008 GDP and may reach as high as 161% of 2008 GDP.

Table 10: Losses to Coastal Lands due to Sea Level Rise

	A2	**B2**
Nominal Losses by 2100 ($mn)	3,988.6	2,732.9
Present Value ($mn) (d = 1%)	1,596.8	1,094.1
Share of 2008 GDP (%)	161.0	110.3
Present Value ($mn) (d = 2%)	645.1	442.0
Share of 2008 GDP (%)	65.0	44.6
Present Value ($mn) (d = 4%)	108.1	74.1
Share of 2008 GDP (%)	10.9	7.5

3. Value of Losses to Coastal Waters

Estimated costs of a rise in SST in 2050 and in present value terms under each discount rate assumption are shown in Table 11. By 2050, losses vary between $1,178 mn and $1,885 mn. Assuming a discount rate of 4%, losses range from $ 226.86 mn for the B2 scenario to about $362.97 mn for the A2 scenario. If a discount rate of 1% is assumed, estimated losses are much greater, ranging from $775-$1,241 mn. As a percent of 2008 GDP, the costs range from 23-125%, depending on the world which is modelled and the discount rate assumed.

Table 11: Losses to Coastal Waters due to Sea Surface Temperature Rise

	A2	**B2**
Nominal Losses by 2050 ($mn)	1,884.8	1,178.0
Present Value ($mn) (d = 1%)	1,241.0	775.6
Share of 2008 GDP (%)	125.1	78.2
Present Value ($mn) (d = 2%)	820.5	512.8
Share of 2008 GDP (%)	82.7	51.7
Present Value ($mn) (d = 4%)	363.0	226.9
Share of 2008 GDP (%)	36.6	22.9

4. Value of Total Losses to Coastal Zone

The value of total losses to the coastal and marine sector are summarised in Table 12. The overall costs of climate change are very large, ranging from 68-286% of 2008 GDP under A2; and 30-189% of GDP under B2.

Table 12: Total Cost of Climate Change on Coastal and Marine Sector

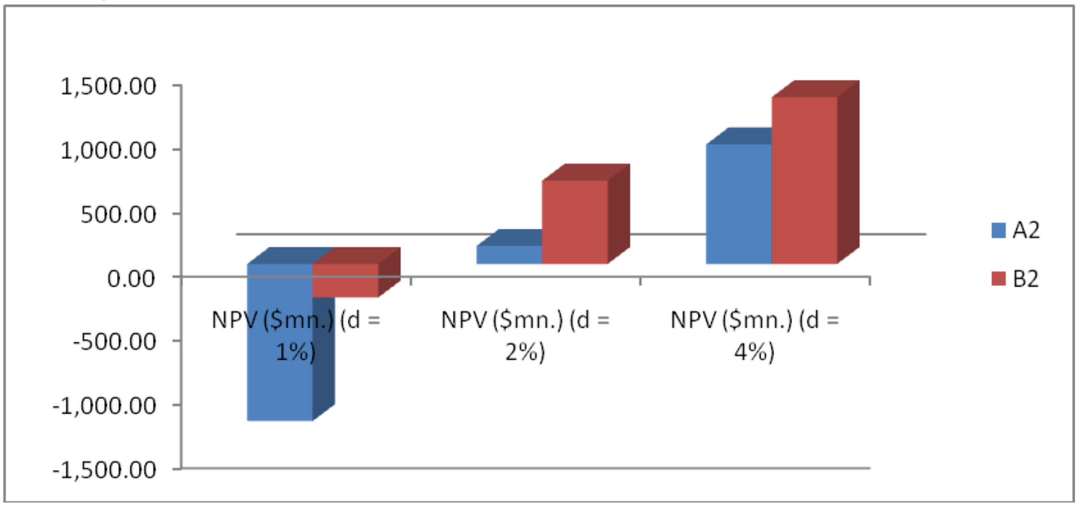
	A2	B2
Present Value ($mn) (d = 1%)	2,837.8	1,869.7
Share of 2008 GDP (%)	286.1	188.5
Present Value ($mn) (d = 2%)	1,465.6	954.8
Share of 2008 GDP (%)	147.8	96.3
Present Value ($mn) (d = 4%)	671.1	301.0
Share of 2008 GDP (%)	67.7	30.3

The net present value of the coastal and marine sector taking into account the costs of climate change is presented in Table 13. When a discount rate of 1% is assumed, the cost of climate change exceeds the sector's current value. For the other assumed rates of discount the NPV of the sector is still positive (see Figure 18).

Table 13: Net Present Value (NPV) of Coastal and Marine Sector

	A2	Decline in Value (%)	B2	Decline in Value (%)
Present Value ($mn) (d = 1%)	-1,230.9		-262.8	
Present Value ($mn) (d = 2%)	141.3		652.1	
Present Value ($mn) (d = 4%)	935.8		1,305.9	

Figure 18: Net Present Value (NPV) of Coastal and Marine Sector



B. Increase in the Cost of Extreme Events due to Climate Change

The estimate of the accumulated costs to 2050, based on a 5% intensification of wind intensity in tropical hurricanes and storms (the B2 scenario), is $167.33 mn, compared to $140.71 mn in the baseline period, an increase of $26.62 mn (see Table 14). In discounted terms this is equivalent to $17.53 mn at a discount rate of 1% and $5.13 mn at a discount rate of 4%.

