Climate Change Risk Assessment Report:

Portland Bight Protected Area

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For:
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ABOUT THIS DOCUMENT

This report will form one of five deliverables of a consultancy awarded by the Caribbean Coastal Areas Management Foundation (C-CAM) to the Climate Studies Group, Mona (CSGM). It is an assessment of the physical and socio-economic vulnerabilities of the Portland Bight Protected Area (PBPA) due to climate threats. The analysis was carried out through reviews of existing relevant literature, limited analysis of climate variables for the region and surveys conducted among some residents of the PBPA.

The original Terms of Reference is provided in the appendices.

Within the context of the Terms of Reference, the objectives of this report are interpreted to be:

(a) To describe what is known about the climatic conditions of the Portland Bight Protected Area.

(b) To describe the climatic hazards to which the PBPA is exposed and the impact of climate change.

(c) To examine the risk posed by the climatic hazards to the biodiversity of the PBPA.

(d) To do the above, where possible for the entire PBPA, but with an emphasis on the two dry forest regions of Hellshire Hills and Portland Ridge.

(e) To provide any additional climatic data as appropriate to support vulnerability analyses of the PBPA and the creation of a robust long term and sustainable adaptation management plan for the PBPA.

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Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

A1B	Scenario generated by the IPCC
A2	Scenario generated by the IPCC
AR4	Intergovernmental Panel on Climate Change Fourth Assessment Report
B2	Scenario generated by the IPCC
C-CAMF	Caribbean Coastal Areas Management Foundation
CC	Climate Change
CEP	Caribbean Environment Programme
CEPF	Critical Ecosystem Partnership Fund
CERT	Community Emergency Response Teams
CSGM	Climate Studies Group, Mona
ENE	East-Northeast
GCM	Global Climate Model
GEF	Global Environment Facility
GOJ	Government of Jamaica
HEART	Human Employment and Resource Training
HURDAT	North Atlantic hurricane database
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter tropical Convergence Zone
IUCN	International Union for Conservation of Nature
JJA	June-July-August
MAM	March-April-May
NAH	North Atlantic High
NEEC	National Environmental Education Committee
NEPA	National Environment and Protection Agency
NGO	Non-governmental organization

ODPEM	Office of Disaster Preparedness and Emergency Management
PBCC	Portland Bight Citizens Council
PBFMC	Portland Bight Fisheries Management Council
PBPA	Portland Bight Protected Area
PBTC	Portland Bight Tourism Council
PIOJ	Planning Institute of Jamaica
PRECIS	Providing REgional Climates for Impacts Studies
RCM	Regional Climate Model
SDC	Social Development Commission
SE	Southeast
SFMA	Special Fisheries Management Areas
SGP	Small Grants Programme
SLR	Sea Level Rise
SON	September-October-November
SPI	Standardized Precipitation Index
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
STATIN	Statistical Institute of Jamaica
Tmax	Maximum Temperature
Tmin	Minimum Temperature
UDC	Urban Development Corporation
UNEP	United Nations Environment Programme

1. INTRODUCTION

Focus: Summary of the background of the area: size, ecological and biological importance of the area.

1.1 Overview of the PBPA

1.1.1 Extent

The Portland Bight Protected Area (PBPA) is the largest protected area in Jamaica. Its terrestrial area is 520 km^2 (200 mi^2) which represents 4.7 % of Jamaica's land mass. Its marine space is 1356 km^2 (524 mi^2) which is 47.6 % of the island's shelf (UNEP, 2009). The PBPA is located on the southern coast of Jamaica and spans southern sections of the parishes of St. Catherine and Clarendon, including coastline from east of Hellshire to almost Milk River (see Figure 1).

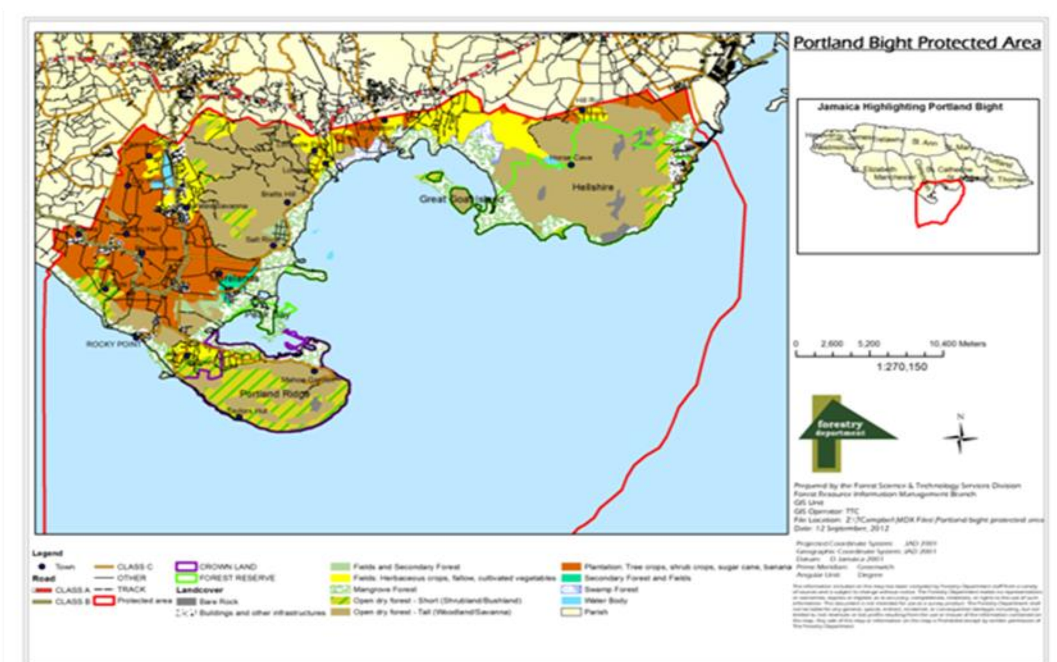


Figure 1 Map of Portland Bight Protected Area.

Much of the land area (41%) within the PBPA is occupied by the dry limestone forests of Hellshire, Portland Ridge and the Braziletto Mountain. Another 16% of the land area is wetlands with continuous mangroves (including the Great Salt Pond, Galleon Harbour, West Harbour, the Goat Islands and almost all areas between). Table 1 provides a summary of areal statistics. The PBPA also includes surrounding coastal land and the marine area out to the 200 metre depth contour (eleven nautical miles or approximately 20 km south of Portland Point). Nearby cays such as Little Goat Island are included in the protected area.

Table 1 Areal Statistics for the Portland Bight Protected Area (C-CAMF, 2013)

Statistic	Area	Notes
Land area	51,975 ha (201 mi^2)	= 5% of Jamaica's land area
Marine area	135,640 ha (524 mi^2)	= 48% of Jamaica's island shelf (53% of the south coast shelf)
Dry forest	21,025 ha (724 mi^2)	Area of Hellshire Hills = 11,400 ha Area of Brazilletto Mountains = 3,000 ha Area of Portland Ridge =4,200 ha
Wetlands	8,200 ha (31.7 mi^2)	= 4% of PBPA area
Total Area of PBPA	187,615 ha (724 mi^2)	

1.1.2 Settlements and Infrastructure

There are 49 residential communities within the PBPA - a number of which are directly on the coast (see Figure 2). The larger towns are Old Harbour Bay, Hayes and Lionel Town while large housing estates within the PBPA include Hellshire, Longville and New Harbour. Squatting is noted as an issue for the area, especially in Old Harbour Bay, Salt River and Portland Cottage and is spreading into the hills near Cockpit (C-CAMF 2013). Major infrastructure includes ports (e.g. Port Esquivel), railways, a section of highway 2000, factories and two power stations at Old Harbour Bay.

Two of Jamaica's largest fishing beaches – Old Harbour Bay and Rocky Point – fall within the protected area. The area also includes recreational beaches (e.g. Hellshire, Welcome Beach and Salt River Spa), and two small private marinas operated by Monymusk Gun Rod and Tiller Club and the PWD Gun Club.

There are three declared quarry zones within the PBPA - in the Brazilletto Mountains, Hellshire and the bed of the Rio Minho.

