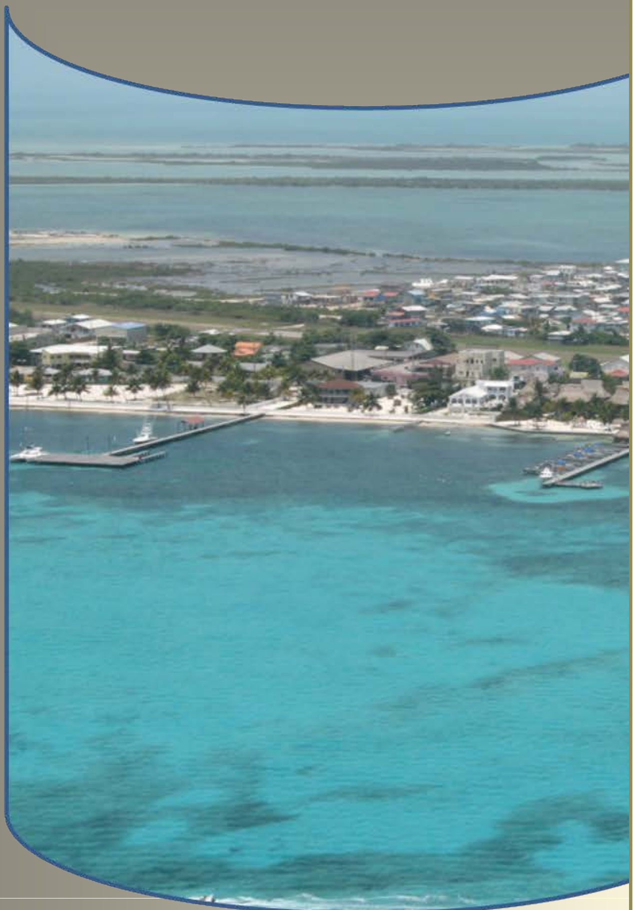

The physical infrastructure, destination sites and natural environment that support Belize's marine-based tourism industry are located within the coastal zone, which increases the vulnerability of this industry to climate impacts. This report discusses the results of a national analysis that looked at identifying coastal tourism areas that are most and least vulnerable to the impacts of climate change in Belize.

Analyzing Vulnerability of the Belize Coastal Tourism Sector

2014

caribsave WWF BELIZE COASTAL ZONE MANAGEMENT AUTHORITY & INSTITUTE Environmental Research Institute University of Belize belize BELIZE TOURISM INDUSTRY ASSOCIATION BTIA CELEBRATING 25 YEARS

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I. PROJECT OVERVIEW

Climate change is affecting coastal ecosystems globally, with severe implications for developing countries heavily reliant on their natural resources for economic growth. In Belize, coral reefs, mangroves and beaches are the cornerstone of the tourism industry and coastal communities rely on mangrove and reef-based fisheries for food security and income. Growth of the tourism industry is viewed as inherent to economic development in Belize but is often accompanied by habitat degradation that directly threatens the resources upon which the industry depends. The challenge faced by decision-makers is how best to move forward with tourism development whilst maintaining healthy, functional ecosystems that support the tourism industry, sustain livelihoods and provide resilience to climate change. The efforts discussed herein are part of a three prong project aimed at i) assessing the vulnerability of Belize's tourism system to climate change, including the coastal ecosystems on which it depends; ii) assessing how current policies facilitate or hinder climate-compatible tourism development based on healthy coastal ecosystems; and iii) exploring the policy reforms and adaptation strategies required to enhance ecosystem resilience to climate change and foster tourism development, at a local and national scale.
The overarching research question addressed by the project is 'how can we achieve sustainable growth of Belize's coastal tourism market while maintaining healthy resilient coastal-marine ecosystems?' and more specifically:

1.) Which tourism areas are most and least vulnerable to the impacts of climate change?

2.) What are the key policy instruments that are supporting or hindering Belize's ability to make progress in achieving climate-compatible coastal tourism development, and where are the gaps in existing policy?

3.) What are the key strategies necessary for enhancing Belize's potential for climate-compatible tourism development based on healthy coastal ecosystems?

The results discussed herein are based on efforts and findings related to question #1: ***Which tourism areas are most and least vulnerable to the impacts of climate change that should be prioritized for adaptation action?***

With limited resources to invest in adapting to current and future changes, decision makers are faced with tough decision about where to target investment. Identifying particularly vulnerable areas and the factors that contribute to vulnerability can inform such decisions. Multiple vulnerability assessments have been carried out in Belize for different geographic areas, sectors and ecosystems, e.g. tourism (Richardson, 2007), mangroves (Cherrington *et al.*, 2010), the coastal zone (CATIE/TNC, 2012), resulting in numerous datasets and maps. Information from these initiatives and other available datasets was reviewed, mapped where possible and aggregated to give a picture of the current status and vulnerability of Belize's coastal areas used for tourism or designated for future tourism development. The factors that contribute to vulnerability in these locations are also be highlighted.

II. METHODOLOGY

Four (4) methodological processes were used to achieve the outcomes of the vulnerability assessment.

1. Review and data acquisition

The first stage involved the building of a central repository of data on the coastal tourism system of Belize[1]. Existing datasets, maps and vulnerability assessments were collated and reviewed, and data relevant to assessing the vulnerability of the tourism sector to climate change were compiled. As a part of this process, requests were made to entities (i.e. data providers) for data in the simplest form to ensure that these were raw, rather than aggregated in order to improve resolution. Sourced maps were scanned, georeferenced and digitized in GIS ArcMap. Data presented in Excel files were converted into shapefiles as points, polylines, and polygons. Non-spatial data were digitized and verified using a combination of Google Earth, local surveys, and confirmation by local scientists though in-person consultations or social media. All analyses were carried out in ArcGIS. A 10 kilometer zone of influence was created landward of the shoreline to capture areas along Belize's coastal zone where mangroves exist and where coastal tourism operations could be having an influence.

2. Development of tourism system base map

A map of the tourism system was developed as the basis of the vulnerability assessment[2]. This map includes coastal habitats that provide the basis for recreational activities, accommodations and other tourism facilities and essential infrastructure. To identify areas of the Belize coastline that are more or less vulnerable to climate change impacts, we utilized the nine planning regions used by the Coastal Zone Management Authority and Institute for its integrated coastal zone management plan (ICZMP) in order to compare the relative vulnerability of each region[3].

[1] See Table 1 for a full listing
[2] Figure 1a
[3] Figure 1b

Figure 1a: Base map of the Belize Tourism System

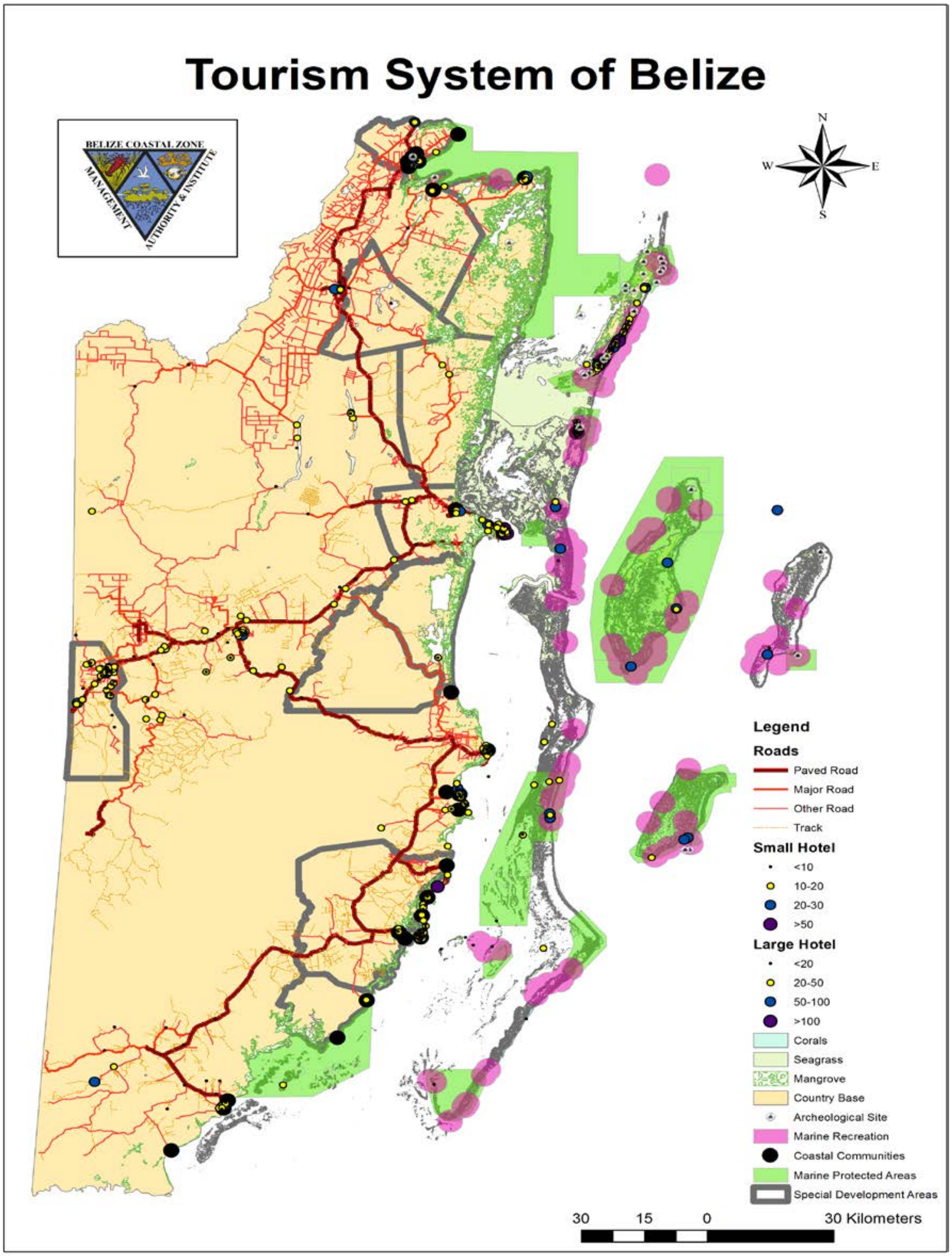
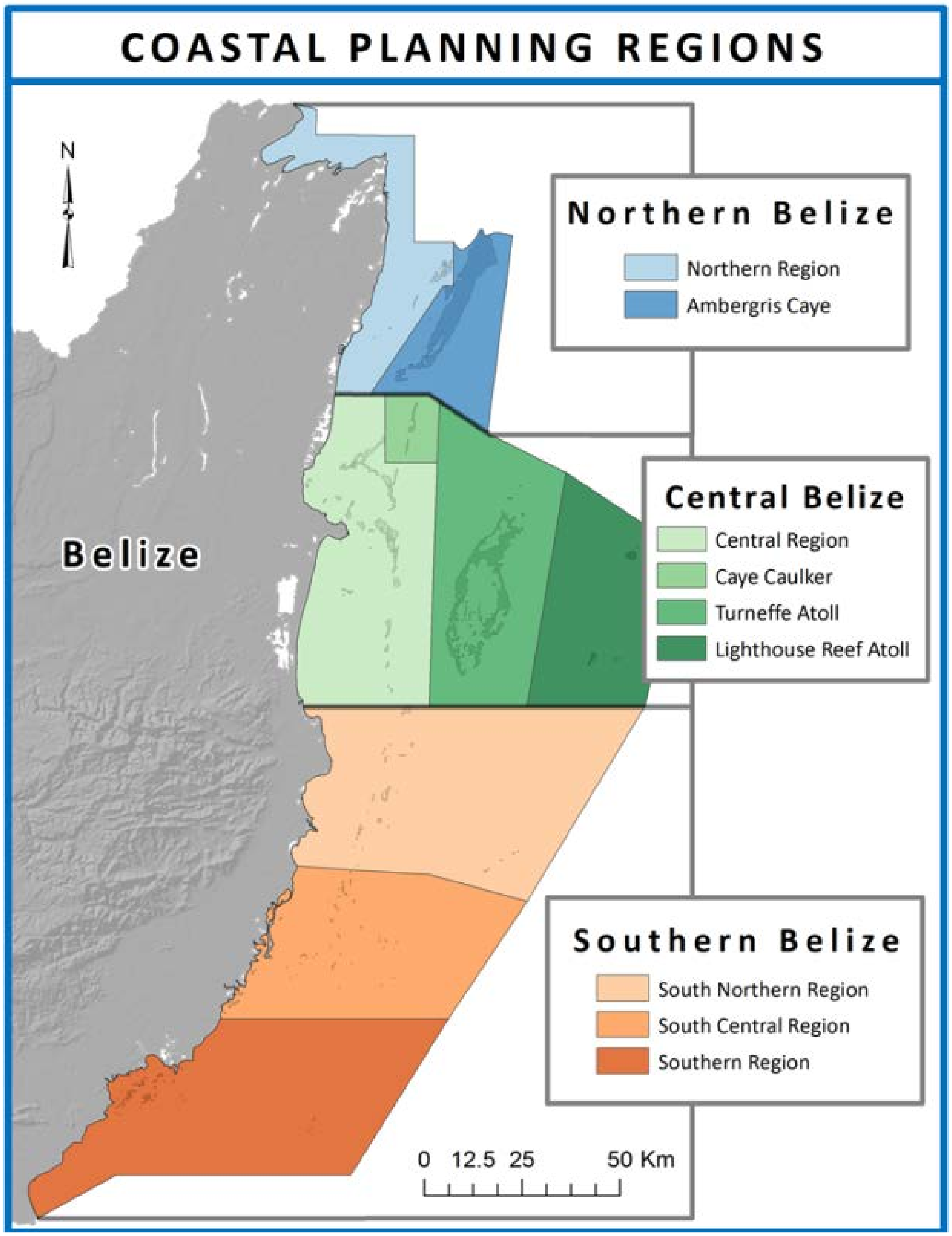