With a 10% increase in the intensity compared to the trajectory observed in the baseline, the increase in costs double in relation to the B2 scenario described above. Specifically, accumulated costs under the A2 scenario are $197.39 mn, $56.68 mn higher than estimated accumulated baseline costs. Under this scenario, the BVI will suffer losses equivalent to $37.32 mn at a discount rate of 1%, or $10.91 mn at 4%. As percentages of 2008 GDP, these costs are insignificant. However, it must be reiterated that the damage costs upon which the entire analysis is based relate only to the direct physical impacts or to losses in fixed capital and inventories and not indirect and secondary effects on economic activity.

Table 14: Incremental Cost of Extreme Events from Climate Change

	A2	B2
Increase in Nominal Losses by 2050 ($mn)	56.68	26.62
Present Value ($mn) (d = 1%)	37.32	17.53
Share of 2008 GDP (%)	0.000004	0.000002
Present Value ($mn) (d = 2%)	24.67	11.59
Share of 2008 GDP (%)	0.000003	0.000001
Present Value ($mn) (d = 4%)	10.91	5.13
Share of 2008 GDP (%)	0.000001	0.0000005

C. BAU TRAJECTORY

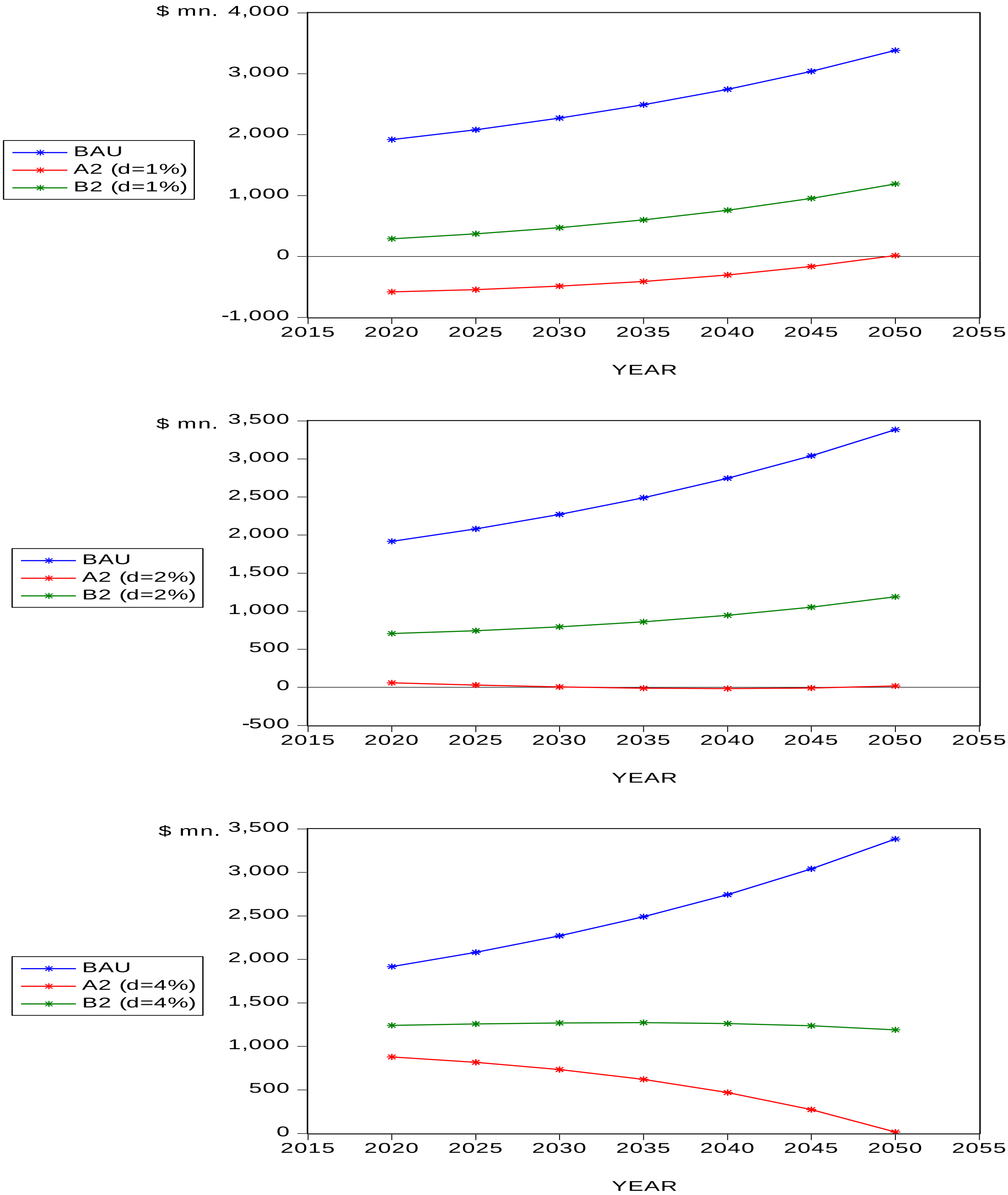
Finally, the trajectory of the value of the coastal and marine sector under the BAU trajectory, the "no climate change pathway", is compared with its trajectory under the A2 and B2 scenarios. Table 15 presents the value in millions of dollars for 5-year intervals from 2020-2050; Figure 19 graphs the various trajectories.