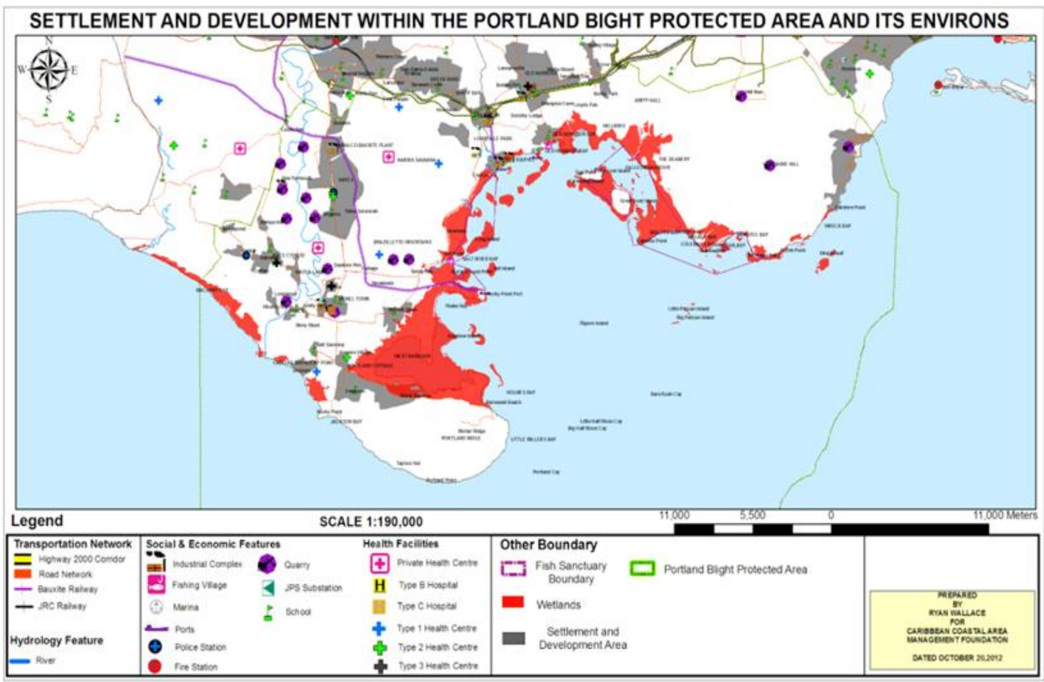


Figure 2 Settlements and Developments within the Portland Bight Protected Area. Source: (C-CAMF, 2013).

1.1.3 Ownership and Management

C-CAMF (2013) details the following about landownership in the PBPA: "Most of the land in the PBPA is owned in large blocks by the Commissioner of Lands or various government-owned organizations, including UDC (Hellshire Hills and the Great and Little Goat Islands), Sugar Company of Jamaica (Monymusk and Bernard Lodge) and J. Wray and Nephew (New Yarmouth). Jamalco owns the land around the Rocky Point port. National Housing Trust owns a block of land in the Brazilletto Mountains/Harris Savanna. The sugar lands of Monymusk and Bernard Lodge have been leased for 40 years to a Pan-Caribbean Sugar Company. The Portland Bight Cays and Portland Ridge are vested in the National Land Agency/Commissioner of Lands. Hellshire and Peake Bay are Forest Reserves. Portland Ridge is leased to two gun clubs, PWD Gun Club and Jacksons Bay Gun Club. JAMALCo owns the land (and wetlands) around the port at Rocky Point."

The National Environment and Protection Agency (NEPA) signed a delegation instrument with C-CAMF in 2003 for management of the PBPA. The delegation agreement expired in 2008 but NEPA is attempting to establish new arrangements in the form of a multi-agency Memorandum of Understanding for the PBPA (C-CAMF, 2012).

1.2 Ecological and Biological Importance

1.2.1 Ecosystems of the PBPA

The PBPA is an area of high ecological and biological importance (Figure 3). Its boundaries includes contiguous terrestrial, marine, wetlands and freshwater ecosystems. A summary of the characteristics of each ecosystem for the PBPA is given in Table 2. The PBPA is a habitat for at least 20 globally threatened species (CEPF, 2010). Table 3 provides a list of some species of importance for the region and their threatened status. Sections of the PBPA were officially named a Ramsar site in 2006, under the Convention on Wetlands (Ramsar, Iran, 1971). The Convention on Wetlands (also called the Ramsar Convention) is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the "wise use", or sustainable use, of all of the wetlands in their territories.

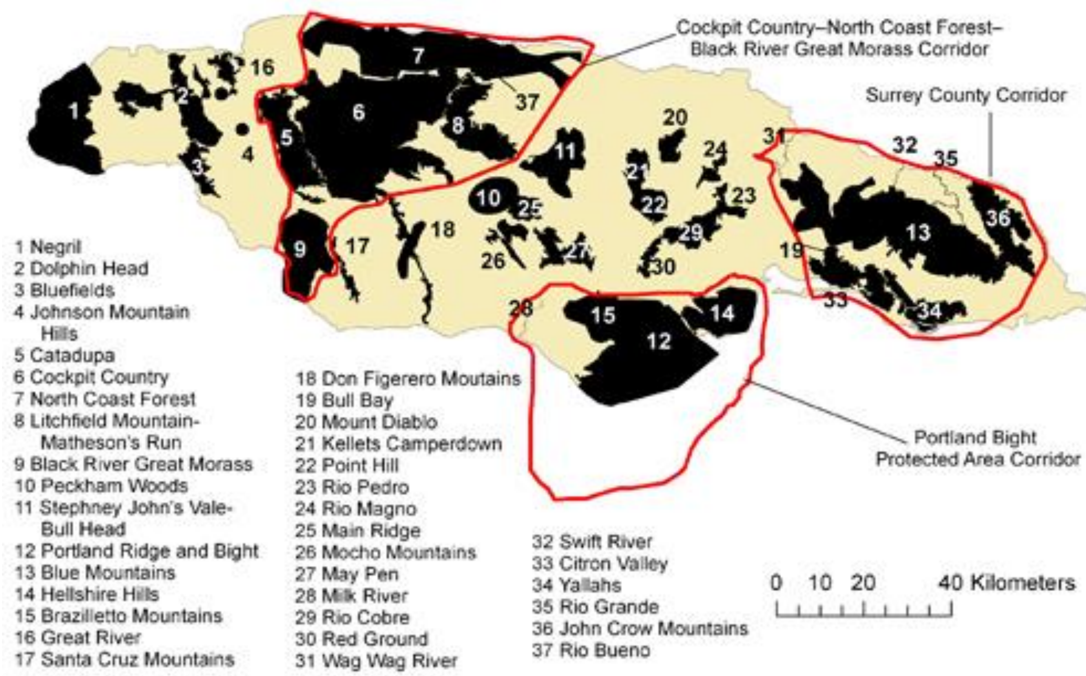


Figure 3 Map showing Key Biodiversity Areas across Jamaica (CEPF, 2010).

Table 2 Ecosystems of the Portland Bight Protected Area (Summarized from C-CAMF, 2013). IUCN is the International Union for Conservation of Nature.

Ecosystems	Notes
Wetlands	Mangroves occupy almost all the suitable coastline of the PBPA. The PBPA has the longest continuous stretches of mangrove coastline in Jamaica. The only freshwater marsh in the PBPA is at Cockpit Saltmarsh. The dominant species in the mangroves are red mangroves (*Rhizophora mangle*), black mangroves (*Avicennia germinans*), white mangroves (*Laguncularia racemosa*) and buttonwood mangroves (*Conocarpus erectus*). The dominant species in the salt marsh are *Typha domingensis* and *Phragmites australis*. Mangroves of the PBPA are home to a number of waterfowl including the West Indian Whistling Duck *Dendrocygna arborea* and crocodiles and provides a nursery for fish and other marine wildlife (CEPF, 2010). The American Crocodile which is found in the PBPA is an endangered species (IUCN) and is protected under the Wild Life Protection Act.
Freshwater	The PBPA includes a range of freshwater ecosystems ranging from the very large Rio Minho to many small springs. The majority of rivers and springs are on the plains.

	Many rivers, streams and gullies empty into the waters of the Portland Bight (e.g. Bowers River, Salt River, Cockpit River, Salt Island Creek, Bower's Gully, Breadnut Gully, Calabash Gully, Coleburn's Gully, Salt Gully). Drainage patterns have been much altered over the centuries to irrigate the sugar plantations and most smaller waterways have been channelized. Freshwater ecosystems have been noted to be amongst the least well conserved ecosystems in Jamaica.
Forests	The limestone hills of the PBPA support dry and very dry forests. Other types of forest and woodland include cactus thorn scrub that survives in the saline alluvial soils to landwards of some wetlands and coastal woodlands on berms beside the coast. The dry forests of the Hellshire Hills and Portland Ridge are discussed in more detail below.
Caves	The limestone landscape of sections of the PBPA support many caves, some of which are well known e.g. Two Sisters Cave, Jacksons Cave, and the Portland Cave (Fincham 1997). Many, however, have yet to be documented. The caves of the PBPA are the known habitat location for the Portland Ridge Land Frog Frog *Eleutherodactylus cavernicola*, and the only known location for a blind cave fish which is probably extinct. Several caves support bats. The rare and endangered Jamaican Funnel-eared Bat *Natalus jamaicensis* has been reported from Portland Cave.

Sandy beaches and cays are also part of the biodiversity of the PBPA. Sandy beaches (white sand and grey or black sand) are found around Hellshire and western Portland Bight. They support nesting sea turtles including Hawksbills *Eremochelys imbricate*, *G*reen Turtles *Chelonia mydas* and Leatherback Turtles *Dermochelys corriacea* (C-CAM, 2013). The beaches and cays also support the nesting of seabirds including Brown Noddies *Anous stolidus*, Bridled Terns *Sterna anaethetus*, the threatened Roseate Tern *Sterna dougalii* and Least Tern *Sternula antillarum* (C-CAMF, 2013). The Portland Cays also support endemic lizards.

The south shelf of Jamaica is at its widest off Portland Point. Much of this shelf area and the waters of the Portland Bight is mud and seagrass, with significant patch and fringing reefs. The seagrass beds are important habitat for finfish and shellfish, while the coral reefs are habitat for reef demersal fish. There have been several coral reef surveys which include the PBPA (see for example Linton et al. 2003; Linton, 2004, NEPA, 2007).