Figure 1b: Nine coastal zone planning regions[4]



[4] Source: ICZMP 2014

Category	Data Group	Description	Source (name, agency, URL, etc)	Resolution	Temporal Extent	Data Format
Physiographic (Land)	Land topography	Digital elevation model	NASA / US Geological Survey, The Natural Capital Project	30m	2011	raster
Oceanographic	Elevation relative to sea level rise (RSLR)	Low-lying coastal areas of mainland Belize	BTFS, CATHTALAC, INEGI, IGN-Guatemala, LIC, UK Ordinance Survey, USGC		2014	polygon
	Sea surface temperature	Time series or event average	Met Service, NOAA website and The Nature Conservancy		2006-2010, 2030-2039	raster
	Air temperature	Time series or event average	Met Service, NOAA website and The Nature Conservancy		2070 - 2099	raster
Biological	Marine habitat	Coral, seagrass, and mangrove	Jan Meerman (Biodiversity and Environmental Resource Data System of Belize - Belize Tropical Forest Studies), Peter Mumby, WRI, WWF, Cathalac, and CZMAI	multiple sources: 20m-1:100,000	2010	polygon
	Marine/coastal reserves	Location of marine reserves including spawning aggregation sites & special development areas	Land Information Centre & Land Utilization Authority & CZMAI	1:800,000	2011	polygon
Infrastructure	Roads	Major road network	Belize Land Information Centre	1:50,000	2010	polyline
	Airstrips	Location of airstrips	Belize Department of Civil Aviation & CZMAI	1:50,000	2011	point
Geopolitical	Country Base	Toledo, Stann Creek, etc	Land Information Centre and CZMAI	1:800,000	2010	polygon
	Coastal Planning Region	It includes 9 planning regions and a 10 km zone of influence to capture maximum areas along Belize's coastal zone where mangroves exist and where coastal tourism operations could be having an influence.	CZMAI	1:800,000	2005	polygon
	Coastal Settlements	Number of people in cities and villages	Statistical Institute of Belize & Election & Boundaries & CZMAI	1:800,000	2000	point
Human Use	Hotels	Locations of hotels and number of beds/rooms	World Wildlife Fund Belize, TNC and BTB	1:800,000	2005 data	point
	Marine tourism recreation	Recreational activities by tourists in Belize: number of tourist diving, jet skiing, kayaking, snorkeling, swimming and wind surfing-days per month at popular sites.	BTB and CZMAI	1:800,000	2011	points and polygon
	Marine transportation	Major shipping route, water taxi routes, and ports	Belize Port Authority and CZMAI	1:800,000	2011	points, polylines and polygon
	Coastal development	This layer highlights cleared land with and without structures	Jan Meerman (Biodiversity and Environmental Resource Data System of Belize - Belize Tropical Forest Studies), DOE & Economic development Department, The Natural Capital Project and CZMAI	1:800,000	2011	polygon
Vulnerability	Flood risk/flood events	Flood risk areas	King et al, channel 5, channel 7, love fm and Jan Meerman		2005-2013	raster
	Weather stations	Locations of station in Belize	Met Service			point
Climatology	Precipitation	Monthly and annual rainfall in mm for 3 stations in Belize	Met Service		10 year averages	excel format

3. Development of vulnerability indicators

The development of indicators to assess various dimensions of climate change is also a recent and emerging area of study. One of the most definitive discourses of such indicators comes from the Inter-governmental Panel on Climate Change Report (IPCC 2007), which examines the concept of exposure, sensitivity and adaptive capacity as the basis for the development of effective climate change indicators. Firstly, vulnerability is a function of exposure to direct (such as changes in temperature and rainfall average) and indirect (e.g. increased risk of natural hazards) impacts. Secondly, it is a function of sensitivity of the region to them. The sensitivity could be environmental (e.g. land use), human (e.g. social structure), and/or economic (e.g. income per capita). Finally, exposure is correlated with adaptive capacity and adaptation in the following manner; reductions in exposure vulnerability as arising from the realization of adaptive capacity can be viewed as adaptation (IPCC 2007).

Four indicators of exposure to climate change were selected for this analysis, representing the four most critical climate change impacts on tourism in coastal areas[5]: rise in sea surface temperature, sea-level rise, increase in hurricane intensity and increase in air temperature. For each indicator of exposure, we selected those elements of the tourism system that we have a good degree of certainty are likely to be impacted and developed sensitivity indicators for each element. Indicators were given a ranking range from very low to high and estimated for three time periods: current (2010), 2030-2039 and 2090-99. Table 2 details the indicators of vulnerability and their rankings.

The adaptive capacity of tourism operators was then assessed. For this assessment, the indicators were based on current conditions only; no future projections were made.

The following is a description of the methodology used to measure the potential impact of each climatic effect, the indicators used and sources of information.

Rise in Sea Surface Temperature

The main concern with an increase in sea surface temperature is the impact on coral reefs and therefore on reef-based activities. Corals begin to stress with an increase of just 1° C over the highest average temperature of the hottest summer month, the maximum monthly mean (MMM)[6], referred to as the "bleaching threshold". Stress caused by water over normal temperatures could begin the bleaching process eight weeks after the initiation of the variation.

[5] WTO-UNEP-WMO 2008
[6] Glynn and D'Croz 1990

Mass coral bleaching and death can occur if corals remain under those conditions for a prolonged period[7].

Thermal stress was evaluated using data from the CATIE/TNC vulnerability analysis[8], which examined current and projected sea surface temperatures (SST) in relation to baseline conditions in the same locations. Sea surface temperature data from NOAA Coast Watch[9] was used to generate a baseline SST for the period 2001 – 2005. Projected SSTs were generated using two emissions scenarios (B1 and A2) for the periods 2030 – 2039 and for 2090 – 2099. Exposure to thermal stress was ranked according to the NOAA Coral Reef Watch methodology for identifying areas at risk of coral bleaching[10].

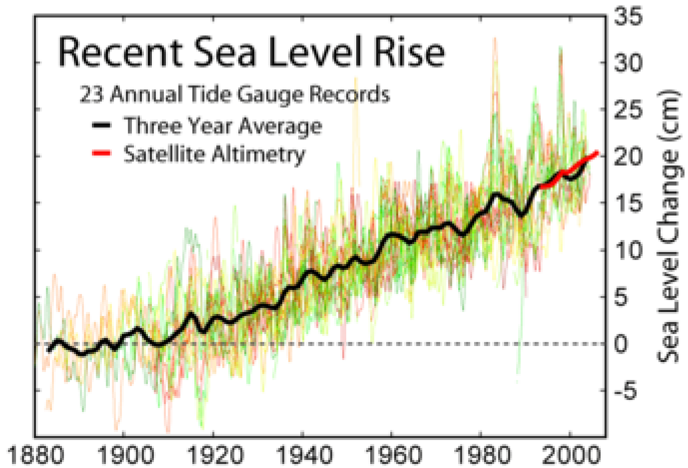
Sensitivity of each region to rising sea surface temperature was measured as the extent and health of coral reef in the region (Table 2).

Rising sea levels

Sea levels have risen at an average rate of 1.8 mm per year since 1961, and at a rate of 3.1 mm per year since 1993. The increase in the rate of sea level rise has been attributed to thermal expansion and the melting of glaciers and polar ice caps[11]. Global sea levels are projected to rise at a greater rate in the 21st century than during the period of 1961 to 2003. Projections of future sea level rise range from 0.18 to 0.59 meters (relative to the average for 1980-1999) by 2099. Changes in sea levels are of particular concern because of the concentration of human settlements in coastal zones and on islands[12]. Figure 2 illustrates the change in global sea level from 1880 – 2000. Future changes in sea level are not expected to be geographically uniform; data from analyses of tide gauges and thermal expansion tend to show greater trends in sea level rise for the North Atlantic Ocean than for the Indian, Pacific, or South Atlantic Oceans (Bindoff et al., 2007). The IPCC Fourth Assessment Report finds that sea levels “are likely to continue to rise on average” around the small islands of the Caribbean Sea[13].

[7] NOAA Coral Reef Watch 2011
[8] CATIE/TNC 2012
[9] http://coastwatch.noaa.gov/)
[10] See Table 2 for details
[11] IPCC, 2007
[12] Bindoff et al.,2007
[13] Christensen et al.,2007, p. 909

Figure 2: illustrates the change in global sea level from 1880 – 2000[14]



Sea level rise could have adverse effect on different sectors and infrastructure along the coast with the most vulnerable sectors being coastal communities and coastal tourism infrastructure[15]. Climate variability and change, coupled with human-induced changes, may also affect ecosystems; for example mangroves and coral reefs which could result in additional consequences for fisheries and tourism[16]. Although the actual extent of the areas to be affected by sea level rise is unknown, it is evident that such rises in sea level could cause coastal erosion and extensive coastal inundation, which will lead to coastal habitat destruction, loss of property and lives. Sea level rise could increase the socio-economic and physical vulnerability of coastal cities and may cost up to 14 per cent of GDP in coastal countries (IPCC 2007b).

The majority of Belize's population resides on the coast and along rivers. Some parts of the coast are at or near sea level. As a consequence, if no action is taken, projected sea level rise can have severe impacts on the low lying areas of Belize. Sea level rise data from the Water Center for the Humid Tropics of Latin America and The Caribbean (CATHALAC) and the Belize National Emergency Management Organization (NEMO) was used to generate current elevation (2014) along low-lying coastal areas of mainland Belize ranging from 0 – 20m above sea level. Projections for sea-level rise at this resolution are not available so elevation was used as a measure of exposure to sea-level rise, low-lying coastal areas being more exposed than higher elevations.

Sensitivity indicator was the number of hotels.

[14] Source: Douglas, 1977
[15] Snoussi etal. 2009).
[16] IPCC 2007b

Increase in Hurricane Intensity

There is little consensus on how hurricane frequency will change over time with climate change, but some studies have suggested an increase in intense hurricane activity in the North Atlantic[17,18]. Projections for changes in hurricane intensity are not available, so as a proxy we examined which elements of the tourism system have historically been more affected by hurricanes.

The Hurricane Center[19] has mapped hurricane trajectories, including intensity, for the last 150 years. Hurricane tracks were mapped using average wind speeds for the period 1951 – 2012.

Sensitivity was looked at based on the presence of key infrastructure/accommodations.

Changes in air temperature

To determine vulnerability of the tourism system to air temperature, current and future scenarios were developed using data from the climate change vulnerability analysis of the Caribbean coast of Belize, Guatemala and Honduras[20].

Exposure

The analysis considered changes in air temperature according to emissions scenarios B1 and A2, for the period 2070-2099. Exposure was measured according to the certainty that an increase of over 3°C will occur, according to the different scenarios modelled. Vulnerability categories are based on the IPCC methodology[21].

To determine vulnerability of the tourism system to air temperature, current and future scenarios were developed using data from the climate change vulnerability analysis of the Caribbean coast of Belize, Guatemala and Honduras.