Table 15: Trajectory of the Value of Coastal and Marine Sector under BAU, A2 and B2

	2020	2025	2030	2035	2040	2045	2050
BAU ($mn)	1,917.3	2,081.4	2,271.1	2,490.7	2,745.1	3,040.4	3,383.4
A2 ($mn) (d=1%)	-580.7	-544.0	-488.2	-409.4	-302.8	-163.0	16.5
B2 ($mn) (d=1%)	289.9	371.0	473.5	601.4	759.5	953.4	1,190.0
A2 ($mn) (d=2%)	58.5	29.2	5.3	-11.0	-16.9	-9.1	16.5
B2 ($mn) (d=2%)	706.4	744.4	795.0	860.9	945.8	1,053.8	1,190.0
A2 ($mn) (d=4%)	879.2	818.4	734.5	621.2	470.6	273.1	16.5
B2 ($mn) (d=4%)	1,241.0	1,258.6	1,270.0	1,272.7	1,263.3	1,237.6	1,190.0

Under BAU the sector is predicted to have a value of $3,383.4 mn in 2050. The value of the sector under the A2 and B2 climate change scenarios reflect the difference between the values under BAU and discounted (under various rates) accumulated costs in 2050. The trajectory of the coastal and marine sector is significantly smaller under the A2 and B2 scenarios for discount rates of 1% and 2%. In contrast, the sector has a large, positive, though declining trajectory, for all years when a 4% discount rate is employed. In Figure 19, it is readily apparent the extent to which climate change under either scenario drastically reduces the value of the coastal and marine sector.

Figure 19: Trajectories of the Coastal and Marine Sector under BAU "no climate change" and Climate Change



VII. ADAPTATION AND BENEFIT-COST ANALYSIS

Climate change adaptation refers to any action to minimise or adjust to the local impacts of climate change (UNFCCC, 2009a). It is distinct from climate change mitigation which refers to efforts to tackle the cause of climate change, that is, efforts to reduce the amount of greenhouse gases (UNFCCC, 2009b). Since the BVI emits minimal greenhouse gases (much less than 1% of global emissions), but will be greatly affected by climate change, our focus is on adaptation.

A. CURRENT STRATEGIES FOR ADAPTATION

The BVI has begun to consider possible options for adaptation. Thus far a *Climate Change Green Paper*, by the Conservation and Fisheries Department, has been completed. The Green Paper identifies and discusses the potential impacts of climate change in the BVI, its vulnerabilities, adaptation options, and capacity to respond. It identifies and discusses potential and existing climate change impacts across key impact areas. The document is to be further refined and developed into a policy document called the *Virgin Islands Climate Change Adaptation Policy and Strategy*.

With regard to coastal and marine resources, the Green Paper notes that the BVI will adopt immediate, near-term, mid-term and long-term measures to protect coastal lands (e.g., coastal defence structures, enforcement of setbacks and restoration of coastal wetlands) as well as promote alternative fishery and resource use activities. The Green Paper also focuses on several other important sectors that could be impacted by climate change including energy security, food security, forestry and biodiversity, human health and tourism, among others. In terms of adaptation options, the Green Paper is detailed. Alternatives for each impact are discussed, and opportunities and constraints that arise from the options assessed.

Apart from the Green Paper, another report, *The Virgin Islands Vulnerability and Capacity Assessment of Tourism Sector to Climate Change*, also by the Conservation and Fisheries Department, has been drafted. The objectives of this report are to provide relevant stakeholders in the country with a clearer picture of the climate hazards predicted to face the tourism sector, how key elements of the tourism product will be impacted by climate change, how the tourism sector perceives and will respond to these hazards, the capacity of the sector to respond and specific options available for responding. The main deficiency in both this and the Green Paper is that the benefit-cost ratios of the options were not calculated.

B. POTENTIAL ADAPTATION STRATEGIES FOR COASTAL AND MARINE SECTOR

The particular adaptation strategies that a country adopts will depend on many factors, including the value asset under threat, the available financial and economic resources, political and cultural values, the local application of coastal management policies, and the ability to understand and implement adaptation options (Yohe, 2000). Our approach, therefore, is to summarise and evaluate the adaptation options and compute the benefit-cost ratios of the ones shortlisted for assessment.

Tables 16 and 17 provide various adaptation options for the BVI. The options presented in Table 16 were suggested and evaluated—at a two-day workshop hosted by the Conservation and Fisheries Department, the BVI, in collaboration with UNECLAC—by local experts from the BVI and the author of this Report. Options in Table 16 are directly related to conservation of the coastal and marine environment.

The options presented in Table 17 are from the perspective of the tourism industry in the BVI, which depends critically on the marine and coastal environment, and were evaluated by experts from the BVI Tourist Board and the Conservation and Fisheries Department, the BVI. These options suggest possible ways in which the tourism industry could adapt to the impacts of climate change on the coastal and marine environment on which it critically depends.

All options were evaluated based on 10 criteria adopted from USAID (2007); options in Table 16 are also evaluated based on an additional criterion—"Ability to Implement." Options in Table 16 were all acceptable to varying extents for implementation. The difference between them in their prioritsation and implementability. In contrast, not all options presented in Table 17 passed the evaluation to be considered for further analysis, for example, "funding discount programmes by hotels".

C. BENEFIT-COST ANALYSIS OF SELECT ADAPTATION STRATEGIES

Benefit-cost analysis is reasonably straightforward when it comes to analysing complicated problems like forward investment programmes. The NPV summarises in a couple of simple statistics a complicated set of data collecting problems regarding the present status of a sector/economy and the future implications of proposed investment.

In an ideal world of measurement it would be best if it were possible to obtain a clear time-path of capital and maintenance costs associated with a new innovation or practice. This would enable initial capital costs to be placed in their correct time sequence and subsequent maintenance costs placed in some future time sequence. The advantage of this arrangement is that the analyst can proceed to a discounted cash flow analysis. Likewise, a clear time-path of the saved costs or benefits from the time of the investment to some future date allows the analyst to proceed.