Table 3 List of some threatened species of importance found in the PBPA. Summarized from C-CAMF (2013). IUCN is the International Union for Conservation of Nature.

		IUCN Status
MAMMALS:	*Geocapromys brownii* (Jamaican Hutia) Endemic	IUCN Vulnerable (IUCN status based on 1980s surveys)
	Orysomys antilleana (Jamaican Rice Rat) Endemic	IUCN Not assessed.
	Trichechus manatus manatus (West Indian Manatee American tropics) EN.	Probably extinct. Occurs close to Hellshire shores.
BIRDS	*Siphonorhis americana* (Jamaican Pauraque) Endemic.	IUCN Critically endangered.
	Mimus gundlachii hillii (Bahama Mockingbird) Endemic sub-species.	IUCN Least Concern. Range restricted and thought to be declining. In Jamaica only occurs in PBPA.
REPTILES Lizards	*Celestus duquesneyi* (Blue-tail Gallywasp) Endemic to PBPA.	IUCN Data Deficient. May be critically endangered (Blair Hedges)
	Sphaerodactylus parkeri (Parker's Banded Sphaero) Endemic – very restricted range.	IUCN Not Assessed. May be endangered (Blair Hedges)
	Anolis valencienni (Jamaican Twig Anole) Endemic.	IUCN Least Concern. May be endangered (Blair Hedges)
	Cyclura collei (Jamaican Ground Iguana) Endemic.	IUCN Critically Endangered. Only found in Hellshire Hills.
	Spondylurus fuligius (Jamaican Skink) Endemic form.	IUCN Not assessed, May be critically endangered (Blair Hedges)
	Ameiva dorsalis (Ground Lizard) Endemic.	IUCN Not Assessed. May be endangered (Blair Hedges)
REPTILE Snakes	*Epicrates subflavus* (Yellow Snake). Endemic	IUCN Vulnerable. May be endangered (Blair Hedges)
	Trophidophis stullae (Portland Ridge Trope)	IUCN Not Assessed. May be critically endangered(Blair Hedges)
	Trophidophis jamaicensis (Jamaican Brown Trope) Endemic.	IUCN Not Assessed. May be endangered (Blair Hedges)
REPTILES Turtles	*Eretmochelys imbricata* Hawksbill Turtle Pan-tropical.	IUCN Endangered.

	Pseudemys terrapen Jamaican Slider	IUCN Vulnerable.
AMPHIBIANS Frogs	*Eleutherodactylus cavernicola* Portland Ridge Land Frog Endemic	IUCN Critically endangered.
PLANTS	*Bursera hollickii* Endemic	IUCN Not assessed May be endangered (Andreas Oberli)
	Lunania polydactyla Endemic	IUCN Vulnerable
	Opuntia jamaicensis Cactus Endemic	IUCN Not assessed. Known only from one site on road to Great Salt Pond (Hellshire) (George Proctor and Andreas Oberli)
	Phialanthus revolutus Endemic	IUCN Endangered

1.2.2 The Hellshire Hills and Portland Ridge

Dry forests within the PBPA cover an area of approximately 210 km^2. They include the Hellshire Hills (114 km^2), Portland Ridge (42 km^2) and the Brazilletto Mountains (30 km^2) (see again Table 1). The dry forests receive little rainfall (see section 2) and are comprised mainly of rugged limestone hills that arise from the karst topography which makes up most of Jamaica. McLaren and McDonald (2003b) note that the Hellshire Hills dry forest is one of the last remaining primary limestone forests in the Caribbean.

The dry forests of the PBPA provide a habitat for a number of bird, invertebrate and plant species endemic to Jamaica (Wilson and Vogel 2000). The forests are dominated by plants in the Rubiaceae, the Euphorbiaceae and the Myrtaceae families, though each range supports a slightly different composition of flora due to variations in rainfall and topography (Loveless and Asprey 1957) and level of disturbance. The Hellshire Hills support at least 271 plant species including 53 endemic species (Adams and DuQuesnay, 1970) with the dominant plant species being *Drypetes lateriflora*, *Metopium brownei*, *Bauhinia divaricata* and *Krugiodendron ferreum* (McLaren et al. 2005).

Significantly more has been documented about the biodiversity of the Hellshire Hills due to ongoing research programs undertaken by the University of the West Indies in that region of the PBPA. However, C-CAMF (2013) notes that *the Hellshire and Portland Ridge (and the more* *disturbed Brazilletto Mountains which lie between them) share many ecological characteristics and most species of concern in the PBPA occur in most or all of the* [aforementioned regions].

The Hellshire Hills also supports the last remaining population of the Jamaican iguana *Cyclura colei*. The Jamaican iguana, which was thought to be extinct by the mid 1900's, was rediscovered in the Hellshire Hills in 1970 and again in 1990 (UNEP, 2009). Since 2012 it has been listed among the world's 100 most critically endangered species (Wilson, 2013). Portland Ridge is the site of the rediscovery of the Blue-tailed Galliwasp (*Celestus duquesneyi*) which is also an endangered endemic reptile (Wilson and Vogel, 2000). Other plant and animal species of concern, include the Portland Ridge Land frog *Eleutherodactylus cavernicola*, Blue-tailed Gallywasp *Celestus duquesneyi*, Parker's Banded Sphaero *Spherodactlus parkeri*, Jamaican Skink *Spondylurus fulgidus),* Yellow Boa *Epicrates subflavus* Portland Ridge Trope *Trophidophis stullae* Plain Pigeon *Patagioenas inornata* and others, as well as the possibly extinct Jamaican Least Paruaque *Siphonorhis americana* and the Jackson's Bay blind cave fish (undescribed species) (C-CAMF 2013). The Portland Ridge Land frog *Eleutherodactylus cavernicola* is entirely restricted to caves within the Portland Ridge.

Dalling *et al.* (1998) suggest that *tropical dry forests are the most endangered and least understood major tropical ecosystem* and it is the recommendation of the Forestry Department (2001) that all of Jamaica's remaining dry forests should be set aside for uses compatible with conservation and forest restoration. The emphasis in the ensuing sections will be on the climate impact on the biodiversity of the Hellshire Hills and Portland Ridge.

1.2.3 Economic Value of the PBPA

There have been at least two economic valuations of the ecological services of the PBPA - see for e.g, Cesar *et al*. 2000 and Guingard, 2008[1]. Details of both valuations are provided by C-CAMF (2013) including a summary of the main ecological services provided by the PBPA ecosystems and a comparison of the management costs under three scenarios with the cost of effective management. According to C-CAMF (2013) both studies suggest that there are economic benefits to be had by protecting the PBPA. These include benefits already being

[1] Guingard et al (2008) is referenced in C-CAMF (2013) the full reference could not be ascertained.

accrued by virtue of the areas contribution to fisheries, coastal protection carbon sequestration, nutrient cycling, water supply and waste treatment.

The PBPA is an important region in the context of Jamaica's natural history and conservation of its precious ecosystem is necessary. In order to protect this hotspot of biodiversity, it is necessary to gain a thorough understanding of the climatic threats. These are considered in the ensuing sections.

2. PHYSICAL VULNERABILITY

Focus: Summary of the vulnerability of the area to climate.

2.1 Present climate of the PBPA

2.1.1 Rainfall

The rainfall climatology of the PBPA mirrors that of Jamaica as a whole. Jamaica has a primary dry season from December through April and a wet season from May through November. The wet season is interrupted by a brief dry period in late July/early August resulting in an early rainfall season (May-July) and a late (August –November) rainfall season (Figure 4). The late season rainfall peak is larger than that for the early season though rainfall totals vary from year to year due to the influence of global climatic fluctuations e.g. the impact of El Niño (Chen and Taylor 2002). As depicted in Figure 4 the bimodal pattern is as a consequence of global climatic mechanisms including the movement of the North Atlantic High (NAH), the appearance of warm sea surface temperatures (SSTs), a decrease in vertical shear and the onset of tropical and easterly waves (CSGM 2012).

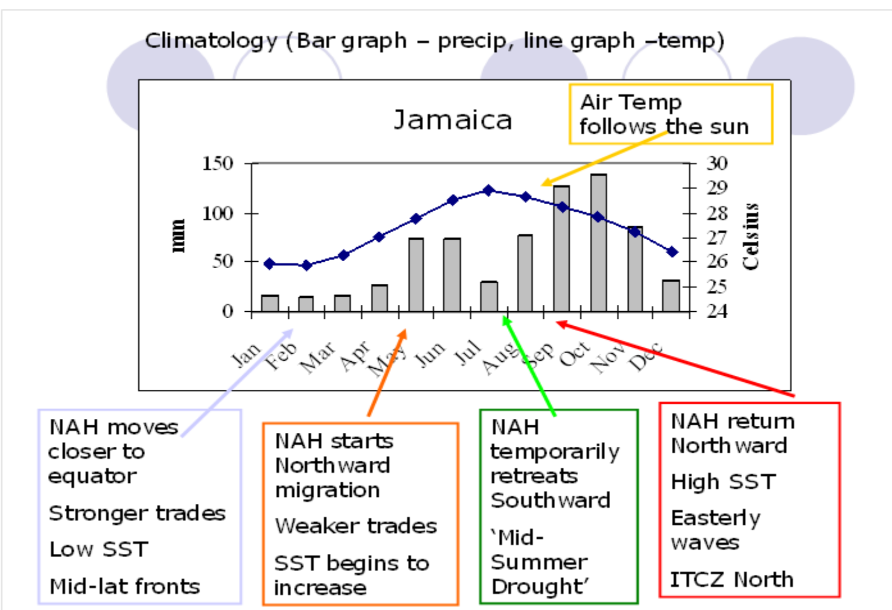


Figure 4 Rainfall and temperature climatologies of Jamaica. Bar denotes rainfall and line denotes temperatures. Schematic also shows timeline of large scale systems that affect the climate of the island throughout the year (CSGM, 2012).