[17] Bender M.A, Knutson T.R, Tuleya R.E, Sirutis J.J, Vecchi G.A, Garner S.T, Held I.M 2010
[18] Holland G and C.L. Bruyere 2014
[19] NOAA 2014
[20] CATIE/TNC 2012
[21] IPCC 2007

Table 2: Vulnerability indicators

		Vulnerability rank				
Indicators	**Measure**	**1 (very low)**	**2**	**3**	**4**	**5 (very high)**
Exposure						
Sea surface temperature	Sea surface temperature anomaly. Difference between the current, or projected SST, and the long-term mean SST.	Hotspot[1] equals 0	Hotspot above zero but SST below bleaching threshold	SST above bleaching threshold; DHW[2] above 0. Possible bleaching	SST above bleaching threshold; DHW 4 or higher. Bleaching likely	SST above bleaching threshold; DHW 8 or higher. Mortality likely.
Air temperature	% of scenarios that predict a 3^0C increase in temperature	<33	33 - 50	51 - 66	67 - 90	90 - 100
Hurricane intensity	Average wind speed (mph)(1951 - 2009)	74-95	96-110	111-130	131-155	>155
Rise in sea-level	Metres above current sea-level	10-20	5-10	2 - 5	0-2	Below Sea level
Sensitivity						
Area of coral reef	Kilometer square (km^2) of coral reef presence	0 - 9	10 - 30	31 - 40	41 - 50	51 - 100
Reef health	Coral bleaching Watch Ranking	No stress	Bleaching watch	Bleaching warning	Bleaching alert level 1	Bleaching alert level 2
Area of mangrove	Kilometer square (km^2) of mangrove	0 - 9	10 - 40	41 - 50	51 - 99	100 - 200
No. hotels		0 -9	10 - 19	20 - 99	100 – 200	>200
Tourism attractions		0 - 4	5 - 13	14 - 19	15 - 20	>20

[1] A coral bleaching hotspot is identified when current SST is above the highest mean value expected in the warmest month.

Degree heating weeks (DHW): cumulative measure of the intensity and duration of thermal stress, measures the hotspot stress over a 12 week period. DHWs over 4 have been shown to cause significant coral bleaching. Values over 8 have caused widespread bleaching and some mortality. Two DHWs is equivalent to one week of HotSpot values at 2 deg C or two weeks of HotSpot values at 1 etc. (from NOAA Coral Reef Watch).

4. Determining regional vulnerability to Climate Change

After evaluating each indicator individually, we examined the relative vulnerability of the planning regions to climate change impacts. This was a two steps process:

a) Ranking of indicators for each region by aggregation of exposure and sensitivity indicators mentioned above.

Aggregation of exposure and sensitivity to potential impacts were determined (see Table 2).

The Weighted Criteria Process considered only the following current exposure indicators:

- Sea Surface Temperature (Thermal Stress) (2006 – 2010)
- Air Temperature (2006 – 2010)
- Hurricane Intensity (1951 – 2009)
- Low Lying Coastal Areas relative to sea level (2014)

The Weighted Criteria Process considered only the following future sensitivity indicators.

- Area of coral reef
- Reef Health
- Area of mangroves
- Number of Hotels
- Tourism Attractions

b) Overall vulnerability

Vulnerability of each region was calculated as a measure of the potential impact of each climate hazard, in terms of exposure and sensitivity. The composite indicators were aggregated into an overall vulnerability value using the following formula:

$$PI = \frac{(EX + SE)}{2}$$

where PI is the potential impact composite indicator, EX is exposure, and SE is sensitivity.

III. RESULTS & DISCUSSION

1. Indicators of vulnerability based on increase in sea surface temperature (Exposure and Sensitivity)

Exposure

The figures below show the influence of increase exposure to elevated sea surface temperature (SST) on Belize's coral reefs[22].

Figure 2: Summary analysis of exposure to thermal stress from 2006-2010

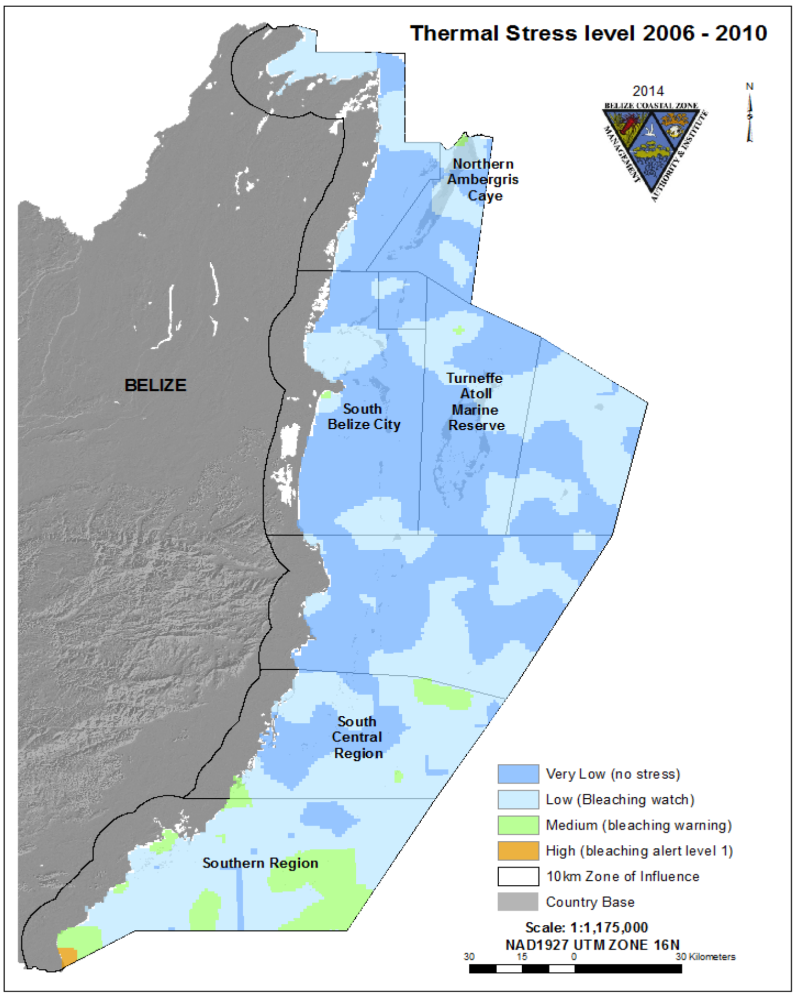
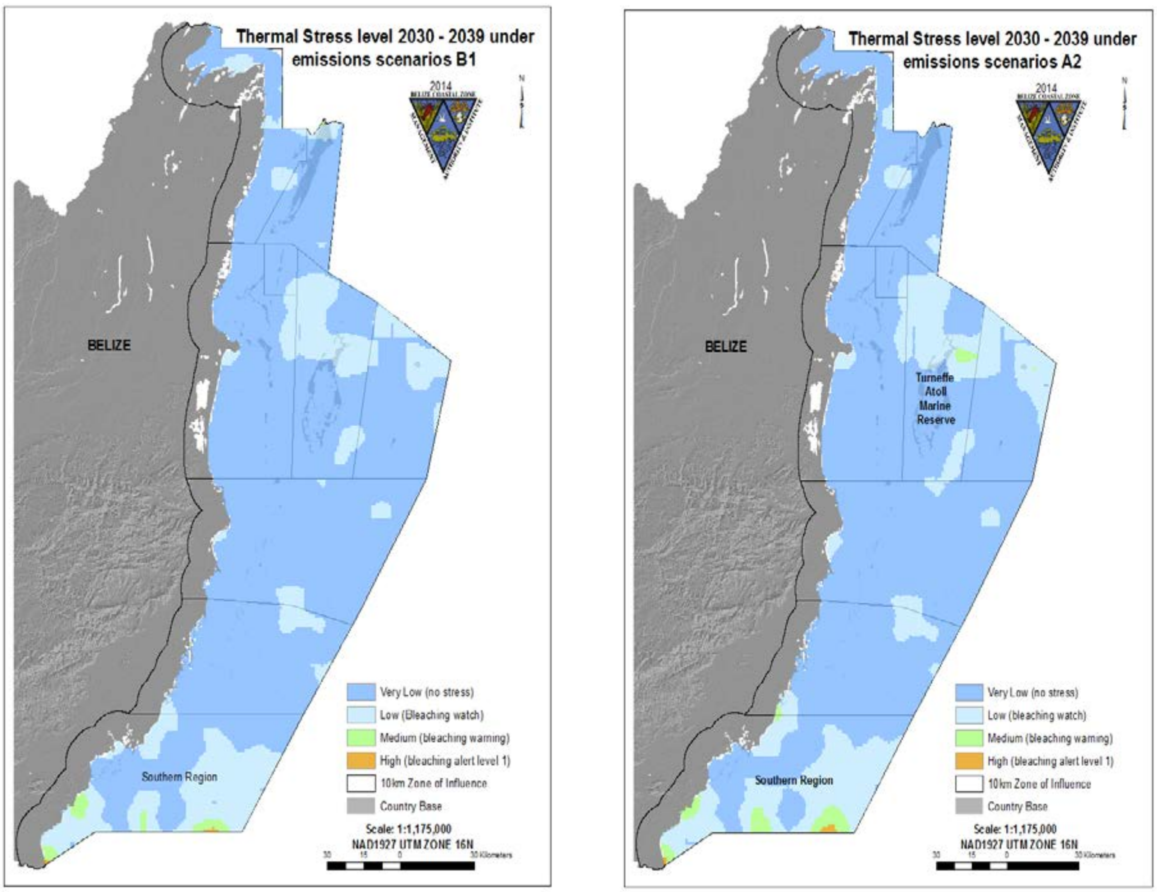


Figure 2 above shows the level of exposure to thermal stress in the study area from 2006 to 2010. Bleaching occurred mainly in northern Ambergris Caye, South Belize City, Turneffe

[22] Data source: CATIE/TNC 2012

Atoll Marine Reserve, South Central Region and Southern Region during this period. Various areas are also undergoing thermal stress, demonstrating the need for a monitoring system in the coastal zone to identify bleaching and the capacity of coral reefs to recover.

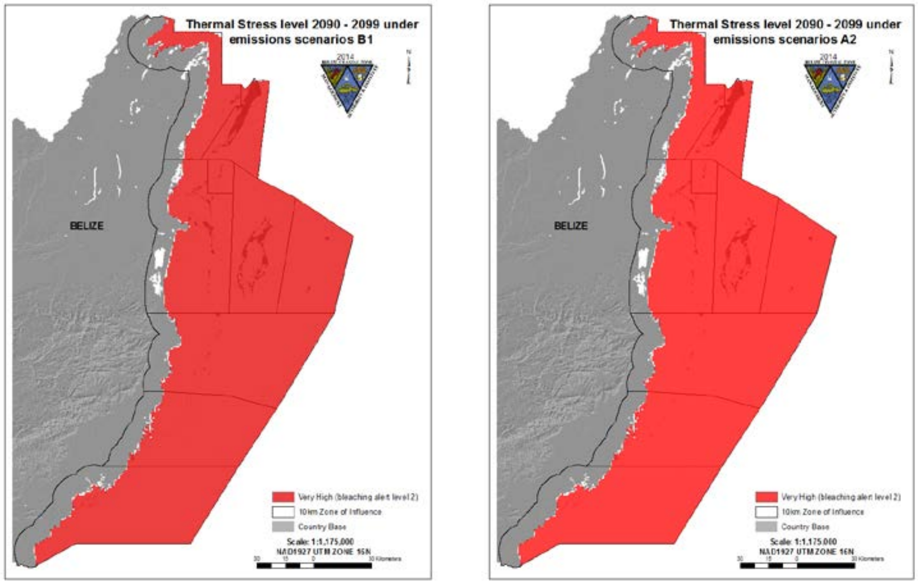
Figure 3a &b: Summary analysis of exposure to thermal stress over 2030-2039 time period based on two difference emission scenarios[23]



An assessment of the future exposure to thermal stress for the study area shows that both emissions scenarios (B1 and A2) for the period 2030-2039 is likely to result in continued warming towards the Southern Region (Figure 3a&b). In addition, emissions scenario A2 illustrates a projected warming towards the Turneffe Atoll Marine Reserve. However, the results for the same emissions scenarios for the period 2090-2099 show that the entire study area will be under increasing thermal stress (Figure 4).

[23] Data source: CATIE/TNC 2012

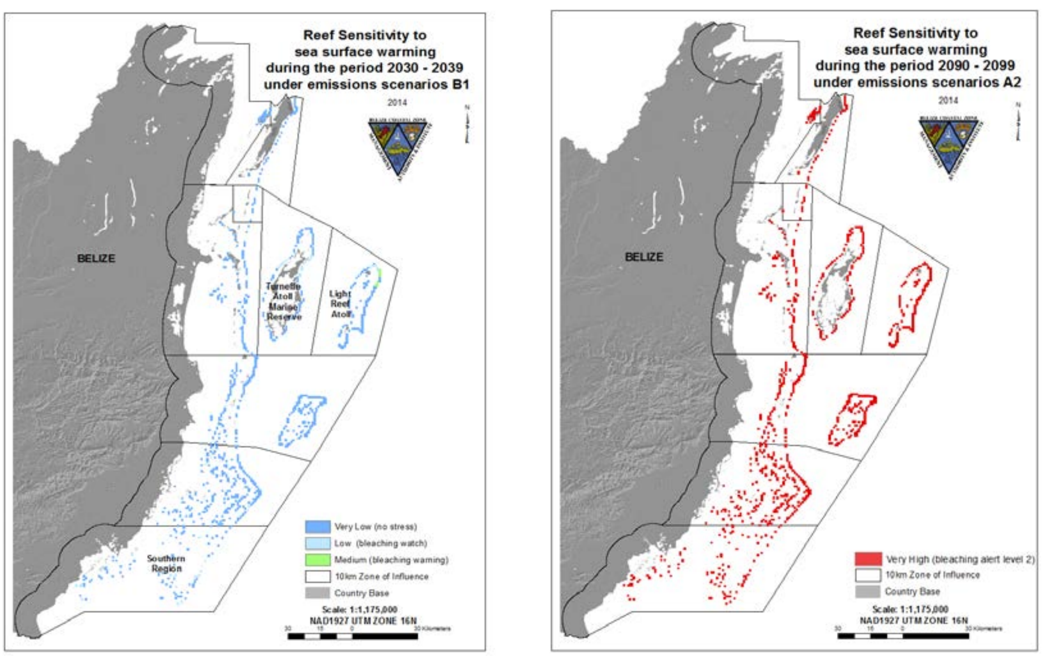
Figure 4a &b: Analysis of exposure to thermal stress over 2090-2099 time period based on two difference emission scenarios[24]



Sensitivity

The figures below show the sensitivity of Belize's coral reefs to sea surface warming[25].