There are wider implications of implementing programmes and introducing regulations to society. On the cost side there are the administrative costs of the whole initiative. On the benefits side, there are the economy-wide implications on other sectors of the economy, and also the saved costs. These costs and benefits can then be combined with the private costs and benefits to reach a nation-wide assessment of the programme.

For the purposes of this report, a small subset of the options in Tables 16 and 17 are shortlisted and benefit-cost analysis undertaken:

1. enhancing monitoring of all coastal waters to provide early warning alerts of bleaching and other marine events;
2. introducing artificial reefs or fish-aggregating devices;
3. introducing alternative attractions;
4. providing retraining for displaced tourism workers; and
5. revising policies related to financing national tourism offices to accommodate the new climatic realities.

1. Recommendations

Table 18 provides a summary of the benefit-cost analyses conducted for the current study. A 20-year horizon was used to evaluate the options. An inflation rate of 3% is assumed and a discount rate of 2% employed. Of the 5 options considered, all 5 had benefit-cost ratios above 1 over a 20-year horizon.

Results in Table 18 show that all adaptation options considered are quite justifiable in national terms. Note though that this is only a very simple picture of the social net benefit. For an ideal benefit-cost analysis, what are needed are all benefits and costs involved in a time frame. This is not feasible at the time of writing this Report; however it opens the opportunities for future study once more data become available.

VIII. CONCLUSION

The main objectives of this Report were to estimate the value of the coastal and marine sector and to estimate the economic impact of climate change on the sector in the BVI. The overall value for the coastal and marine sector is USD $1,606 million (mn). This is almost 2% larger than BVI’s 2008 GDP. Tourism and recreation comprises almost two-thirds of the value of the sector.

By 2100, the effects of climate change on coastal lands are projected to be $3,988.6 mn, and $2,832.9 mn under the A2 and B2 scenarios respectively. In present value terms, if A2 occurs, losses range from $108.1-$1,596.8 mn and if B2 occurs, losses range from $74.1-$1,094.1 mn, depending on the discount rate used. Estimated costs of a rise in SST in 2050 indicate that they vary between $1,178.0 and $1,884.8 mn. Assuming a discount rate of 4%, losses range from $226.6 mn for the B2 scenario to $363.0 mn for the A2 scenario. If a discount rate of 1% is assumed, estimated losses are much greater, ranging from $775.6-$1,241.0 mn.

Factoring in projected climate change impacts, the net value of the coastal and marine sector suggests that the costs of climate change significantly reduce the value of the sector, particularly under the A2 and B2 climate change scenarios for discount rates of 1% and 2%. In contrast, the sector has a large, positive, though declining trajectory, for all years when a 4% discount rate is employed.

Since the BVI emits minimal greenhouse gases, but will be greatly affected by climate change, the Report focuses on adaptation as opposed to mitigation strategies. The options shortlisted are: (1) enhancing monitoring of all coastal waters to provide early warning alerts of bleaching and other marine events; (2) introducing artificial reefs or fish-aggregating devices; (3) introducing alternative tourist attractions; (4) providing retraining for displaced tourism workers; and (5) revising policies related to financing national tourism offices to accommodate the new climatic realities. All adaptation options considered are quite justifiable in national terms; each had benefit-cost ratios greater than 1.

Table 16: Potential Adaptation Options (Conservation)

Priority Rank	Option	*Cost*	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential negative Environ-mental or Social Impacts*	*Potential to Sustain over time*	*Ability to Implement (high, medium, low)*
1	Pass the draft Environmental Management and Conservation of Biodiversity Bill	√	√	√ *(more education needed)*	√	√	√	√	√	*X*	√	*high*
2	Develop and pass planning regulations to support Physical Planning Act	√	√	√ *(more education needed)*	√	√	√	√	√	*X*	√	*high*
3	Construction of tertiary sewage treatment systems and pump-out stations	√	√	√	√	√	√	√	√	*X*	√	*high*
4	Reduce sedimentation and improve drainage – early road paving and landscaping, development mitigation measures	√	√	√ *(more education needed)*	√	√	√	√	√	*X*	√	*high*
5	Maintain special marine zones / Enhance management of marine protected areas (MPAs) / fisheries protected areas (FPAs)	√	√	√	√	√	√	√	√	*X*	√	*high*
6	Control discharges from known point sources such as vessel operations and offshore sewage	√	√	√	√	√	√	√	√	*X*	√	*medium*

Priority Rank	Option	*Cost*	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential negative Environ-mental or Social Impacts*	*Potential to Sustain over time*	*Ability to Implement (high, medium, low)*
7	Develop innovative partnerships with, and provide technical guidance to landowners and users to reduce land based sources of pollution	√	√	√	√	√	√	√	√	*X*	√	*medium*
8	Re-nourish beach	√ *(depending on method used – i.e. must be comprehensive so beach is stabilised)*	√ *(depending on method used – i.e. must be comprehensive so beach is stabilised)*	√	√	√	√	√	√	*X*	√ *(in some locations/ situations)*	*high*
	Limit sand mining for building materials	√	√	√	√	√	√	√	√	*X*	√	
9	Develop and implement beach management plans	√	√	√	√	√	√	√	√	*X*	√	*high*
10	Implement pro-active plans to respond to non-native invasive species	√	√	√	√	√	√	√	√	*X*	√	*medium*