The PBPA falls within the dry zones of Jamaica (Figure 5). The Meteorological Service of Jamaica records rainfall data for a number of stations within the PBPA. Figure 6a shows the location of 13 Meteorological Service stations which consistently reported rainfall data from 1992-2010. Figure 6b is a plot of the mean monthly totals for all 13 stations. The characteristic bimodal pattern of Jamaica rainfall is evident for all 13 stations with peaks in May and October. Unlike the mean Jamaica pattern, the onset of the summer rainfall minimum in the PBPA region is in June (as opposed to July), and the period of diminished rainfall persists through August. Except for four months (May, September, October and November), monthly rainfall totals never exceed 100 mm. In general 70-80% of the rainfall received in the PBPA falls between May and November, while 45-50% falls in the months of May, September, October and November.

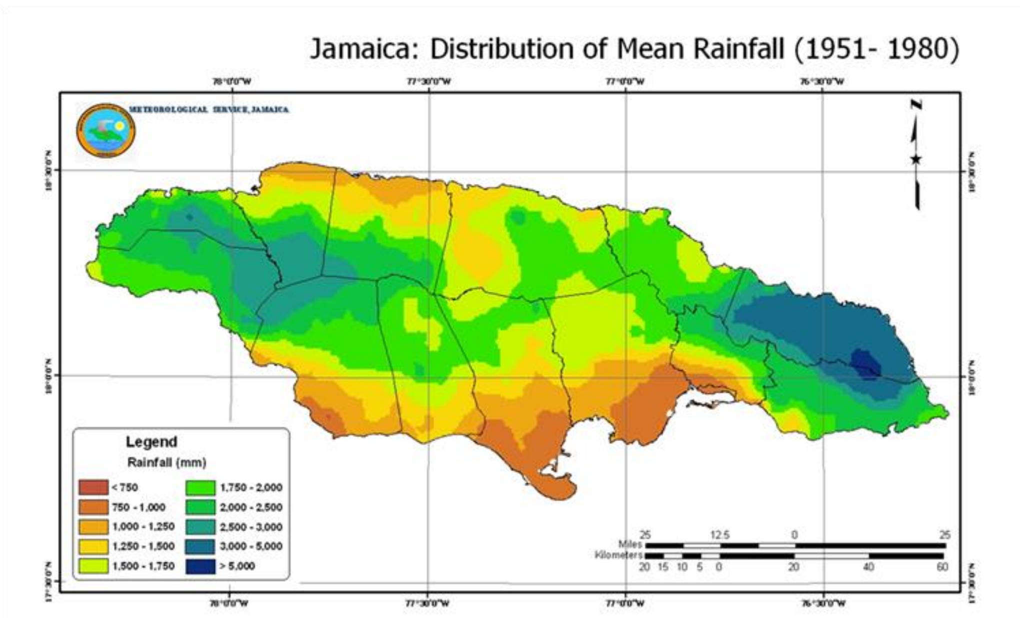


Figure 5 Mean annual rainfall distribution across Jamaica. Source: Meteorological Service of Jamaica.

There is spatial variability in the average rainfall across the PBPA (see again Figure 5). The gradient reflects decreasing rainfall going from west to east over the PBPA and from north to south i.e. approaching the coast. Both the Portland Ridge and Hellshire Hills forests fall within the driest regions of the PBPA. The Meteorological Service does not have any weather stations in either location, however, the University of the West Indies recently installed an automatic weather station in the Hellshire Hills in 2010. Though the dataset is too limited to make generalizations, readings taken over the course of 2010-2012 indicate that the rainfall is bimodal, concentrated over only a few months and of low total values (Figure 7b).

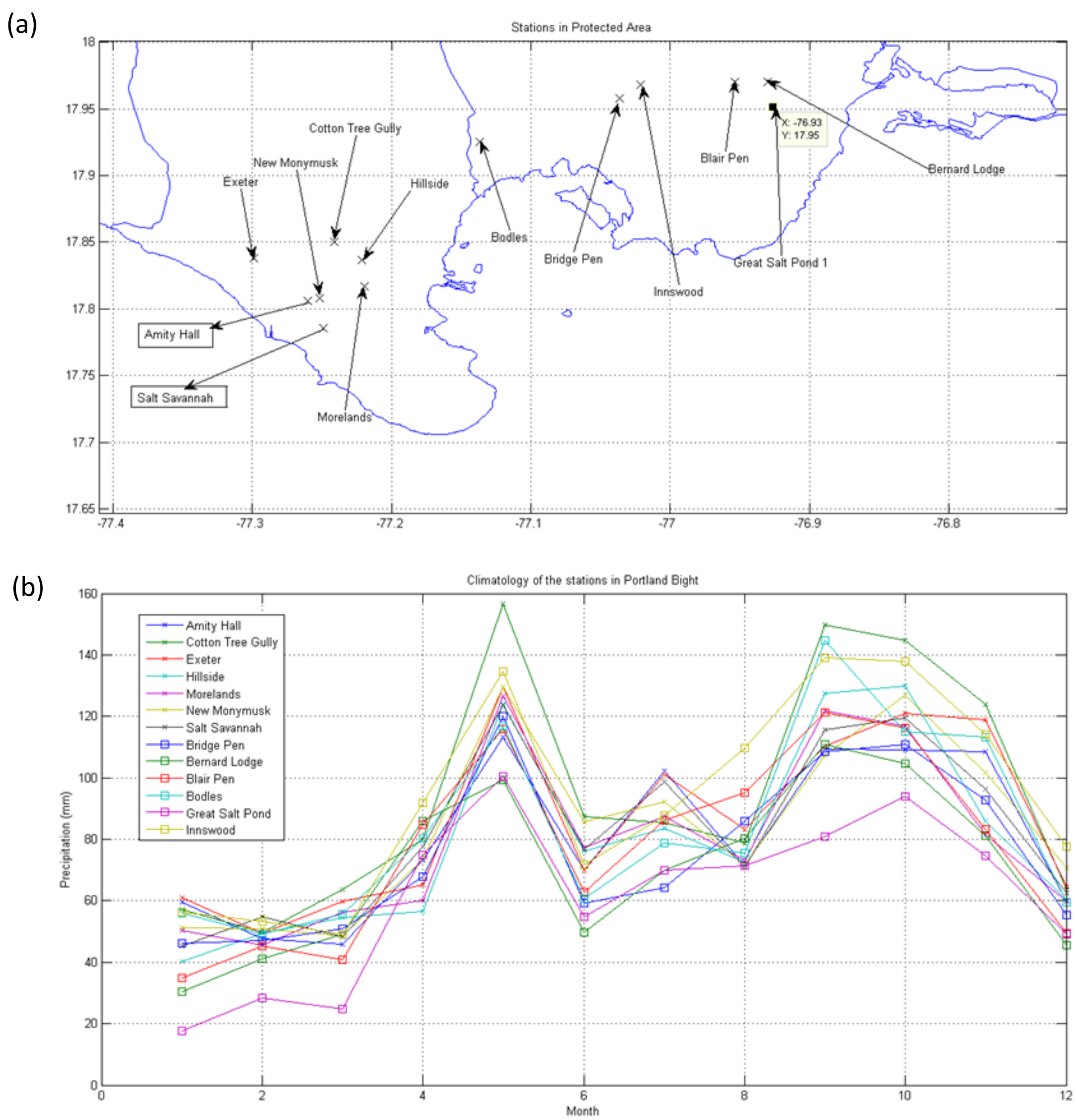


Figure 6 (a) Rainfall stations within the PBPA. (b) Mean monthly rainfall for 13 stations within the PBPA. Means calculated for 1992-2010. Data source: Meteorological Service of Jamaica.