Figure 5a&b: Reef sensitivity to sea surface warming



[24] Source: CATIE/TNC 2012

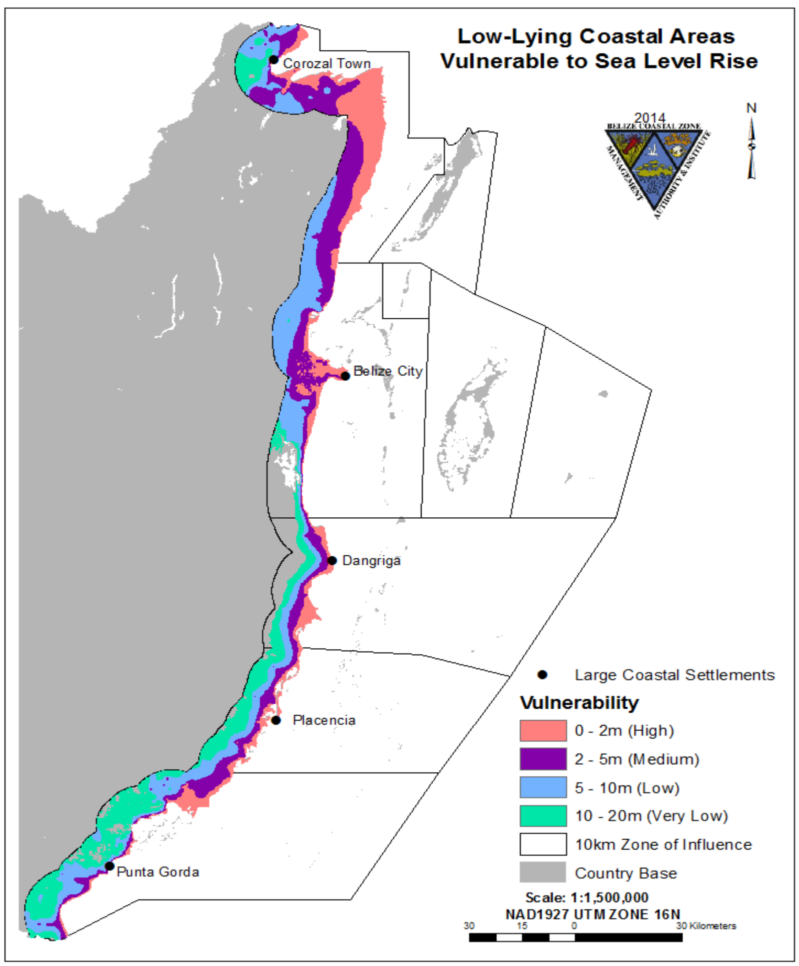
[25] Data source: CATIE/TNC 2012

Figure 5a&b show the future thermal stress on coral reefs. Results indicate that under a 2030-2039 thermal stress Belize's coral reef will receive medium bleaching warning for coral reefs north of Lighthouse Reef Atoll and a bleaching watch for Turneffe Atoll and Southern Region (Figure 5a). The 2090-2099 period shows that coral reefs will be exposed and suffering from very high thermal stress with potentially a high impact (Figure 5b). Thus, coral mortality from climate change may reduce the appeal of visitors that would like to participate in underwater recreational activities.

2. Indicators of vulnerability based on rising sea level (Exposure and Sensitivity)

Exposure

Figure 6: Vulnerability of Coastal Areas relative to sea level[26]



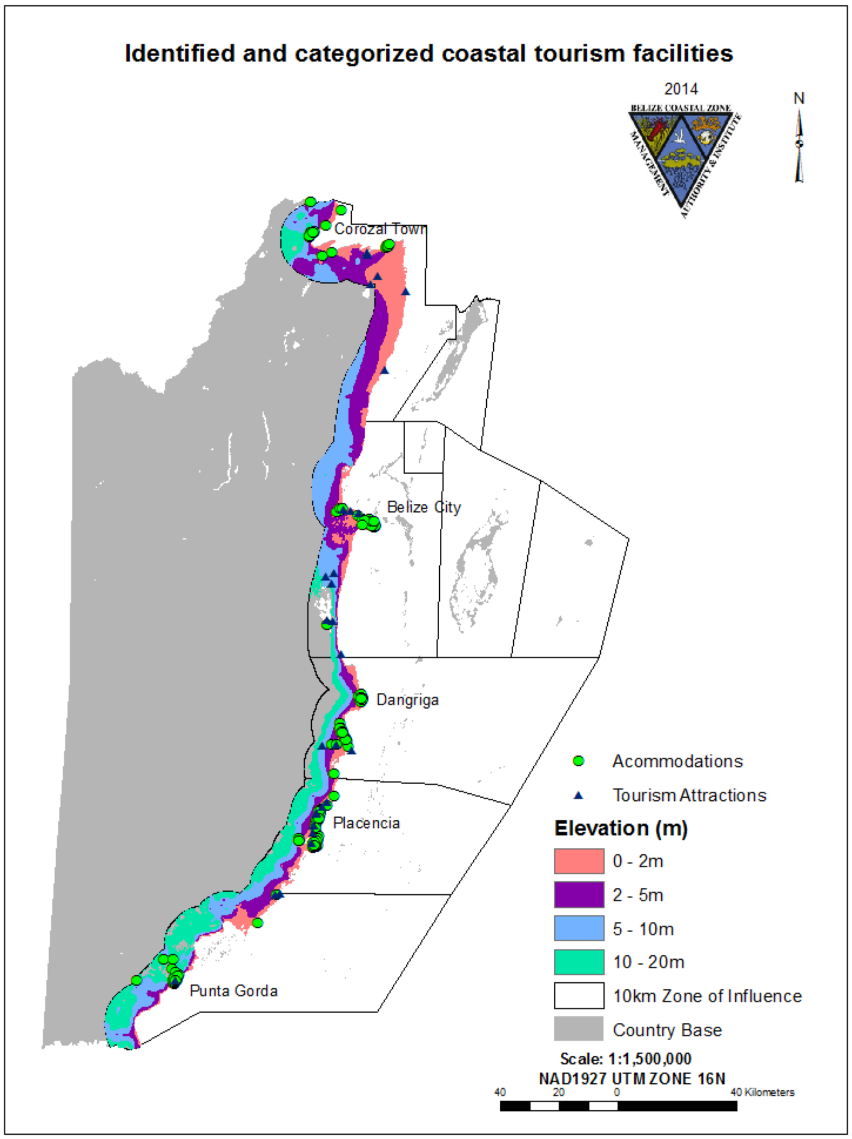
[26] Data source: BTFS, CATHALAC, INEGI, IGN-Guatemala, LIC, UK Ordinance Survey, USGS, 2014

Figure 6 show that Belize's low-lying areas, particularly locations with elevations ranging from 0-5m will be the most vulnerable to sea level rise. These areas account for a significant portion of Belize's coastal zone, especially when considering a 3km inward extent along the coast where a lot of development activities are occurring.

Sensitivity

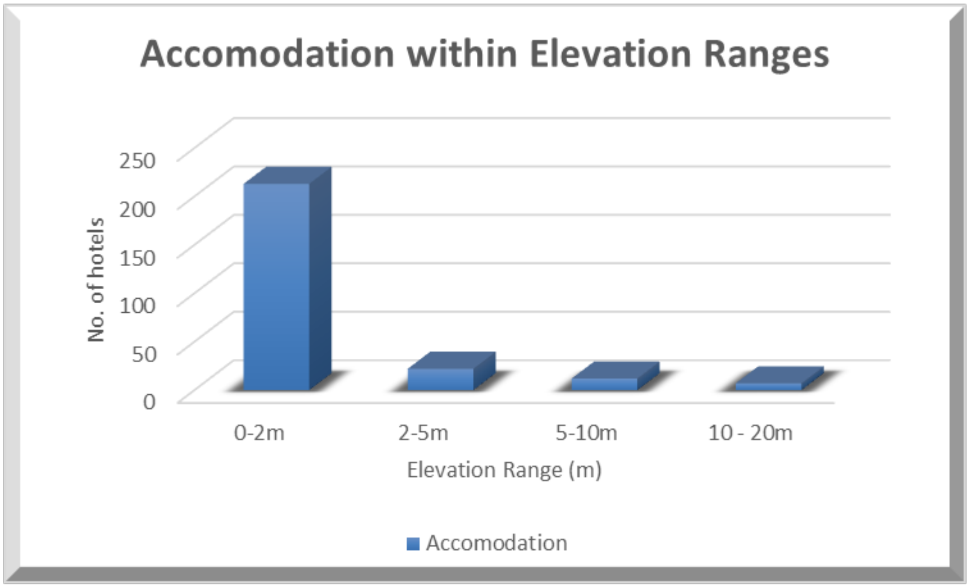
Figure 7 below illustrates coastal tourism facilities that are vulnerable to relative sea level rise.

Figure 7: Locations of vulnerable tourism accommodations and attractions



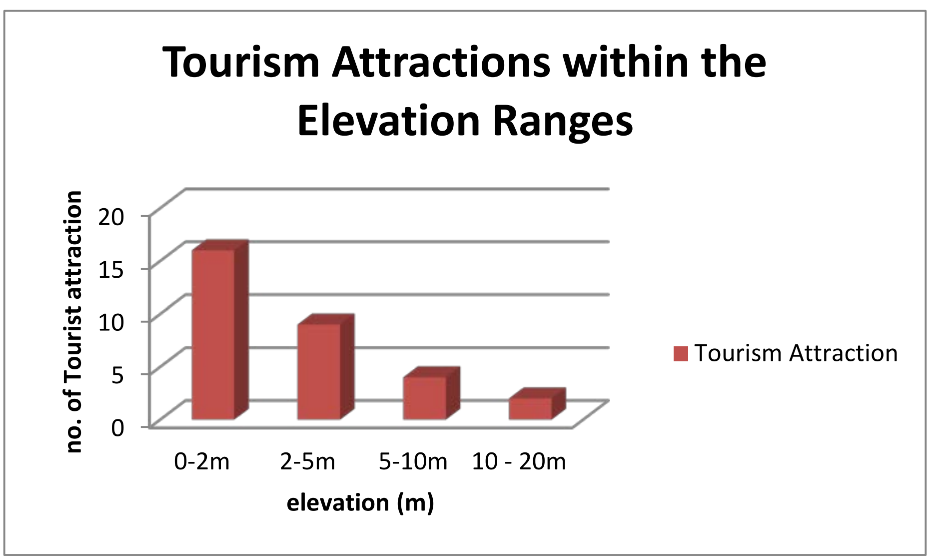
Graph 1 below shows the number of tourism accommodation that exists within varied elevation ranges. It is noteworthy that the highest number of establishments is within the lowest elevation range and is likely the most vulnerable to sea level rise.