Priority Rank	Option	*Cost*	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential negative Environ-mental or Social Impacts*	*Potential to Sustain over time*	*Ability to Implement (high, medium, low)*
11	Introduce fish-aggregating devices	√	√	√	√	√ *(must be limited and carefully planned)*	√	√	√	*X*	√	*high*
12	Enhance monitoring of all coastal waters to collect a variety of data, including water temperature and salinity	√	√	√	√	√	√	√	√	*X*	√	*high*
13	Replant mangrove swamps	√	√	√	√	√	√ *(depending on location of planting and species)*	√	√	*X*	√	*high*
14	Increase capacity and maintenance of the mooring buoy system	√	√	√	√	√	√	√	√	*X*	√	*medium*
15	Increase beach monitoring activities	√	√	√	√	√	√	√	√	*X*	√	*high*

Priority Rank	Option	*Cost*	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential negative Environ-mental or Social Impacts*	*Potential to Sustain over time*	*Ability to Implement (high, medium, low)*
16	Introduce legislation/implement artificial reefs	√	√	√	*X*	√ *(protection of natural reefs preferred; must be limited and carefully planned)*	√	√	√	*X*	√	*high*

Table 17: Potential Adaptation Options (Tourism Industry)

	Cost	***Effectiveness***	***Acceptability to Local Stakeholders***	***Acceptability to Financing Agencies***	***Endorsement by Experts***	***Time Frame***	***Institutional Capacity***	***Size of Beneficiaries Group***	***Potential negative Environ-mental or Social Impacts***	***Potential to Sustain over time***
Increase advertising in key source markets	√	√ *(if effort is consistent)*	√	*X*	√ *(already happening)*	√	√	√	*?* *(if exceeds carrying capacity)*	√ *(if right groups are targeted and product is maintained)*
Fund discount programmes run by airlines	√ *(if tailored specifically to BVI needs)*	√ *(if tailored specifically to BVI needs)*	√	√	√ *(as a short term measure and if tailored specifically to BVI needs*	√	√	√	*?*	*X*
Fund discount programmes run by hotels	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*
Introduce "green certification" programmes for hotels	√	√	√	√	√	√	√	√	*X*	√
Conduct energy audits and training to enhance energy efficiency in the industry	√	√	√	√	√	√	√	√	*X*	√
Introduce built attractions to support/complement natural attractions	√	√	√	√ *(if there is a historical/ environmental focus)*	√	√	√	√	*(depends on specific attraction choice and implementation)*	√

	Cost	***Effectiveness***	***Acceptability to Local Stakeholders***	***Acceptability to Financing Agencies***	***Endorsement by Experts***	***Time Frame***	***Institutional Capacity***	***Size of Beneficiaries Group***	***Potential negative Environ-mental or Social Impacts***	***Potential to Sustain over time***
Introduce alternative attractions, e.g., museums , cultural villages and restoration of historical sites	√	√	√	√	√	√	√	√	√	√
Provide re-training for displaced tourism workers	√	√	√	√	√	√	√	√	*X*	√
Revise policies related to financing national tourism offices to accommodate the new climatic realities	√	√	√	*X*	√	√	√	√	*X*	√
Develop, approve and implement a National Tourism Policy and a Tourism Development Master Plan	√	√	√	*X*	√	√	√	√	*X*	√
Develop and implement a Carbon Levy (Carbon offset) for tourists, including the setting up of a Trust Fund to manage revenues from the Levy	√	√	√	√	√	√	√	√	*X*	√
Ensure that tourism infrastructure and properties are built in safe locations and in a climate resilient fashion and have disaster management plans and adequate insurance in place	√	√	√	*X*	√	√	√	√	*X*	√

Table 18: Benefit-Cost of Select Options

	Details	Benefit-Cost Ratio	Payback Period (years)
Option 1	Enhance monitoring of coastal waters to provide early warning alerts of bleaching and other environmental events	30.0	1
Option 2	Introduce artificial reefs or fish-aggregating devices	162.4	1
Option 3	Introduce alternative attractions	1.8	7
Option 4	Provide re-training for displaced tourism workers	3.4	1
Option 5	Revise policies related to financing national tourism offices to accommodate the new climatic realities	1.2	4