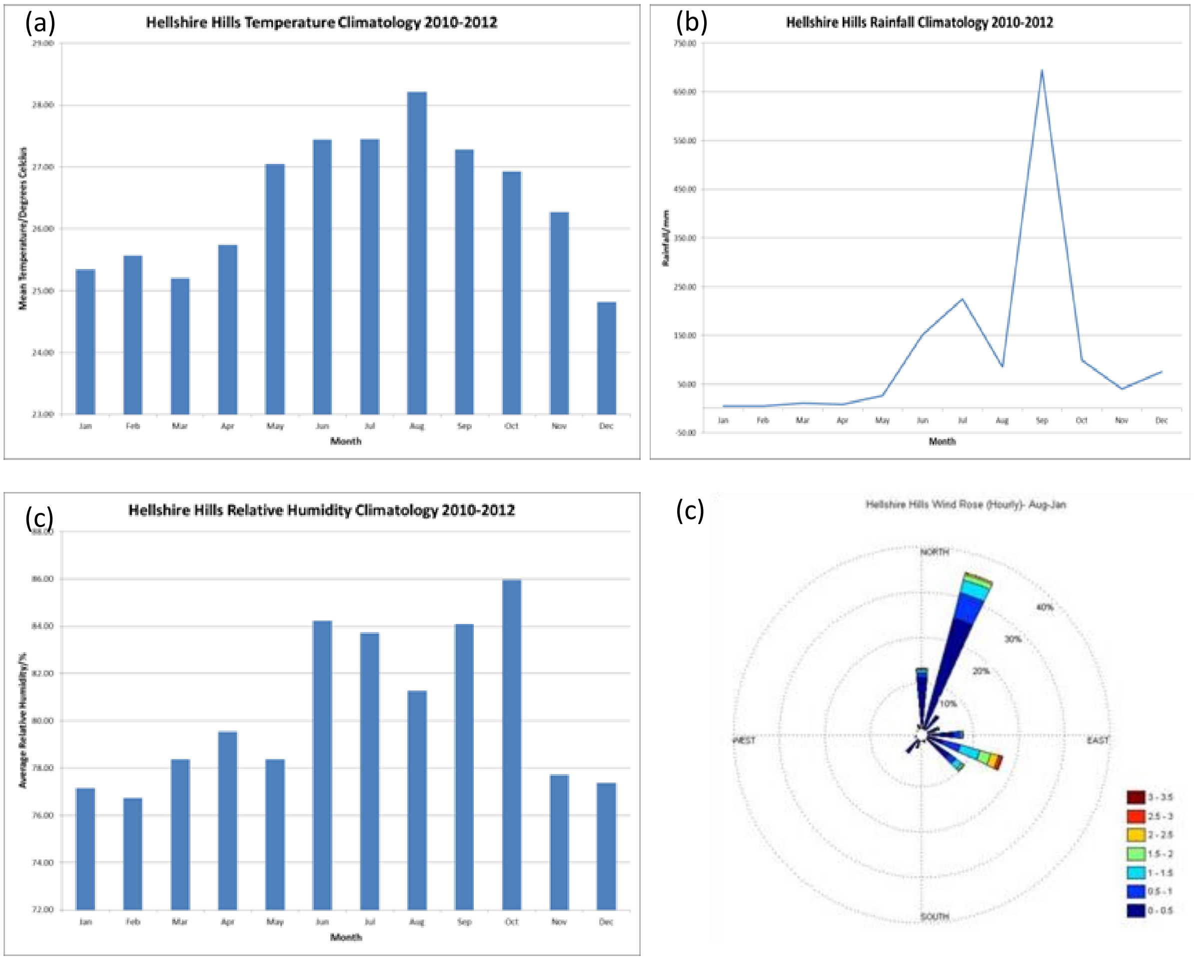
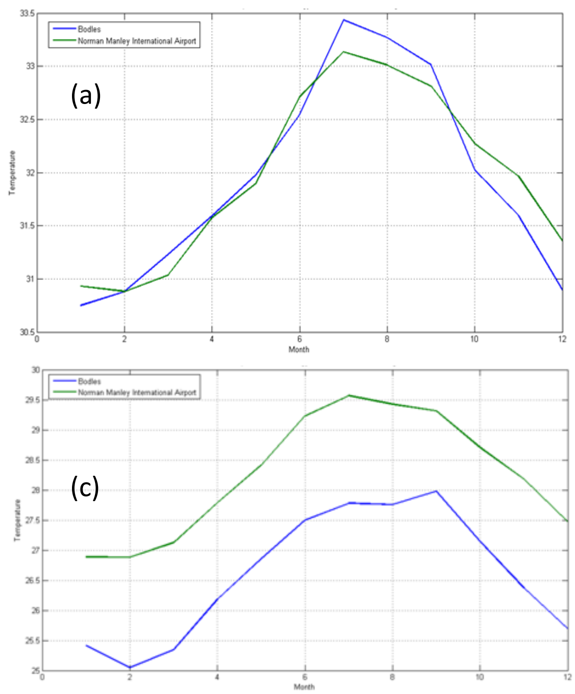


Figure 7 Climatologies of the Hellshire Hills over the period 2010-2012. The variables represented are a) temperature b) rainfall c) relative humidity (d) wind speed and direction. (Stephenson et al., 2012).

2.1.2 Temperature

There is significantly less long- term temperature data compared to rainfall data at stations within the protected area. This restricts the analysis possible. Figure 8 shows minimum, maximum and mean temperature variations for Bodles and for comparison Norman Manley. Table 4 gives the monthly mean temperature vales for Bodles. In the mean, annual temperature variation at Bodles is only three degrees (between 25 and 28 ^{o}C). The general pattern in the PBPA is one of cooler in Northern Hemisphere winter and warmer in summer with a peak in September. However, mean temperatures exceed 27 °C from June through October i.e. for at least five months for the year Figure 8a). The same is generally true for the Hellshire Hills (Figure 7a) suggesting that the PBPA is hot year round. Maximum day-time temperature at Bodles varies between 30 and 32 °C and peaks in July (Figure 8a). Minimum night-time temperature varies from a low of 19 °C in February to as high as 23°C in June and August (Figure 8b). The diurnal temperature variation is greater for Bodles than for Norman Manley due to lower minimum temperatures.

There is insufficient temperature data to enable analysis of spatial variations in temperature across the PBPA.



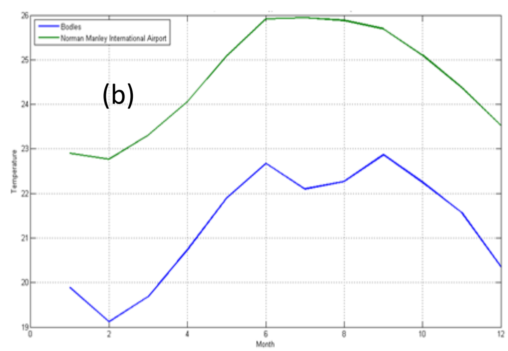


Figure 8 Mean monthly variation of (a) maximum temperatures (b) minimum temperatures (c) mean temperatures for Norman Manley and Bodles. Base period: 1992-2010. Data: Meteorological Service of Jamaica.

Table 4 Monthly Temperature Values at Bodles station for 1992-2008. Data Source: Meteorological Service of Jamaica.

Months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Temperature (°C)	25.4	25.0	25.30	26.2	26.9	27.5	27.8	27.8	28.0	27.1	26.4	25.7

2.1.3 Wind Speed and Humidity

In general, wind speeds vary inversely with rainfall i.e. peaking in February/March and June/July when it is driest. The data shown in Figure 9 is from the Norman Manley Airport. Analysis of data from that station indicate that winds were predominantly from the ENE to SE directions with light speeds averaging 6-8 m/s over 20 percent of the time i.e. outside of times of bad weather.

Relative humidity mirrors rainfall. It is highest in the wettest months (Figure 9) and lowest in the dry periods. Data from Norman Manley suggest that humidity attains maximum values of 90% in the wettest seasons.

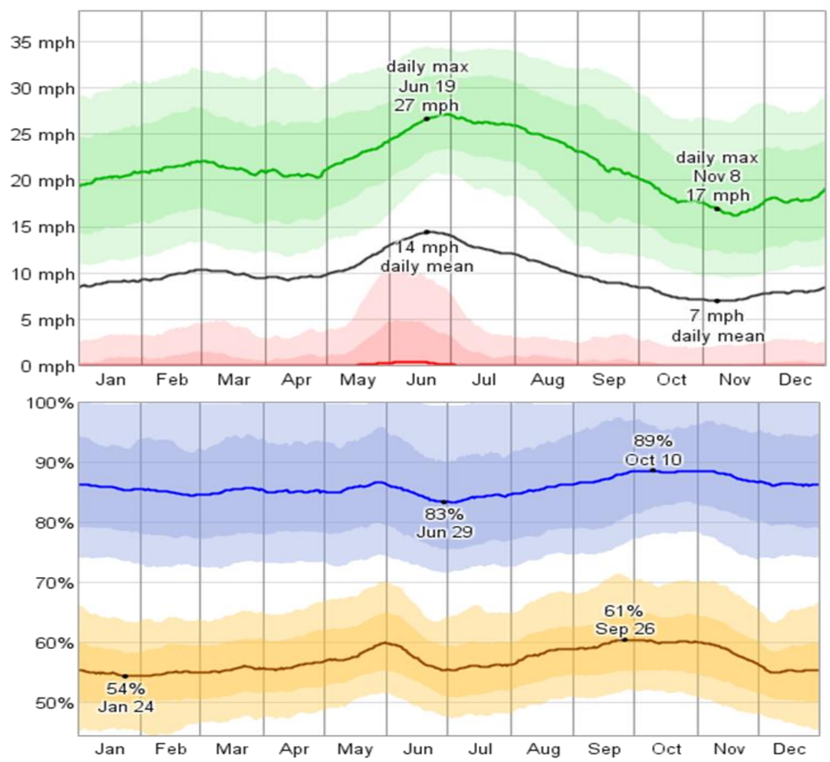


Figure 9 Climate data for Norman Manley Airport station. **Top**: The average daily minimum (red), maximum (green), and average (black) wind speed with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile). **Bottom**: The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer ba.ds from 10th to 90th percentile). Base period: 1974-2012. Source: http:// weatherspark.com

2.1.4 Hurricanes

Jamaica lies in the Atlantic hurricane belt and is prone to strong tropical systems and/or hurricanes. The hurricane season coincides with the wet season, with the likelihood of strong tropical cyclones peaking in September/October. Figure 10 depicts the number of hurricanes and tropical systems that passed within 200 km of Jamaica from 1940 – 2008. Of the 34 systems depicted, approximately two-thirds approached the country from the south.