Graph 1: Number of accommodation within elevation ranges



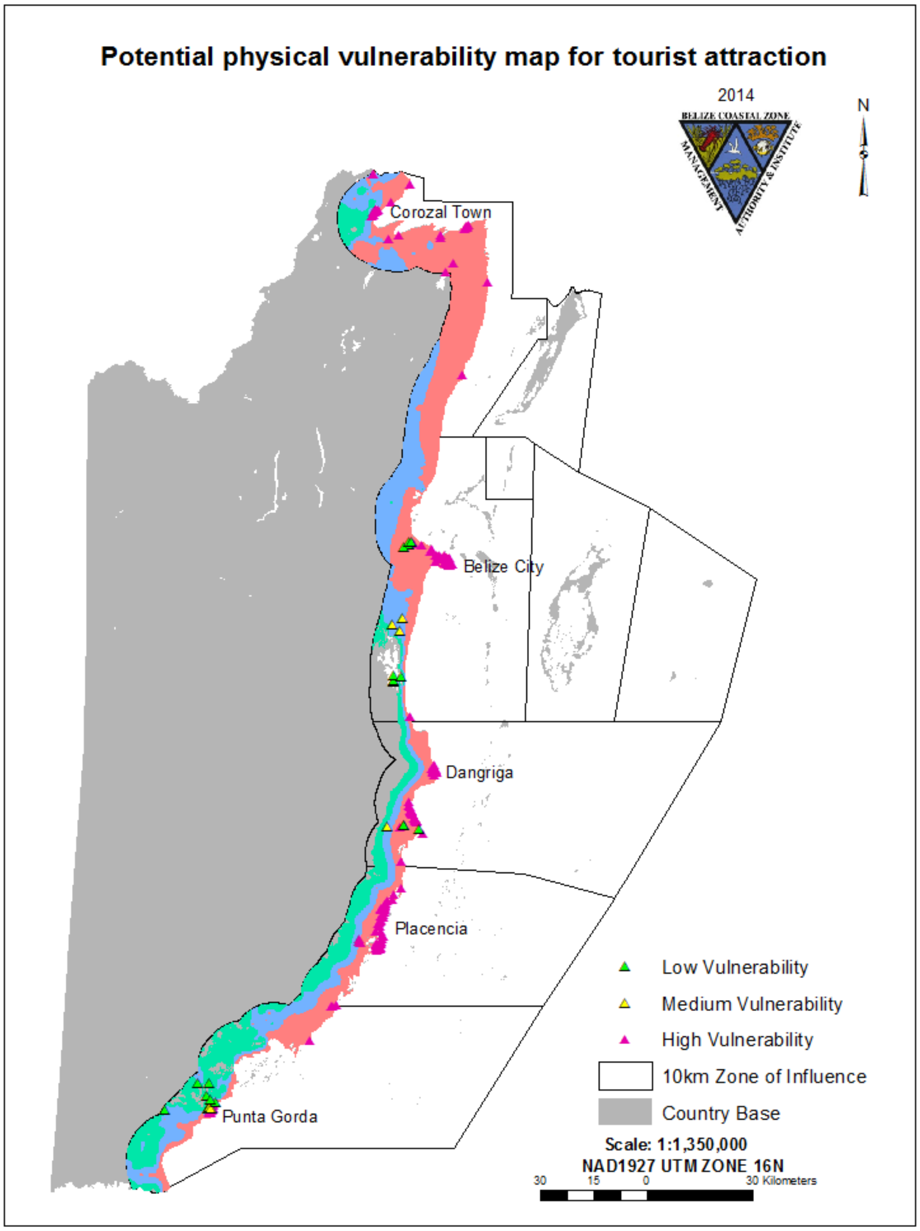
Graph 2 below shows the number of tourism attractions that exists within varied elevation ranges. It is noteworthy that the highest number of attractions is within the two lowest elevation ranges and is likely the most vulnerable to sea level rise.

Graph 2: Tourism attractions within elevation ranges



The vulnerability of tourism attractions to sea level rise in Belize is depicted in Figure 8 below.

Figure 8: Vulnerability of tourism attraction to sea level rise



Identification and classification of elements at risk for tourism

Tourism facilities identified were categorized into accommodation and tourist attraction, and further grouped per elevation class as shown in the map (Fig. 7). Accommodation facilities are comprised of mainly hotels and lodges; and tourist attractions comprise of bird and manatee watching sites, to name a few.

A total of 291 tourism facilities were identified along the coast based on recognized facilities by the Belize Tourist Board. Of these, 263 were accommodation facilities; and 28 were tourist attractions. Accommodation facilities are located on varying elevation classes with approximately 94% found to be within the lower elevation. Approximately 79 % of tourist attractions were located within the lower elevation comprising of manatee and bird watching. Within 10 km from the shoreline 86 % of the tourism facilities were found to be in the low elevation class (0 - 5 m above MSL), 9 % in the moderate elevation class (5 -10 m) and 5 % were in high elevation class (10 - 15 m). (Fig. 7) Facilities in the low elevation class were considered to be more at risk to any inundation.

Assessment of potential physical and socio-economic impact of elevated sea level rise (SLR)

Analysis of the potential physical impact on tourism facilities vulnerable to sea level rise (SLR) indicated that out of the total number of tourist facilities at risk, 86 % of these facilities are highly vulnerable to SLR and 6 % moderately vulnerable. Eight (8) of the accommodation facilities are moderately vulnerable and eight (8) less vulnerable to the SLR. Out of the seven (7) food services facilities at risk all are moderately vulnerable. From a total of sixteen tourist attraction facilities made up of beaches, lagoons and mangrove - ten (10) of these facilities are highly vulnerable, three (3) moderately vulnerable and the rest (3) less vulnerable (Fig.8).

In addition, as can be noted above, the extensive coastal plain of Belize lies largely below 20m above sea level, with substantial areas below 10m and many denoted “subject to inundation” on hazard maps. Along the river valleys, notably the Belize River, there are vast areas below 10m which are also subject to inundation. Major roads are likely to be affected by inundation from sea level rise, including the New Northern Highway and the Old Northern Highway. Moreover, much of the northern part of the capital, Belize City, is on land below 10m, and thus will potentially be affected by sea level rise.

In Belize City, residential areas such as Vista del Mar, Bella Vista, Belama and Fort George that are constructed on drained and reclaimed wetlands are extremely vulnerable to the projected sea level rise. Similarly, the infrastructure developments in most of the other coastal communities like Dangriga, Corozal Town, the Placencia Peninsula, Ambergris Caye and the other offshore islands are currently threatened by even a 20 cm rise in sea level. If these communities are to cope with rising sea level, a constant supply of large volumes of sediment would be required. The sources of supply of natural and alternative sediment to these areas have been significantly reduced. Protecting these urban areas might require the construction of sea walls and dikes that could withstand the impacts of the projected sea level rise through the new century. Impacts to GDP in Belize are also important to note. The impacts of 1m of SLR will lead to just over a 2% loss in GDP, or US $61,373,301.00, primarily from lost tourism.

The IPPC's assessment report of 1999 stated that approximately 60% of coastal areas were permanently inundated. Considering that most of the mainland coastline between the existing communities is wetland dominated, a one meter rise in sea level would transform the wetlands to lakes. Dry land within a few meters of high tide levels would provide potential areas for new wetland formation.

A changing climate, along with sea level rise, would result in loss of beaches, properties and public infrastructure and will make Belize less attractive as a tourist destination. The loss of beaches and coastline due to erosion, inundation and coastal flooding, and loss of tourism infrastructure, and natural and cultural heritage would reduce the amenity value for coastal users (IPCC AR4, 2007).

Because of the lack of data available, this study was not able to account for projected sea level rise impacts. However, a recent study (CARIBSAVE, 2012) estimated the beach area losses for three beach areas in Caye Caulker, Rocky Point and San Pedro. At 0.5 m SLR scenario, Rocky Point is projected to lose 75% of its beach area, followed by San Pedro (19%) and Caye Caulker (17%). With a 1 m SLR, Caye Caulker would lose almost its entire beach area (96%), followed by Rocky Point (90%) and San Pedro (45%). With a 2 m SLR, both Caye Caulker and Rocky Point would lose all of their beach area, with San Pedro losing its beach area with a 3 m SLR scenario (See Table 3).

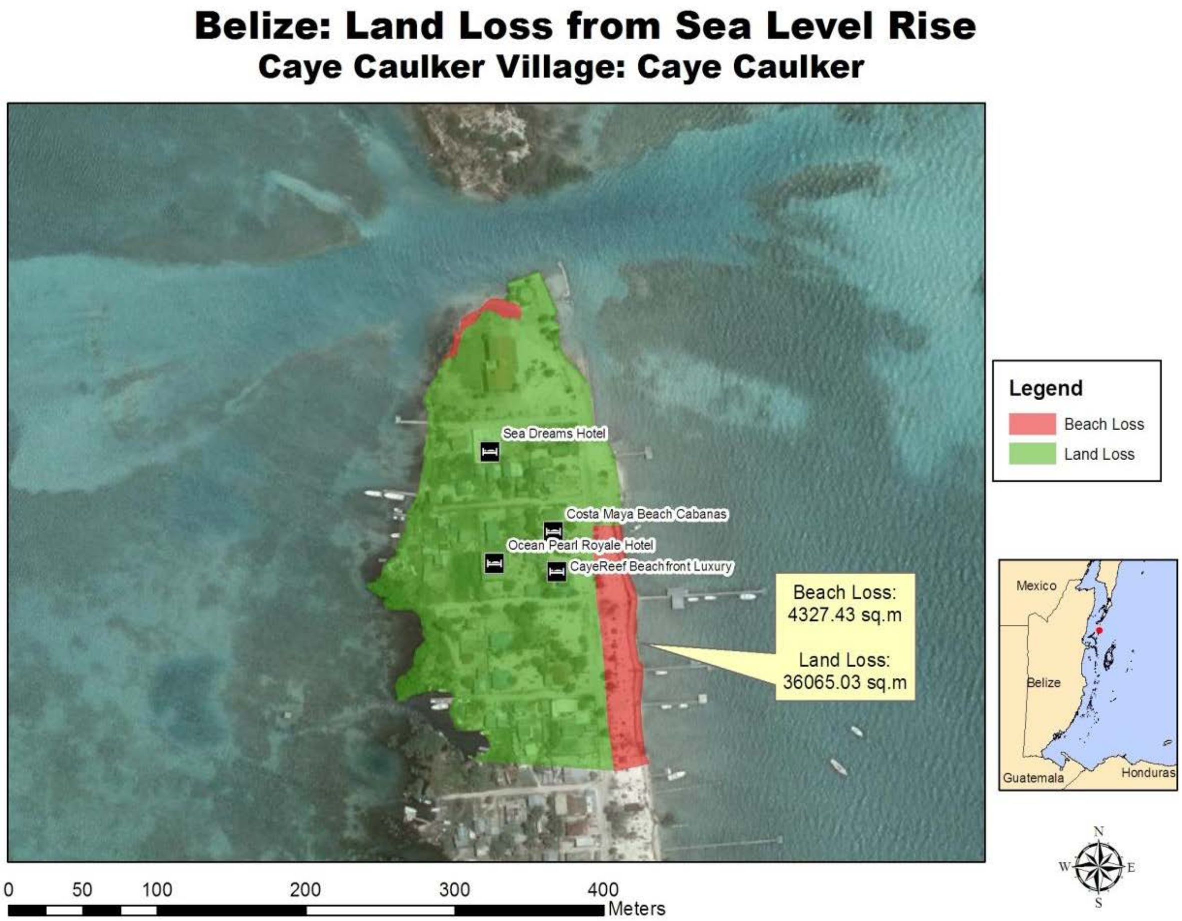
Table 3: Beach area (m^2 and %) losses due to varying scenarios of Sea Level Rise (SLR) for Caye Caulker, Rocky Point and San Pedro (Ambergris Caye)[27]

	Caye Caulker		Rocky Point		San Pedro	
SLR Scenario	Beach Area Lost To SLR (m^2)	Beach Area Lost (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost (%)
0.5m	723	17%	6112	75%	7375	19%
1.0m	3424	96%	1251	90%	10147	45%
2.0m	180	100%	788	100%	18662	93%
3.0m	-	-	-	-	2596	100%

The following images were taken directly from the Belize Climate Profile (CARIBSAVE Partnership 2012) which shows the projected effects of 100cm sea-level rise on Caye Caulker (Figure 9) and Rocky Point Ambergris Caye (Figure 10). In the case of Caye Caulker, a portion of the island would be submerged including homes and hotels. The land that would be lost at Rocky Point on Ambergris Caye is not currently occupied by homes or businesses, though the beach is a tourist attraction. The tourist value of the area would be lost if the predicted impacts of 100cm sea-level rise were to occur. Therefore, losses of beach area and land loss would have severe repercussions for the tourism industry of Belize (CARBSAVE 2012).