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APPENDIX A: CORAL DISEASES IN THE BRITISH VIRGIN ISLANDS

Table A1: Coral Disease in the British Virgin Islands

Reef name:	Disease:	Species:	Qualitative Disease Incidence:
No reef name specified	Black Band Disease		No record of mortality
No reef name specified	Aspergillosis		Extensive mortality, equal or greater than 50% of all colonies
No reef name specified	Aspergillosis		Extensive mortality, equal or greater than 50% of all colonies
No reef name specified	Aspergillosis		Extensive mortality, equal or greater than 50% of all colonies
No reef name specified	Aspergillosis		Extensive mortality, equal or greater than 50% of all colonies
Great Dog	Other disease		Partial mortality, less than 50% of all colonies
BVI, Virgin Gorda: Eustacia Reef	Disease unspecified		
BVI, Virgin Gorda: Eustacia Reef	Disease unspecified		
BVI, Virgin Gorda: Eustacia Reef	Disease unspecified		
Diamond Reef	Other disease		Partial mortality, less than 50% of all colonies
Diamond Reef	Other disease		Partial mortality, less than 50% of all colonies
Guana	White plague		
Guana	White band disease		
BVI, Anegada: Herman's Reef	White band disease	Acropora cervicornis	
Guana	White band disease	Acropora cervicornis	Partial mortality, less than 50% of all colonies
South George Dog	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
West Dog	White band disease	Acropora palmata	No record of mortality
Cane Garden Bay, fringing reef	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
East Seal Dog	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
No reef name specified	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
No reef name specified	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
West Green Cay	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
No reef name specified	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Eustatia Reef	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Colquhon Reef	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Necker Island	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Cane Garden Bay, upper fore reef	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
West Seal Dog	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Cane Garden Bay, reef pavement	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Pelican	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Indians	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Great Dog North	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
South Cockroach Island	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
Great Dog South	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
North Cockroach Island	White band disease	Acropora palmata	Partial mortality, less than 50% of all colonies
No reef name specified	White band disease	Acropora palmata	Extensive mortality, equal or greater than 50% of all colonies
No reef name specified	White band disease	Acropora spp.	No record of mortality
Guana	White plague	Agaricia agaricites	Partial mortality, less than 50% of all colonies
BVI, Guana Island: Iguana Head	White plague	Colpophyllia natans	
BVI, Guana Island: Iguana Head	Disease unspecified	Colpophyllia natans	
BVI, Guana Island: Iguana Head	Disease unspecified	Colpophyllia natans	
Guana	White plague	Colpophyllia natans	Partial mortality, less than 50% of all colonies
No reef name specified	Tumours	Dichocoenia stokesii	No record of mortality
Guana	White plague	Diploria clivosa	Partial mortality, less than 50% of all colonies
Guana	Black Band Disease	Diploria clivosa	Partial mortality, less than 50% of all colonies
BVI, Anegada: Horseshoe Reef	Yellow Band Disease	Diploria strigosa	
BVI, Anegada: West Cow Wreck	Dark spots disease	Diploria strigosa	
Guana	Black Band Disease	Diploria strigosa	Partial mortality, less than 50% of all colonies
Guana	White plague	Diploria strigosa	Partial mortality, less than 50% of all colonies
Guana	White plague	Favia fragum	Partial mortality, less than 50% of all colonies
No reef name specified	Aspergillosis	Gorgonia flabellum	No record of mortality
Guana	Aspergillosis	Gorgonia flabellum	Partial mortality, less than 50% of all colonies
No reef name specified	Aspergillosis	Gorgonia ventalina	No record of mortality
Guana	Black Band Disease	Madrepora annularis	Partial mortality, less than 50% of all colonies
Guana	White plague	Madrepora annularis	Partial mortality, less than 50% of all colonies
Guana	Yellow Band Disease	Madrepora annularis	Partial mortality, less than 50% of all colonies
BVI, Guana Island: Iguana Head	Yellow Band Disease	Montastraea annularis	
BVI, Anegada: Jack Bay	Disease unspecified	Montastraea annularis	
BVI, Virgin Gorda: Eustacia Reef	Disease unspecified	Montastraea annularis	
BVI, Virgin Gorda: Eustacia Reef	Disease unspecified	Montastraea annularis	

BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea cavernosa	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea cavernosa	
BVI, Anegada: Jack Bay	Disease unspecified	Montastraea cavernosa	
BVI, Anegada: West Cow Wreck	Disease unspecified	Montastraea cavernosa	
BVI, Guana Island: Iguana Head	White plague	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Black Band Disease	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Black Band Disease	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea faveolata	
BVI, Guana Island: Iguana Head	White plague	Montastraea faveolata	
BVI, Guana Island: Iguana Head	White plague	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea faveolata	
BVI, Guana Island: Iguana Head	Yellow Band Disease	Montastraea franksi	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea franksi	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea franksi	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea franksi	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea franksi	
BVI, Guana Island: Iguana Head	Disease unspecified	Montastraea franksi	
BVI, Guana Island: Iguana Head	White plague	Montastraea franksi	
No reef name specified	Black Band Disease	Montastraea spp.	No record of mortality
Guana	Aspergillosis	Plexaura homomalla	Partial mortality, less than 50% of all colonies
BVI, Anegada: West Cow Wreck	Disease unspecified	Porites astreoides	
Guana	Aspergillosis	Pseudopterogorgia americana	Partial mortality, less than 50% of all colonies
Guana	Black Band Disease	Pseudopterogorgia americana	Partial mortality, less than 50% of all colonies
BVI, Guana Island: Iguana Head	Black Band Disease	Siderastrea siderea	
BVI, Guana Island: Iguana Head	Disease unspecified	Siderastrea siderea	
BVI, Guana Island: Iguana Head	Disease unspecified	Siderastrea siderea	
BVI, Guana Island: Iguana Head	Black Band Disease	Siderastrea siderea	
BVI, Guana Island: Iguana Head	Disease unspecified	Siderastrea siderea	
BVI, Anegada: Horseshoe Reef	Dark spots disease	Siderastrea siderea	
Guana	White plague	Siderastrea siderea	
Guana	Black Band Disease	Siderastrea siderea	
Guana	Dark spots disease	Siderastrea siderea	

Source: United Nations Environmental Programme (UNEP) World Conservation Monitoring Centre (WCMC)

APPENDIX B: TECHNICAL NOTES AND DATA SOURCES FOR VALUATION OF COASTAL AND MARINE SECTOR

A. Coral Reef- and Mangrove-Associated Tourism

The value of reef-related tourism in the BVI is assessed using the WRI (2009) method. This approach involves calculating gross revenues and taxes from tourism associated with reef recreation, coralline beach use, and spending on accommodation, food, and other things.