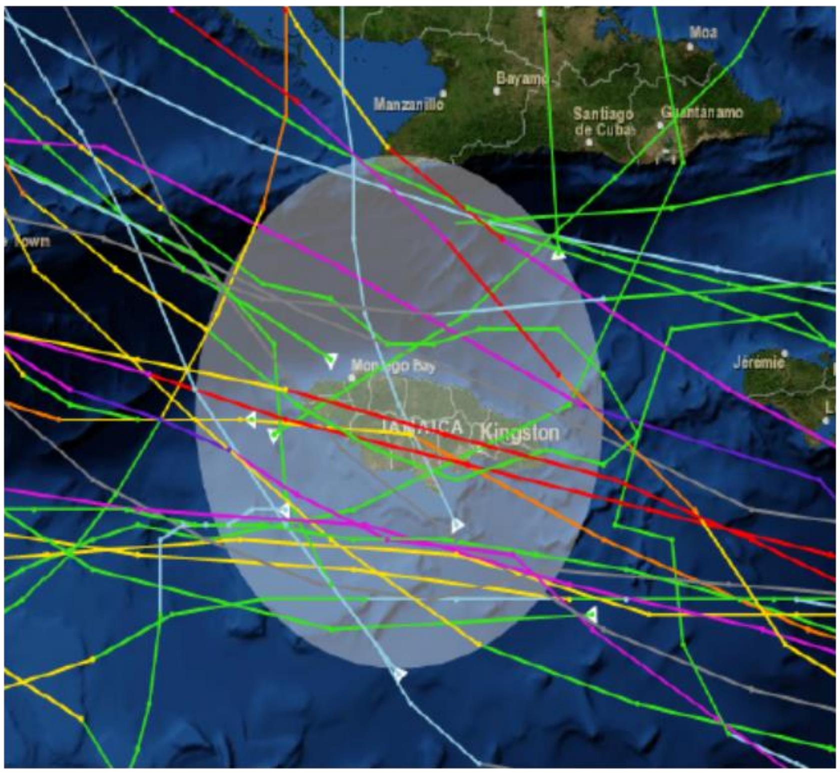


Figure 10 Hurricane and storms passing near (within 200 km) of Jamaica 1940-2008. Data source: HURDAT reanalysis.

2.2 Climate Trends and Future Projections

2.2.1 Temperature

Temperature trends within the PBPA are unlikely to be very different from that for the rest of the island. Data from the airport stations indicate historical warming of 0.20 – 0.31 °C per decade, with greatest warming occurring between June and August. There has been an increase in the number of warm days and nights, a decrease in cold days and nights, and a decrease in the daily temperature range (CSGM, 2012a).

Global Climate Models (GCMs) project that Jamaica's mean annual temperature will increase by 0.7 to 1.8˚C by the 2050s, 1.0-3.0˚C by the 2080s, and 1.1 to 3.2 degrees by the 2090s. Projected mean temperatures increase most rapidly in June-July-August (JJA). The frequency of 'hot' Jamaican days and nights will also increase, reaching 30-98% of all days annually by the 2090s. 'Hot' is classified according to current climate standards. 'Hot' days/nights are projected to increase most rapidly in JJA and SON. There will be fewer 'cold' days/nights, with these occurring on a maximum of 2% of days/nights by the 2080s. Cold days/nights decrease in frequency most rapidly in JJA. Similar patterns are projected for the PBPA from an analysis of temperature data for Bodles (Figure 11).

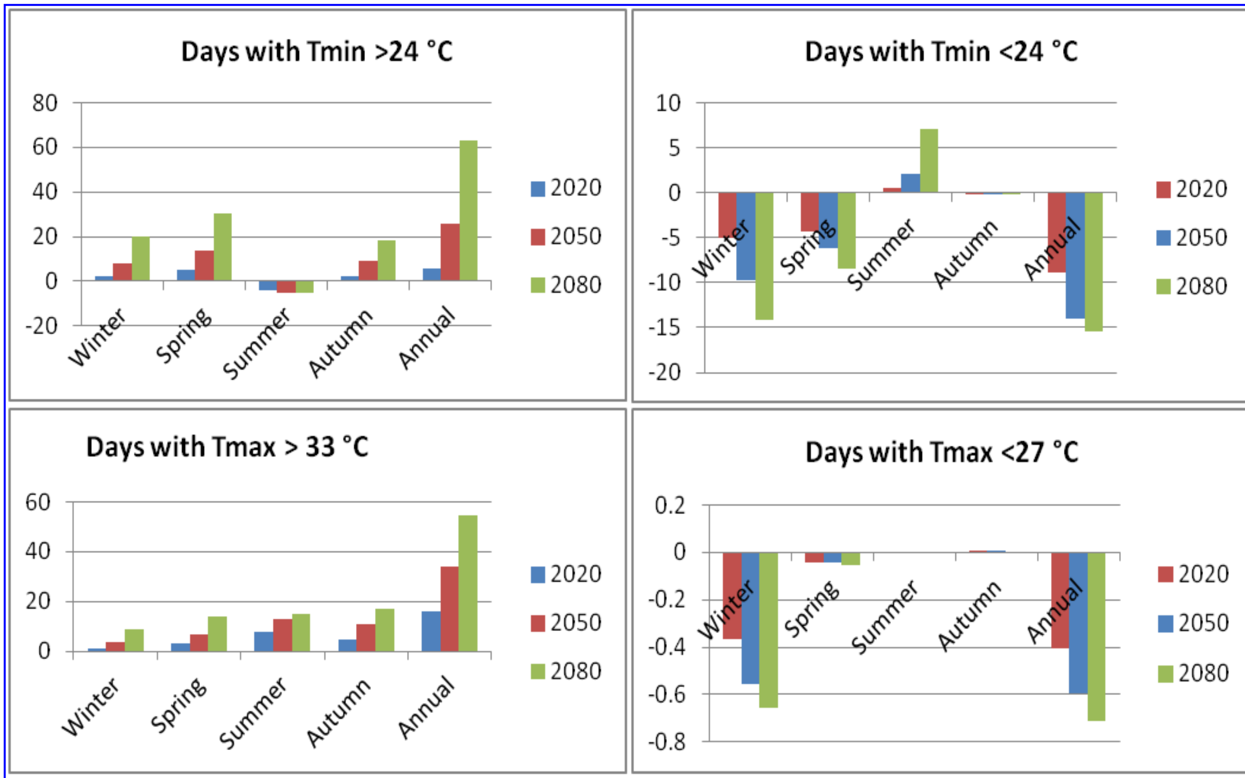


Figure 11 Projected temperature extremes. **Top**: Frequency of days with Tmin greater (left) less (right) than 24°C for SRES A2 scenario. **Bottom**: Frequency of days with Tmax greater (left) less (right) than 33°C for two SRES scenarios. Data for Bodles. (CSGM 2013 analysis).

The PRECIS Regional Climate Model (RCM) has been run over Jamaica. Results from the RCM indicate much more rapid increases in temperature than that projected by the GCMs. The RCM projects increases of 2.9-3.4˚C by the 2080s, with land surfaces warming more rapidly than the nearby ocean. PRECIS divides the island into grid boxes for analysis. Grid boxes 3, 4, 5 and 6 (see Figure 12) experience slighter higher warming than all the other grid boxes indicating that southern Jamaica is projected to warm faster than northern Jamaica. The PBPA falls in boxes 1 and 5. Data for these two grid boxes are summarised in Table 5 and indicate an overall average annual increase in temperatures between 2^{o}C and 3^{o}C by the end of the century. Greatest seasonal increase is projected for the May to June period.

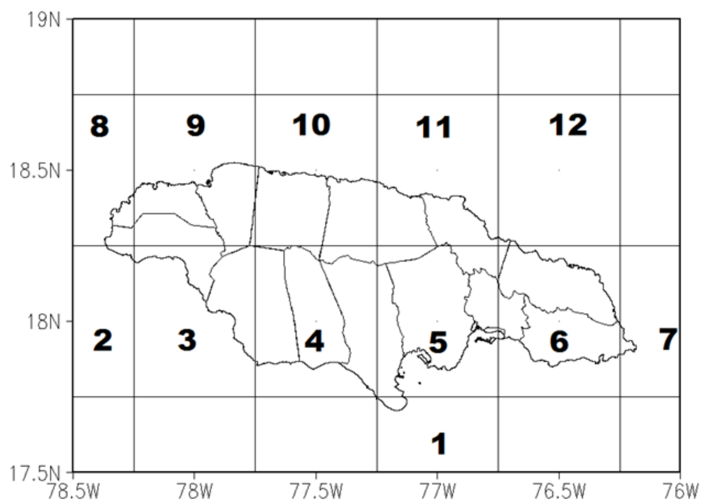


Figure 12 PRECIS RCM grid box representation at a resolution of 50 Km over Jamaica. Source: CSGM (2012a).