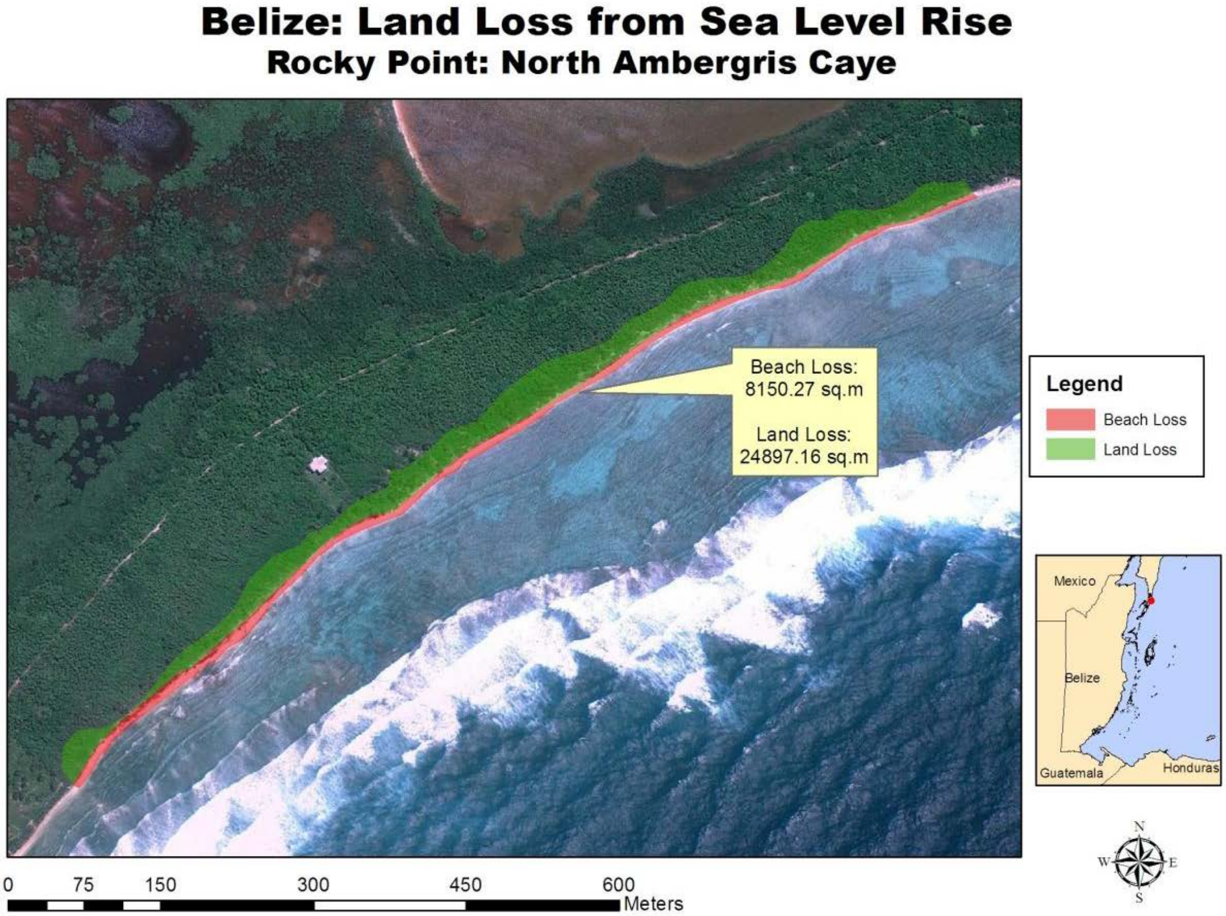
[27] Source: CARIBSAVE, 2012

Figure 9: Image of Caye Caulker showing predicted beach and land loss from 100 cm sea level rise[28]



[28] Source: CARIBSAVE, 2012

Figure 10: Image of Rock Point San Pedro Ambergris Caye showing predicted land and beach loss for 100 cm sea level rise [29]



[29] Source: CARIBSAVE, 2012

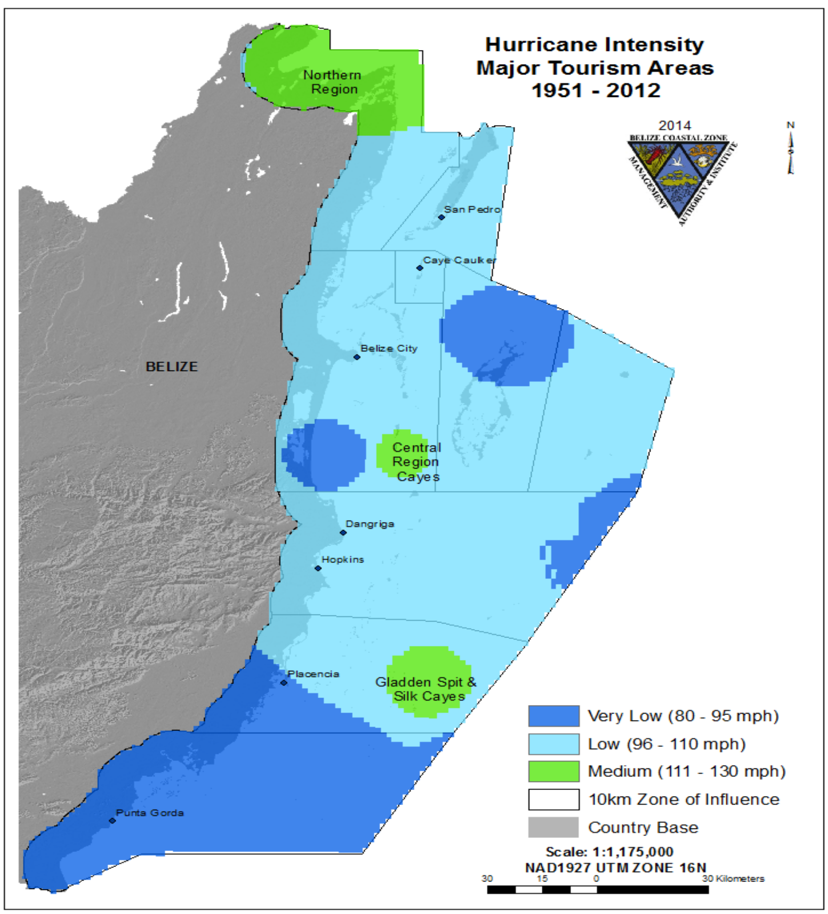
3. Indicators of vulnerability based on increase in hurricane intensity

Belize lies in the Tropical Atlantic Hurricane Region. Historically, tropical storms and hurricanes have affected the country once every three years. The Atlantic Hurricane Season officially runs from June 1 until November 30 each calendar year, and tropical storms and hurricanes often threaten to hit Belize. In the past, major hurricanes have caused extensive damage, serious injuries, and deaths. For instance, Belize City, the former capital was destroyed twice by hurricanes in the 20th century.

Exposure

Figure 11 below shows the average wind speed of hurricanes from 1951 – 2012. The Northern Region, Central region cayes (Alligator Caye, Colson Caye, Bluefield Range, Rendevous Caye & The Triangle), Gladden Spit and Silk Cayes are the only areas that had moderate exposure.

Figure 11: Hurricane wind speed average from 1951-2012



Only coastal locations are vulnerable to hurricane force winds from a Category 1 hurricane, while the entire country is vulnerable to hurricane force winds from a Category 5 hurricane. Hurricanes have affected the entire country but are more frequent in the north. Figure 11 shows the areas in Belize most exposed to hurricane damage are the cayes and coastal areas, including popular destinations such as San Pedro on Ambergris Caye, Caye Caulker, and Placencia on the mainland.

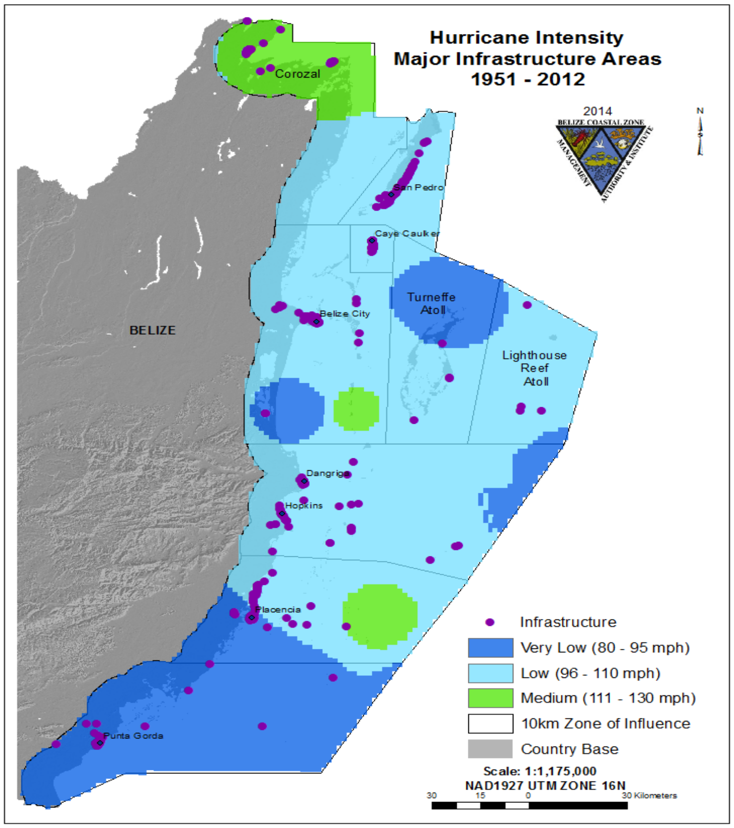
Belize is vulnerable to storm surge. The continental shelf is about 15 miles from the mainland providing a shallow bathymetry, which allows high waves to be generated by low pressure and strong onshore wind. Coastal Belize is also very flat. If not for Belize's Barrier Reef that runs along the coastline like a bulwark, storm surges would be able to move several miles inland before they meet any significant elevation. The coastline has several bays, which funnels water inward creating higher local surges. A storm surge of 20 feet is predicted for Belize City for a Category 5 hurricane. Other locations could get storm surges approaching 25 feet. With such high levels of storm surge, the barrier reef is not able to effectively damper their strength and level of impact. Therefore, storm surges could be expected on have far reaching impact along the coast. Belize's vulnerability increases from north to south. According to the Meteorology Department the area to be most affected in the future will be central Belize.

The Belize Risk Profile 2012 illustrates that the North Atlantic hurricanes and tropical storms appear to have increased in intensity over the past 30 years. Observed and projected increases in sea surface temperatures indicate potential for continuing increases in hurricane activity and model projections indicate that this may occur through increases in intensity of events but not necessarily though increases in frequency of storms.

Sensitivity

Figure 12 below shows the major infrastructure that is within hurricane intensity zone.

Figure 12: Major infrastructure and hurricane intensity



4. Indicators of vulnerability based on changes in air temperature

Exposure

The mean annual global temperature has risen close to one degree (0.6°C) since 1888 (Figure 12). In Central America the average annual temperature has risen approximately 1°C since 1900; the number of hot days and nights increased 2.5% and 1.7% respectively per decade, while cold nights and days decreased -2.2% and -2.4% respectively. Extreme temperature have risen 0.2°C to 0.3°C per decade (Aguilar et al. 2005).

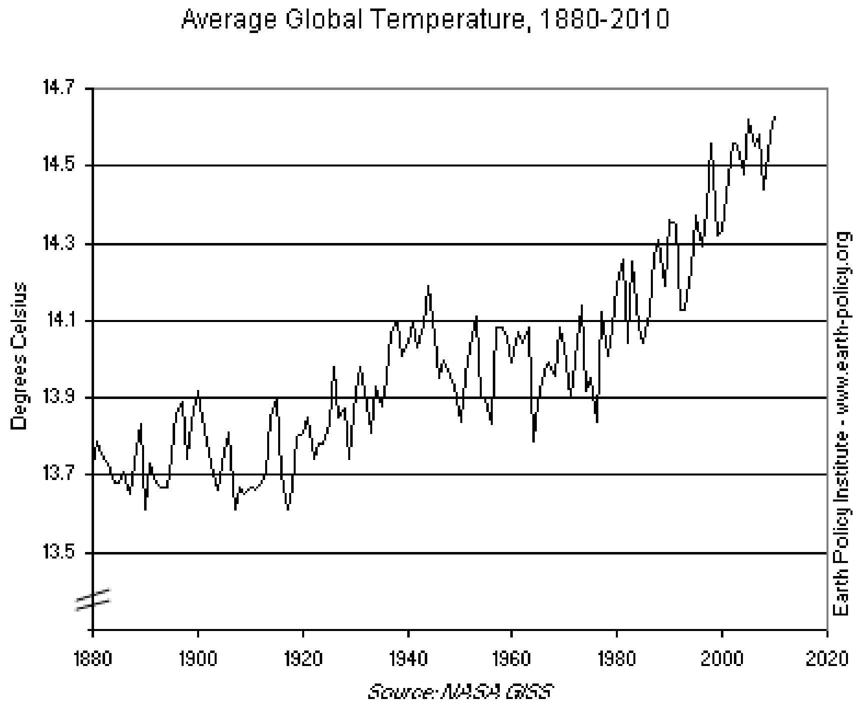
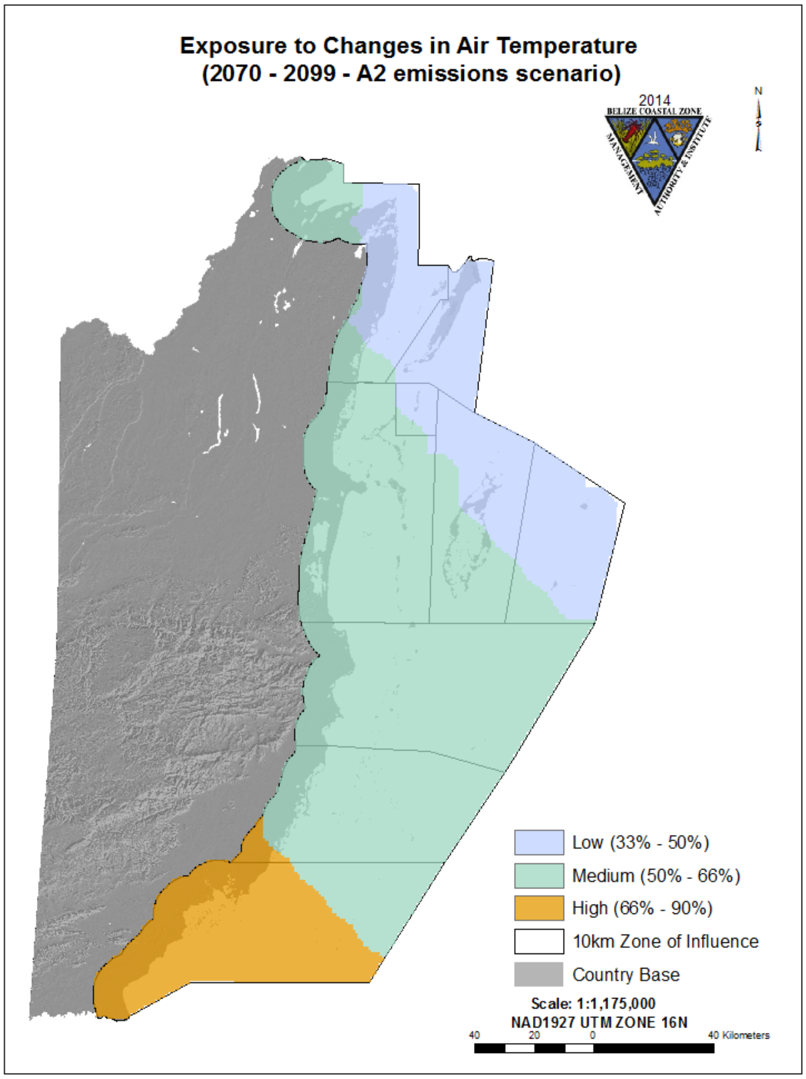