<u>Data and Assumptions</u>

Recreation and Tourism Profile

- Annual number of stay over visitors
  - 346,034
- Average length of stay
  - 10
- Percent of visitors using the beach, dive, snorkel or go on a boat trip
  - 96%

Accommodation Default Values

Costs, Taxes and Service Charges

- Average hourly hotel wage
  - $4
- Hours worked per week
  - 40
- Persons employed per room
  - 1.7
- Non-Labour costs (as a percentage of base revenue)
  - 25%
- Tax rate (%)
  - 7%
- Service charge rate (%)
  - 10%

Leakages

- Percent of rooms that are foreign-owned
  - 20%

Average Revenues

- Average room rate (excluding taxes and service charges)
  - $562
- Average occupancy rate
  - 71%
- Average number of rooms
  - 12
- Number of accommodations
  - 287

Moorings Programme Gross Revenues

- National Parks Trust
  - $742,042
- Central Government
  - $137,094

Dive Revenue Inputs

- Percent of visitors diving
  - 40%
- Average number of dives per diver
  - 10
- Percent of dive certifications issued
  - 1% of divers
- Average dive price
  - $160
- Average price for dive certification
  - $320
- Average price per dive of equipment rental
  - $42
- Proportion of all dives with equipment rentals
  - 50%

Dive Costs

- Labour costs in dive operations (as a proportion of revenue)
  - 40%
- Other costs (as a proportion of revenue)
  - 35%

Snorkel and Boating Revenue Inputs

- Percent of visitors snorkelling
  - 20%
- Average number of trips per snorkeler
  - 10
- Average trip price
  - $56
- Average price of equipment rental
  - $14
- Proportion of all snorkelers that require equipment
  - 50%
- Proportion of trips charging for equipment rental
  - 100%

Dive Costs

- Labour costs in snorkel and boating operations (as a proportion of revenue)
  - 40%
- Other costs (as a proportion of revenue)
  - 35%

Local Use

Coralline Beach Benefits

- Percentage of local population visiting coralline beaches for pleasure
  - 50%
- Average number of visits per year (per person)
  - 12
- Average duration of visit
  - 2 hours

Reef Recreation Benefits

- Percentage of local population visiting engaging in reef recreation (outside organised tours)
  - 50%
- Average number of visits per year (per person)
  - 12
- Average duration of visit
  - 2 hours

Other Values

Consumer Surplus

- Diving
  - 1.15%
- Snorkelling
  - 0.9%
- Tourism Multiplier
  - 1.6

Table B1: Value of Coral Reef- and Mangrove-Associated Tourism and Recreation

1. Accommodation	
Reef-associated Gross Revenue	$498,308,558
Reef-associated Net Revenue (Gross minus costs)	$325,569,401
Net revenue remaining in the country (net revenue - leakages)	$260,455,521
Transfers to the economy (taxes, via wages and service charges)	$132,874,472
Total Value	**$393,329,993**
2. Diving	
Gross Revenue	$251,192,936
Net Revenue (Gross minus costs)	$62,798,234
Transfers to the economy (taxes, via wages and service charges)	$100,477,174
Total Value	**$163,275,408**
3. Snorkelling and Boating	
Gross Revenue	$46,506,970
Net Revenue (Gross minus costs)	$11,626,742
Transfers to the economy (taxes, via wages and service charges)	$18,602,788
Total Value	**$30,229,530**
4. Moorings at Marine Park and Dive Sites	
Gross Revenue	$742,042
Net Revenue (Gross minus costs)	**$742,042**
5. Other Revenues	
Cruising Permits	$1,393,797
Moorings and Berthings (Central Government)	$134,094
Total Value	**$1,527,891**
TOTAL DIRECT ECONOMIC IMPACTS	**$589,104,865**
6. Total Indirect (secondary) Impacts (from multipliers)	**$415,063,165**
TOTAL DIRECT AND INDIRECT IMPACTS	**$1,004,168,030**
7. Un-captured Value	
Local Use of Coralline Beaches	$1,354,224
Local Use from reef recreation	$1,354,224
Diving and Snorkelling Consumer Surplus	$3,307,281
Total Un-captured Value	**$6,015,729**
TOTAL ECONOMIC IMPACT OF REEF- AND MANGROVE- RELATED TOURISM AND RECREATION	**$1,010,183,759**

B. Coral Reef- and Mangrove-Associated Fisheries

The value of reef-related tourism in the BVI is assessed using the WRI (2009) method. Formal and informal revenues and values from commercial fishing, local subsistence fishing and fish processing for coral reef-associated fish are estimated net of the cost of undertaking these activities. The following data and assumptions were employed in the fisheries valuation.

Data and Assumptions

Fisheries Profile

Commercial Fishermen

- Number of full-time fishermen
  - Full-time fishermen are defined within the BVI as fishermen whose primary source of income is the product of fishing activity: 33
- Number of part-time fishermen
  - Part-time fishermen are defined within the BVI as fishermen whose primary source of income is not the product of fishing activity: 202

Boats

- Number of small boats (< 15 feet)
  - Unregistered
- Number of large boats (> 15 feet)
  - 72
  - All vessels are less than 25 metres (82 feet)

Facilities and Landing Sites

- Number of landing sites
  - 1 Government approved, though catch is landed and directly sold from most points of anchor
- Number of fish processing facilities
  - 1 (the BVI Fishing Complex)

Economy

- Annual GDP from fisheries sector (2008)
  - $5,397,000

Fish Prices

- Average price of reef fish per pound
  - $5.00
- Average price of shellfish per pound
  - $2.50

Fisheries Cost Values

Commercial Fishing Harvesting Costs

- Labour costs (as a percentage of revenue)
  - 25%
- Non-labour operating costs (as a percentage of revenue)
  - 10%

Fish Processing Costs

- Labour costs (as a percentage of revenue)
  - 25%
- Non-labour operating costs (as a percentage of revenue)
  - 10%