Table 5 Projected end-of century changes in temperature (°C) and rainfall (%), comparing baseline to the period 2071-2099. Projected changes are shown annually and seasonally for the A2 (worst case) and B2 (best case) SRES emissions scenarios for each of the 2 grid boxes representing the PBPA (CSGM, 2012a).

	A2			B2		
	GRID_1	GRID_5	*Average*	GRID_1	GRID_5	*Average*
	TEMPERATURE					
Annual	2.46	4.28	*3.4*	2.03	2.81	*2.4*
NDJ	2.43	3.39	*2.9*	2.06	2.34	*2.2*
FMA	2.64	3.95	*3.3*	1.99	2.91	*2.5*
MJJ	2.54	4.89	*3.7*	2.07	3.03	*2.6*
ASO	2.22	4.90	*3.6*	1.99	2.96	*2.5*
	RAINFALL					
Annual	-63.2	-51.5	*-57.4*	-38.1	-27.6	*-32.9*
NDJ	-58.2	-45.3	*-51.8*	-35.8	-21.6	*-28.7*
FMA	5.8	1.4	*3.6*	-12.3	-5.1	*-8.7*
MJJ	-70.3	-58.0	*-64.2*	-26.4	-24.3	*-25.4*
ASO	-74.5	-62.4	*-68.5*	-57.7	-40.4	*-49.1*

2.2.2 Rainfall

Between 1992 and 2010, areas of increasing rainfall occured over the centre of the island while areas of decreasing rainfall occured over the eastern and western parishes (Figure 13). For the same period, a 0.9-1.2 mm/year decrease in annual rainfall is noted for the lower part of the PBPA while a decrease of 0.9-0.6 mm/year decrease is seen over the remaining protected area. Long-term precipitation data for Jamaica also suggest small percentage decreases in the rainfall per decade for the late wet season (August-November) i.e. the period which accounts for the majority of the PBPA rainfall. The largest decrease is in the June-August period which corresponds to the mid-summer drought period of the PBPA (see again Figure 6).

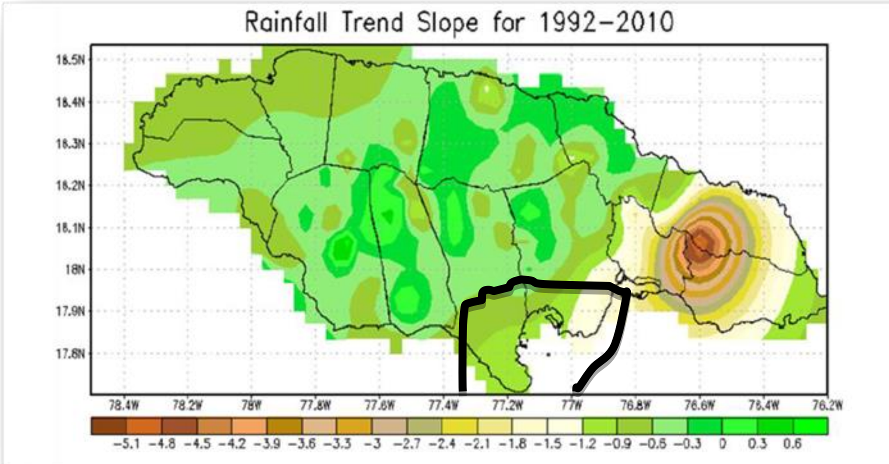


Figure 13 Rainfall trends for the period 1992-2010. A positive trend indicates increased rainfall, and a negative trend indicates a decrease. Rainfall trends over the PBPA are generally negative (CSGM, 2012a).

The trends noted above are, however, small and mean rainfall for Jamaica (as a whole) shows no statistically significant trend over the period 1880 to present. This is due to significant inter-annual (year-to-year) variability in the rainfall record associated with global fluctuations including El Niño. The year-to-year variability is superimposed upon decadal variability which manifests itself as groups of years for which rainfall is largely above normal (1930s, 1950s, early 1990s, 2000s) and years for which rainfall is below normal (1920s, 1970s). This pattern is noted in the records of three rainfall stations in the PBPA and in the Standardized Precipitation Index (SPI) derived from these records and plotted in Figure 14. Figure 14 also shows that since 2000, swings between extreme conditions (wet versus dry) have become more frequent in the PBPA i.e. there is a general pattern for increased short-term variability.

Statistically significant decreases have been observed in the proportion of total rainfall that occurs in ‘heavy’ events and in peak 1-day and 5-day rainfall for Jamaica (CSGM 2012a). These ‘trends’ should, however, be interpreted cautiously given the relatively short period over which they are calculated, and the large year-to-year variability in rainfall noted previously.

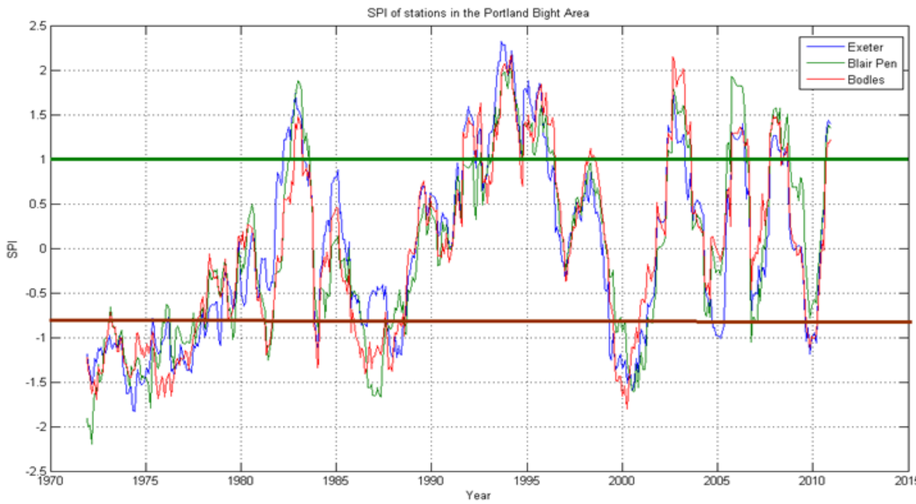


Figure 14 12 month Standard Precipitation Index (SPI) for three rainfall stations in the PBPA. SPIs are an index of very wet (above 1) and very dry (drought) (below -1) conditions.

GCM projections of future rainfall for Jamaica span both overall increases and decreases, but most models project decreases, especially by the end of the century. Projected rainfall changes range from -44% to +18% by the 2050s and -55% to +18% by the 2080s. The overall decrease in annual rainfall is strongly impacted by decreased July to August (early wet season) and September to November (late wet season) rainfall (-39% to +11%). The drying will firmly establish itself somewhere in the middle of the current century but until then, short term variability will be a strong part of the rainfall pattern, i.e. superimposed upon the drying trend.

The projections of rainfall extremes are mixed across the ensemble. By the 2080s the range of changes is -19 to +9% for the proportion of rainfall falling as heavy events and -29 mm to +25 mm for 5-day maximum rainfall.

The PRECIS RCM projections of rainfall for Jamaica are strongly influenced by which driving GCM provides boundary conditions. The most conservative simulations suggest moderate decrease in MAM and JJA rainfall, as well as in total annual rainfall (-14%). The more severe projections suggest significantly larger decreases in annual rainfall (-41%), and JJA and SON rainfall by the 2080s. The largest end-of-century decreases occur from May onward, and rainfall in the months of September through November is the most impacted. Rainfall in January through

April is least affected. Rainfall changes for the two grid boxes over the PBPA are given in Table 5. Like the rest of the island, annual drying is projected for the area. The PBPA is projected to be between 33 and 57 percent drier by end of century. Though greatest seasonal decrease is projected for the August to October period (late rainy season), there is potential for an increase in rainfall between February and March.

If one considers both the GCMs and the RCM the picture that emerges is of a Jamaica (and by extension the PBPA) which in the short term (2020s) will be slightly wetter than present day conditions but which will transition to a much drier state by the end of the century. Consensus from available data suggests that the 2020s will be wetter in the mean across all seasons except the early wet season (May through July). By the 2050s the country will be biased to being drier in the mean due to a decrease in rainfall during the traditional wet period (May through November), though the main dry season (December through March) may be slightly wetter. The same pattern will likely hold but intensify by the 2080s, when the models agree on a robust picture of drying (up to 60%) particularly during the two wet seasons (Watson 2010).