Figure 12: Increase in global temperature from 1880 to 2010

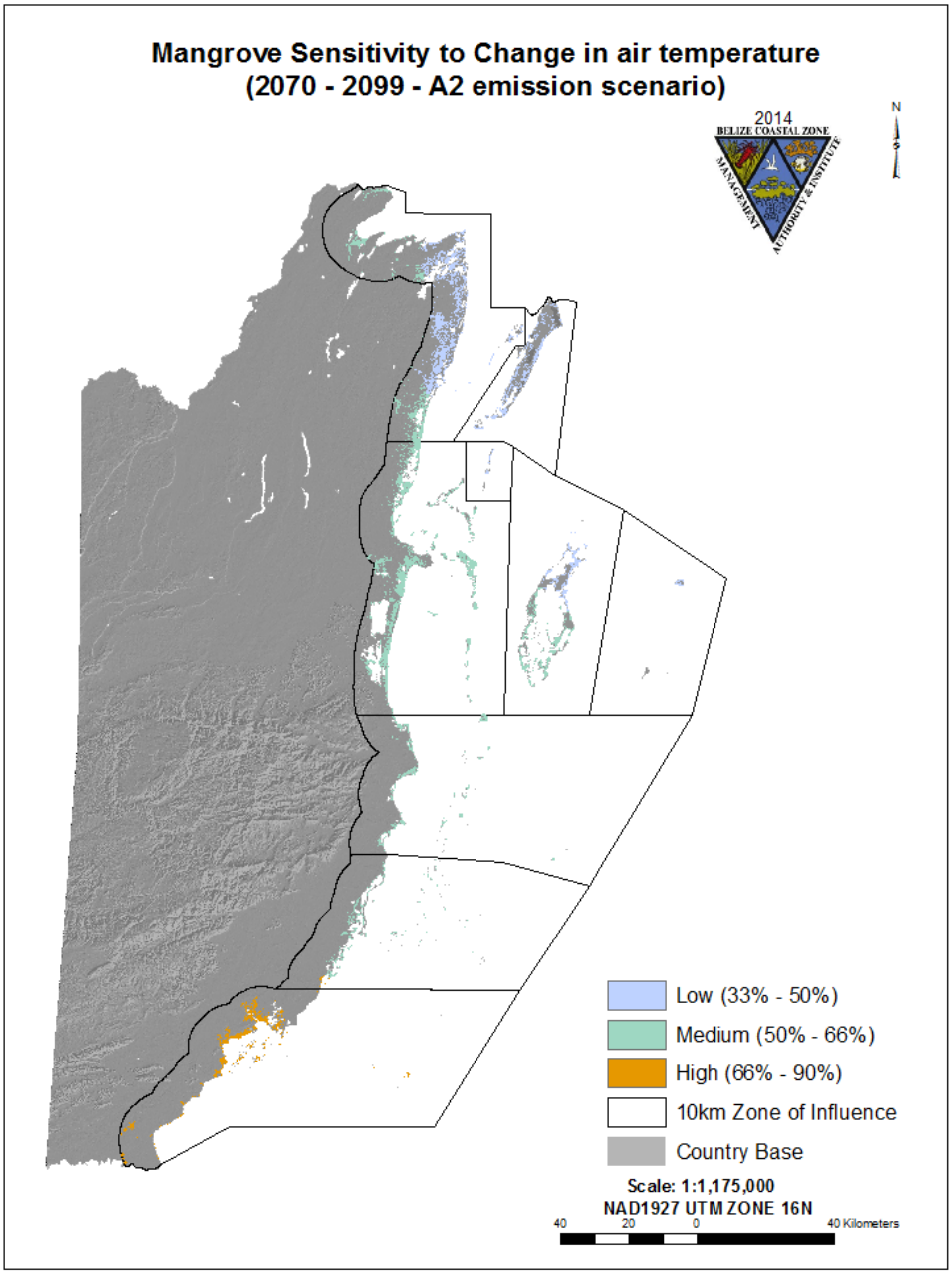
Figure 13 below shows the exposure to air temperature changes for Belize based on the A2 emission scenario. Exposure to air temperature increases from north to south with a very large percentage of the country's coastal marine areas showing medium to high exposure to changes to air temperature. This means that these areas are likely to be quite vulnerable to changes in air temperature.

Figure 13: Exposure to Changes in Air Temperature



Sensitivity
Figure 14 illustrates the sensitivity of Belize coastal marine areas to changes in air temperature. This finding correlates strongly with that found for the exposure analysis. Greater than 75% of Belize coastal-marine areas and ecosystems depict a medium to high sensitivity to the modelled changes in air temperature.

Figure 14: Mangrove Sensitivity to air temperature



Tourism recreational activities that are sensitive to change in air temperature are shown in Figure 15. The majority of these exhibit a medium to high sensitivity to changes in air temperature.

Figure 15: Tourism Recreation Sensitive to change in air temperature

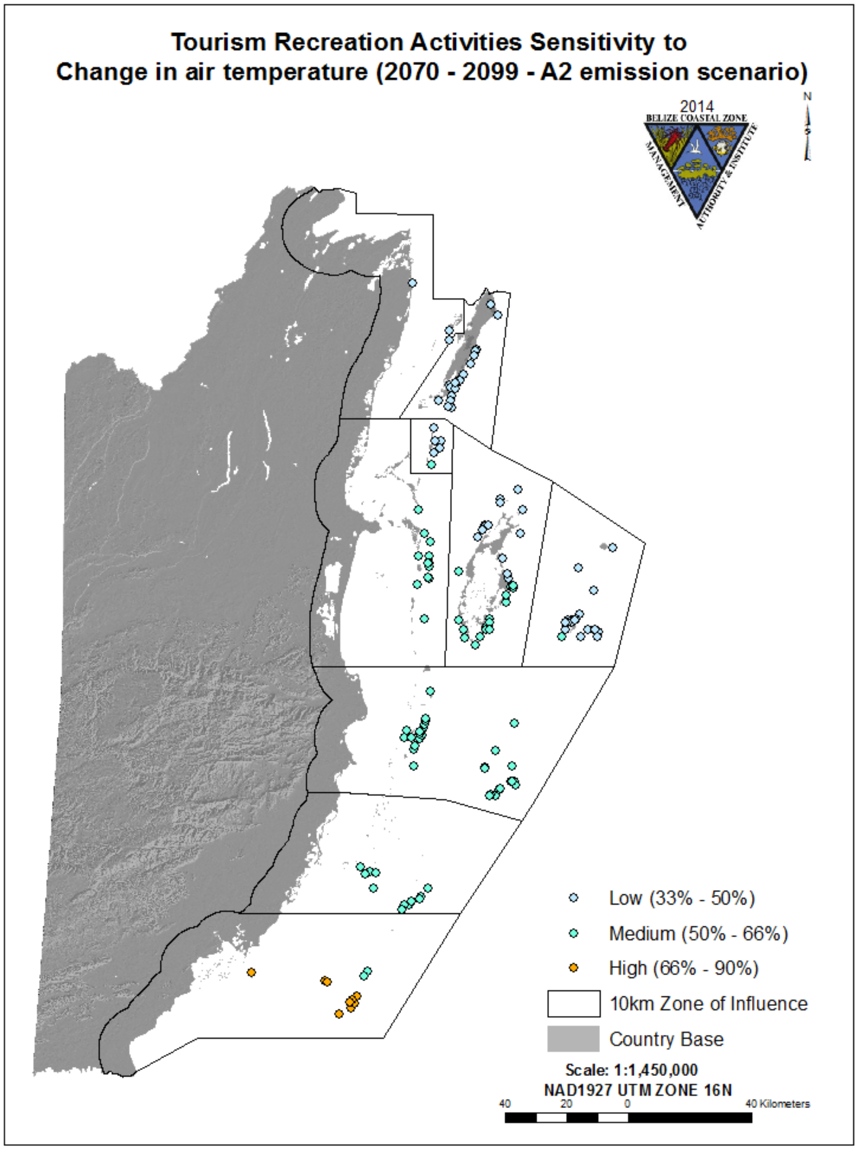
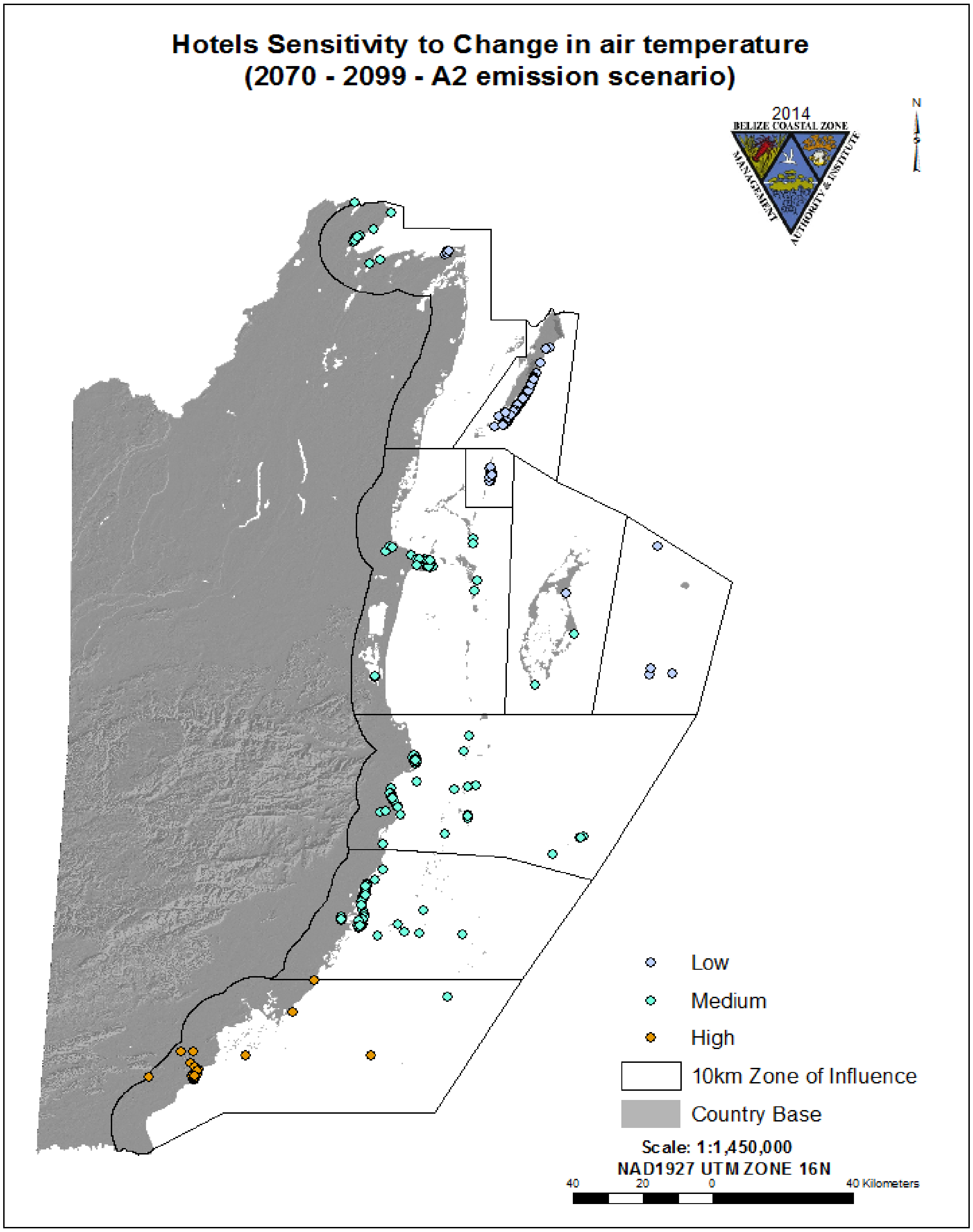


Figure 16 below illustrates the sensitivity of hotels to change in air temperature.