Reef Abundance

Reef Extent

- 40.23 square kilometres (live coral reef)
- Annual reef productivity
  - 3-5 metric tonnes per square kilometre
- Average price of fish caught
  - $8,267 per metric tonne

Commercial Fish Processing Data

For each species

- Purchase price per pound (typically reef fish)
  - $4.25
- Sale price per pound (typically reef fish)
  - $5.00

Value Added – Cleaning Data

For the landing site:

- Number of cleaners
  - 6
- Average number of days per year
  - 5
- Average number of hours per day
  - 8
- Average revenue per hour
  - $4 (minimum wage)

Local Fishing Data (Non-Commercial)

Percent of Population Fishing

- For consumption
  - 0.1%
- For enjoyment
  - Local persons fishing from land based locations do not require licensing and thus numbers obtained for this sector are estimated and highly variable depending on season and village
  - 0.1%

Fish Consumption

- Average catch per trip (pounds)
  - 15
- Average sale price per unit ($/pound)
  - $5-$12 (median value of $8.50 employed)
- Average annual days in activity (days)
  - 50

Local Fishing Enjoyment

- Average time spent fishing (hours per day)
  - 6
- Average annual days in activity (days)
  - 50
- Average hourly wage
  - $4

Multiplier Effect

Indirect/induced effects of fishing industry

- Multiplier
  - 1.4

Table B2 Value of Coral Reef- and Mangrove-Associated Fisheries

1. Commercial Fisheries	
Gross Revenue	$1,330,326
Net Revenue	$864,712
Transfers to the economy (Wages)	$332,581
Total Commercial Fishing Value	$1,197,293
2. Fish Processing and Cleaning	
Gross Revenue from Processing	$200,000
Net Revenue from Processing Sale	-$40,000
Transfers to the economy (Wages)	$20,000
Total Revenue from Cleaning Fish	$49,920
Total Fish Processing and Cleaning Value	$29,920
3. Local Fishing	
Value of Local Fish Consumption	$89,929
Value of Local Fish Enjoyment	$33,856
Total Local (non-commercial) Fishing Value	$123,785
4. Other Revenues	
Fishing Licences	$183,185
Total Direct Economic Impacts (including local use)	**$1,534,183**
5. Indirect (Secondary) Economic Impacts	$544,098
TOTAL ECONOMIC IMPACT OF REEF- AND MANGROVE- RELATED FISHERIES	**$2,078,281**

C. Coastal and Marine Biodiversity

The value of services provided by coastal and marine biodiversity is calculated as follows:

Table B3: Value of Biodiversity

Biome	Value/hectare	Cover/hectare	Total Value
coral reef (live and dead)	$4,136	5,377	$22,239,272
shelf to 30 metre depth	$2,240	206,000[a]	$461,440,000
mangroves	$12,881	61	$785,741
seagrass beds	$27,609	3991	$110,187,519
TOTAL VALUE OF COASTAL AND MARINE BIODIVERSITY			**$594,652,532**

Note: [a]Burke and Maidens (2004)

APPENDIX C: TECHNICAL NOTES FOR LOSS ESTIMATES

A. Losses to Coastal Waters

Table C1: Value of Losses to Coastal Waters

	2050 Value/ha	Current Cover (ha)	A2 (80% loss)	B2 (50% loss)
Seagrass beds	$103,656.84	3,991	$330,955,557.10	$206,847,223.19
Coral reefs	$33,136.85	4,023	$106,647,634.96	$66,654,771.85
Coastal shelf	$8,781.68	206,000	$1,447,220,532.28	$904,512,832.68
TOTAL VALUE OF LOSSES TO COASTAL WATERS IN 2050			**$1,884,823,724.34**	**$1,178,014,827.71**

B. Losses from Extreme Events

Table C2: Value of Losses from Extreme Events

Baseline Wind Speed/mph (1960-2000)	Costs ($mn)	A2 (10% increase) Wind Speed/mph (2009-2050)	A2 Costs ($mn)	Increase in Costs over Baseline ($mn)	B2 (5% increase) Wind Speed/mph (2009-2050)	B2 Costs ($mn)	Increase in Costs over Baseline ($mn)
138	23.84	151.80	33.44	9.60	144.90	28.345	4.51
40	0.29	44.00	0.41	0.12	42.00	0.35	0.06
86	4.45	94.60	6.24	1.79	90.30	5.29	0.84
40	0.29	44.00	0.41	0.12	42.00	0.35	0.06
58	1.10	63.80	1.54	0.44	60.90	1.31	0.21
49	0.60	53.90	0.85	0.24	51.45	0.72	0.11
75	2.73	82.50	3.84	1.10	78.75	3.25	0.52
138	23.84	151.80	33.44	9.60	144.90	28.35	4.51
58	1.10	63.80	1.54	0.44	60.90	1.31	0.21
132	20.36	145.20	28.56	8.20	138.60	24.21	3.85
109	10.31	119.90	14.47	4.15	114.45	12.27	1.95
86	4.45	94.60	6.24	1.79	90.30	5.29	0.84
58	1.10	63.80	1.54	0.44	60.90	1.31	0.21
104	8.73	114.40	12.25	3.52	109.20	10.38	1.65
75	2.73	82.50	3.84	1.10	78.75	3.25	0.52
150	32.05	165.00	44.97	12.91	157.50	38.12	6.06
75	2.73	82.50	3.84	1.10	78.75	3.25	0.52
	$140.71 mn		**$197.39 mn**	**$56.68 mn**		**$167.33 mn**	**$26.62 mn**