Figure 16: Hotels sensitive to change in air temperature



If future scenarios correspond to B1 type emissions, then the probability of a 3°C change in air temperature for our area of study would be very low. However, changes under emissions scenario type A2 would exceed 3°C with a high probability of occurrence mainly in Southern Belize. Values for the rest of the region show a medium probability, which could possibly result in important impacts on coastal habitats such as lagoons and mangroves due to the increase in surface temperature.

5. Determining vulnerability to climate change

More than 70% of tourists visit Belize's cayes and approximately 80% participates in reef based activities such as snorkelling and diving (BTB 2012). However, climate change has the potential to reduce the appeal of the coastal areas owed to heat stress, erosion and declining reef health (Singh et al. 2013). Table 4 - 6 shows the vulnerability and impact ranking for different coastal-marine areas in Belize.

Table 4: Showing weighted decision matrix applied to tourism climate change exposure indicators

Regions	Selected Weight Criteria* (1 = very low, 2 = low , 3 = Medium, 4 = High and 5 = Very High)				Vulnerability Rank
	Sea Surface Temperature	Air Temperature	Hurricane Intensity	Rise in Sea level	
Northern	3	3	1	4	Medium
Ambergris Caye	2	2	2	4	High
Central	3	3	2	4	High
Caye Caulker	2	2	2	4	High
Turneffe Atoll	2	2	2	4	High
Lighthouse Reef Atoll	2	2	2	4	High
South Northern	3	3	2	3	Medium
South Central	3	3	2	4	High

Southern	4	4	1	3	Medium

Table 5: Showing weighted decision matrix applied to tourism climate change sensitive indicators

Regions	Selected Weight Criteria* (1 = very low, low 2 = low, 3=medium, 4 = High, 5 = Very High)					Vulnerability Rank
	Area of Reef cover	Reef Health	Area of Mangroves	Number of Hotels	Tourism Attractions	
Northern	1	2	5	3	1	Medium
Ambergris Caye	2	2	3	5	5	High
Central	2	2	5	3	5	High
Caye Caulker	1	2	1	3	5	High
Turneffe Atoll	4	2	4	1	5	High
Lighthouse Reef Atoll	3	2	1	1	5	High
South Northern	5	2	2	3	5	Medium
South Central	3	3	3	4	5	High
Southern	4	4	4	3	2	Medium

Table 6: Showing overall potential impact to the key tourism vulnerable hotspots

Region	Vulnerability Component exposure	Vulnerability Component sensitivity	Potential Impact
Northern	Medium	Medium	Medium
Ambergris Caye	High	High	High
Central	High	High	High
Caye Caulker	High	High	High
Turneffe Atoll	High	High	High
Lighthouse Reef Atoll	High	High	High
South Northern Region	Medium	Medium	Medium
South Central Region	High	High	High
Southern Region	Medium	Medium	Medium

Figure 17 below shows the relative vulnerability of tourism areas to the potential impact by climate change threat factors. This assessment illustrates that the highest potential impact to the tourism areas will be to the popular destination of Ambergris Caye, Central Region, Caye Caulker, Turneffe Atoll, Lighthouse Reef Atoll and South Central Region. Considering this, there is a great need to prioritize these areas for adaptation interventions. The Northern Region, South Northern Region and Southern Region are likely to experience medium level impact, which is still of concern.

Figure 17: Relative vulnerability of tourism areas

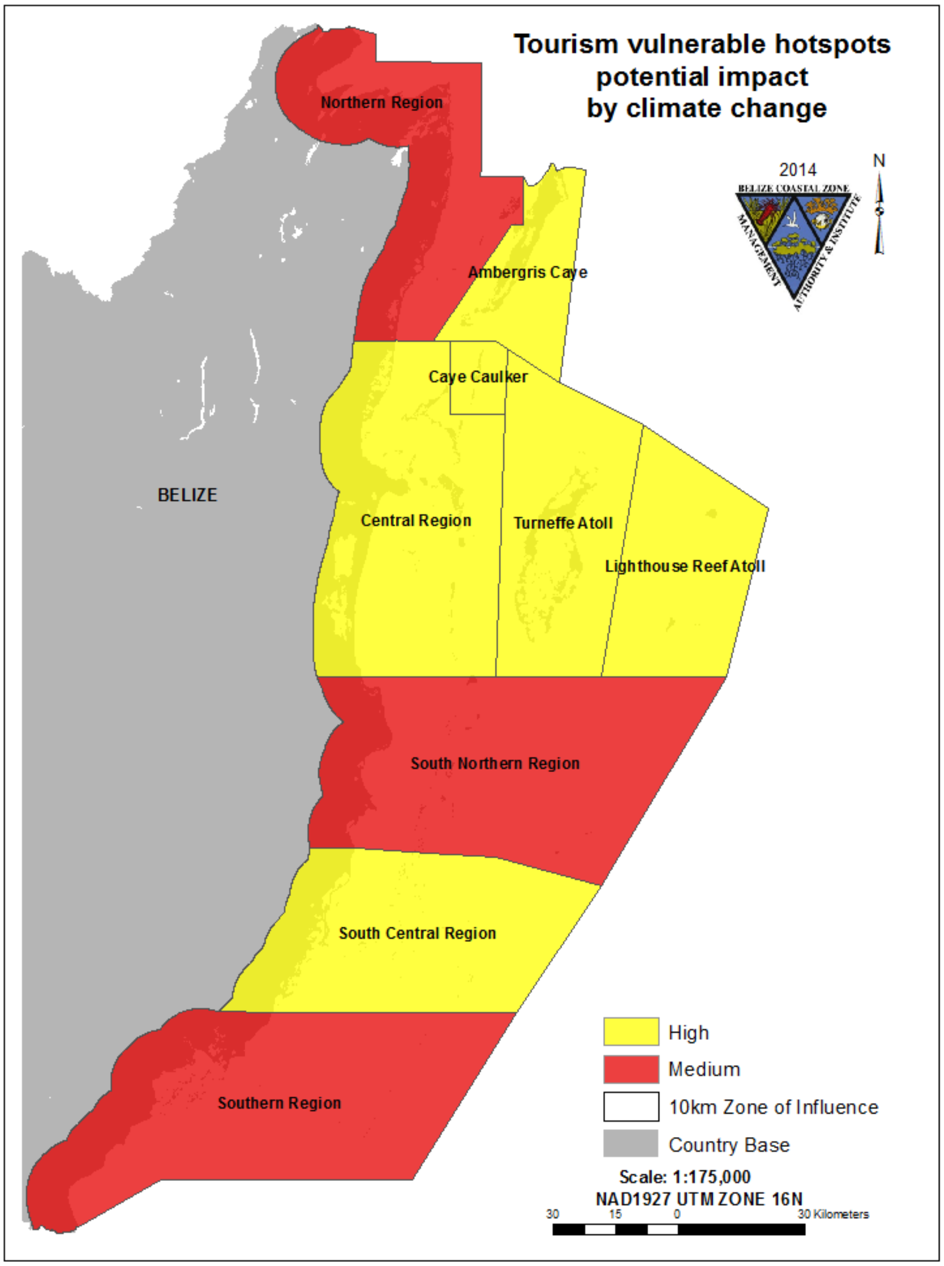
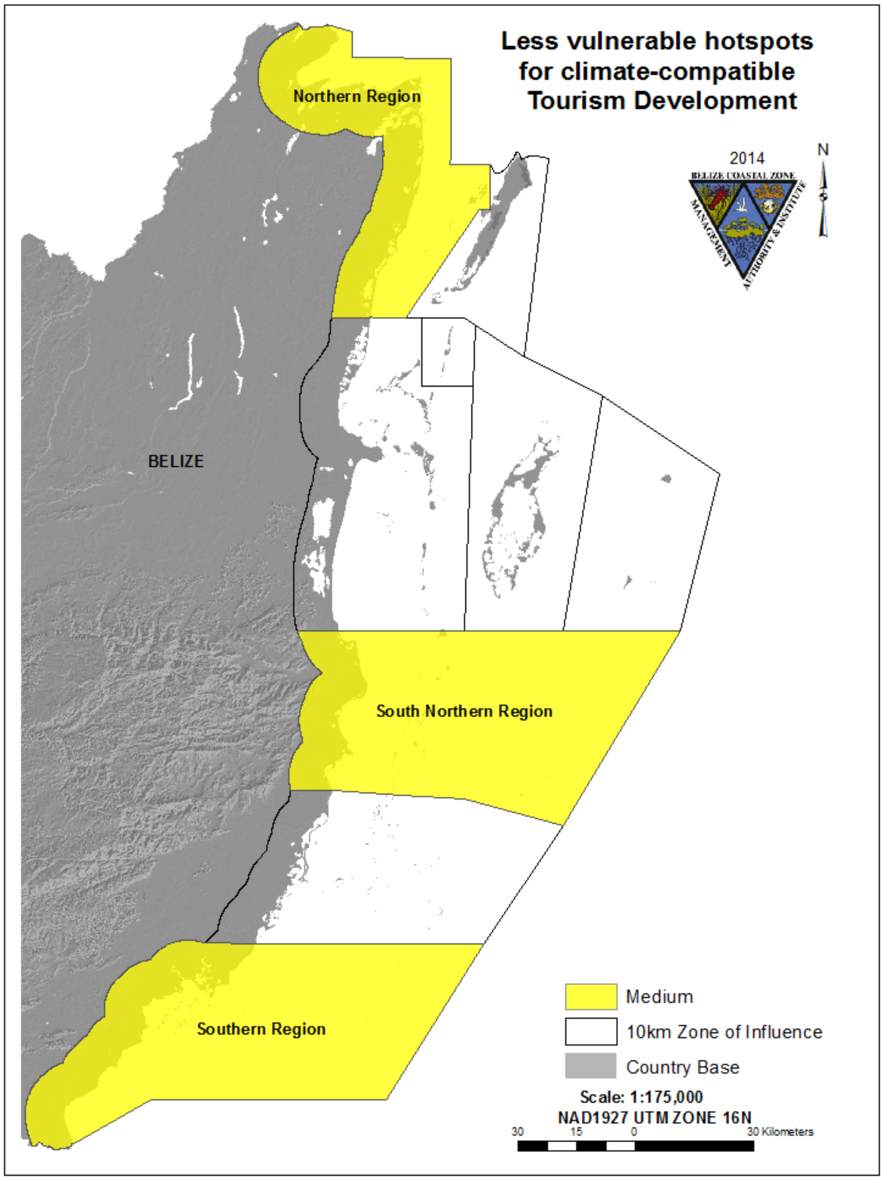


Figure 18 below shows the potentially less vulnerable hotpot areas.

Figure 18: Less vulnerable hotspots



This assessment also illustrates areas that may be prioritized for future research into their potential for climate-compatible tourism development. These include: Northern Region, South Northern Region and Southern Region. These areas have the potential for low impact hotel development with proper guidelines as per established by the draft Integrated Coastal Zone Management Plan (ICZMP) 2013. In addition, more tourism recreation activities can support the tour operators within these areas. However, proper awareness on climate change must be given to these operators to enhance their knowledge about the impact of climate change on the tourism industry they heavily rely on for their livelihood.

IV. CONCLUSION

The potential impact of climate change on Belize's tourism sector can occur indirectly through the degradation of coastal water quality, loss of beach, coral reef degradation and subsequent decline in fish stocks. This assessment shows that there will be a high potential impact of climate change on the Tourism Industry which could place the industry at risk in the future. It should be noted however that this study just looked at the physical vulnerability of the sector to key climate change variables and did not analyzed the adaptive capacity of the industry. It is therefore recommended that adaptive capacity of the sector be analyzed as part of a future study for Belize's tourism industry to be able to better understand the full vulnerability of this sector.

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