2.2.3 Hurricanes

Tropical cyclone activity in the Caribbean and wider North Atlantic Basin has increased since 1995 (CSGM 2012a). Both frequency and duration of hurricanes are increasing (CSGM 2012a) though how much of the increase is attributable to global warming is still the subject of research. The increase is in part attributable to the Atlantic being in the warm phase of a Multidecadal Oscillation. The resulting upswing in the number of hurricanes impacting Jamaica in the last decade is depicted in Figure 15. While the number of intense hurricanes has been rising, the maximum intensity of hurricanes has remained fairly constant over the recent past. El Niño and La Niña events strongly influence the location and activity of tropical storms. Generally, fewer hurricanes track through the Caribbean during an El Niño and more during a La Niña.

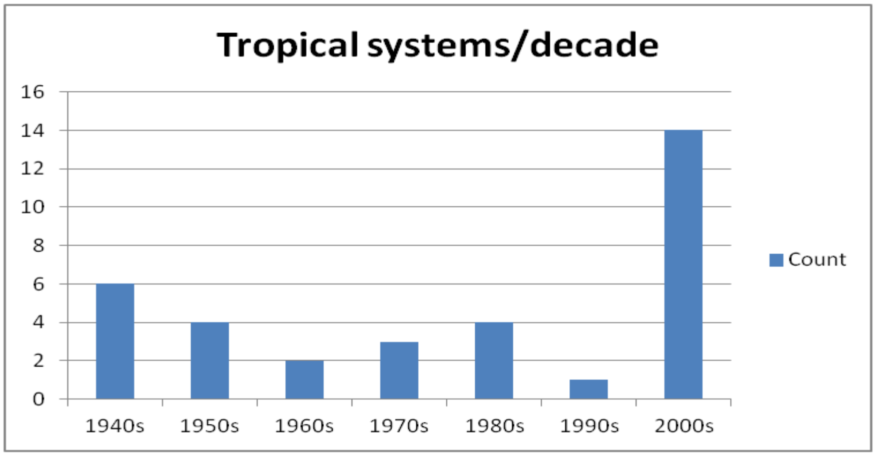


Figure 15 Number of tropical storms or hurricanes per decade to pass within 200 km of Jamaica (as depicted in Figure 10). Data for the 2000s only include up to 2008. Data source: HURDAT reanalysis.

Recent research suggests that there will be increases in rainfall intensity as well as in associated peak wind intensities and mean rainfall associated with tropical storms under climate change (see Table 6). Under a high emission scenario, one regional model (Knutson et al., 2008), projects an increase of 2.9% in the peak wind intensity of hurricanes in the Atlantic while a high resolution GCM for the North Atlantic (Oouchi et al., 2006) projects a 20% increase (see Table 6). There is no consensus on whether the frequency of tropical storms will increase. Though some studies show that the frequency of storms may decrease due to decreases in vertical wind shear in a warmer climate, many of the same studies suggest an increase in the intensity of the hurricanes when they do occur.

Table 6 Changes in near-storm rainfall and wind intensity associated with Tropical Storms under global warming scenarios.

Reference	GHG Scenario	Type of Model	Domain	Change in near storm rainfall activity	Change in peak wind intensity
Knutson et al., (2008)	A1B	Regional Climate Model (RCM)	Atlantic	(+37, 23, 10)% when averaged within 50, 100 and 400 km of the storm centre	+2.9%

Knutson and Tuleya (2004)	1% per year CO_2 increase	9 GCMs + nested RCM with 4 different moist convection schemes	Global	+12 - 33 %	+5 – 7 %
Oouchi et al (2006)	A1B	High Resolution GCM	Global	N/A	+14%
			North Atlantic		+20%

Source: CARIBSAVE Climate Change Risk Atlas – Jamaica (2012)

2.2.4 Sea Levels

It is estimated that global sea levels have risen by 0.17 ± 0.05 m over the 20th century. Satellite measurements suggest the rate of rise may have accelerated in recent years to about 3 mm/year since the early 1990s. Estimates of observed sea level rise from 1950 to 2000 show that rise in the Caribbean is near the global mean. Sea level measurements at Port Royal between 1955 and 1971 indicate a 0.9 mm/year rising trend.

Table 7 shows the range of sea level rise (SLR) projections for the globe and for the Caribbean by the century's end from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC 2007). Global mean sea levels are projected to rise by between 0.18-0.59 m by 2100 relative to 1980-1999 levels. Recent studies have challenged these estimates as being too conservative. Rahmstorf (2007) suggests that future SLR might be in the order of twice the maximum level of the IPCC report i.e. up to 1.4m by 2100 (see Table 7).

Table 7 Projected increases in sea level rise from the IPCC AR4.

Scenario	Global Mean Sea Level Rise by 2100 relative to 1980 – 1999	Caribbean Mean Sea Level Rise by 2100 relative to 1980 – 1999 (± 0.05m relative to global mean)
IPCC B1	0.18 – 0.38	0.13 – 0.43
IPCC A1B	0.21 – 0.48	0.16 – 0.53
IPCC A2	0.23 – 0.51	0.18 – 0.56
Rahmstorf, 2007	Up to 1.4m	Up to 1.45m

Source: CARIBSAVE Climate Change Risk Atlas – Jamaica (2012).

2.2.5 Other Variables

Increasing trends have been recorded in wind speed, number of sunshine hours and sea surface temperatures surrounding the island, but no statistically significant trend in relative humidity (CSGM 2012). Wind speed, sunshine hours and sea surface temperatures are projected to increase by the end of the century (CSGM 2012a).

2.2.6 Summary of Projected Changes

The likely change in key climate variables for the PBPA is summarised in Table 8 below and Figure 16. Figure 16 presents results for two climate change scenarios and for both there is simultaneous warming and decrease in rainfall projected for the PBPA by the 2080s, particularly over the early and late wet seasons. October is projected to experience the greatest percentage change in both variables. These two factors suggest a much drier climate in the PBPA year-round with higher rates of evaporation coupled with monthly decreases in relative humidity.

Table 8 Summary of projected changes in climate variables for the PBPA.

Variable	Projected end-of-century change
Temperature	Warmer (up to 3 degrees in the annual mean); more hot days and hot nights
Rainfall	Highly variable through middle of century. Significantly drier (up to 60% less rainfall) by the end of the century, particularly during traditional wet season.
Hurricanes	More intense when they do occur. Greater wind speeds and more mean rainfall.
Sea Level Rise	Up to 2 m likely.

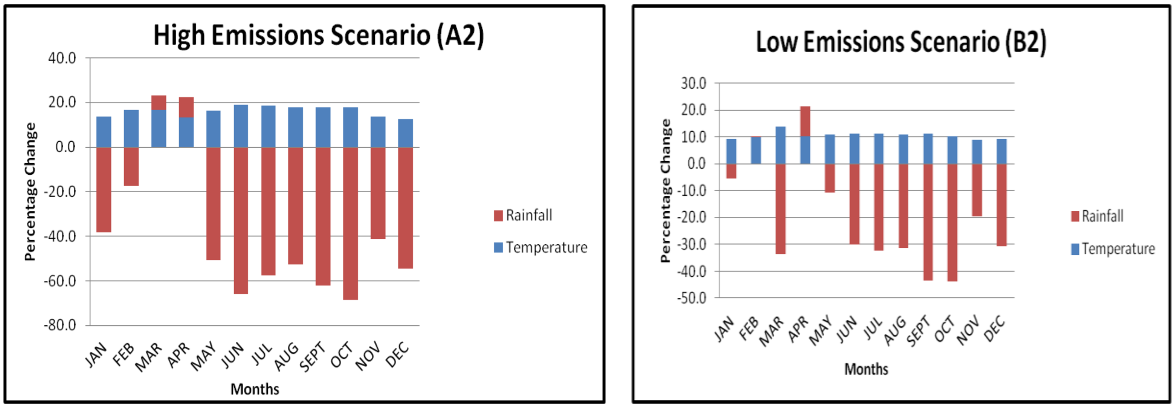


Figure 16 Projected percentage change in monthly rainfall and temperature by the end of the century under high (left) and low (right) emission scenarios. Projections are from the PRECIS model and for the grid boxes covering the PBPA.

2.3 Climate Hazards

2.3.1 Floods

Flooding associated with rainfall extremes pose a significant climatic threat to the PBPA region. Notwithstanding its location in the dry zone of Jamaica the PBPA is susceptible to flooding (Figure 17) because of its location which includes the lower halves of two watershed management units, the Rio Cobre and the Rio Minho. The watershed units stretch from the central spine of Jamaica to the coast, with the lower watersheds including the coastal alluvial plains. In the wet season, the alluvial plains are very vulnerable to severe flooding due to heavy rainfall events (ORM-Tecsult 2002).

The passage of recent extreme weather events highlights the vulnerability of the PBPA. For example, the continuous rainfall due to antecedent conditions leading up to Hurricane Nicole resulted in sections of the PBPA receiving 200-300% more rainfall during two days than typical for the entire month of September (Figure 18a). PIOJ lists several communities within the PBPA as severely impacted by the system (Figure 18b) (PIOJ 2010). Similarly the amount of rainfall received in the PBPA during over September 10-12, 2004 during the passage of Hurricane Ivan was greater than the total mean rainfall for the PBPA for January to April. Flooding from Ivan contributed to excessive damages in the PBPA (PIOJ 2004).

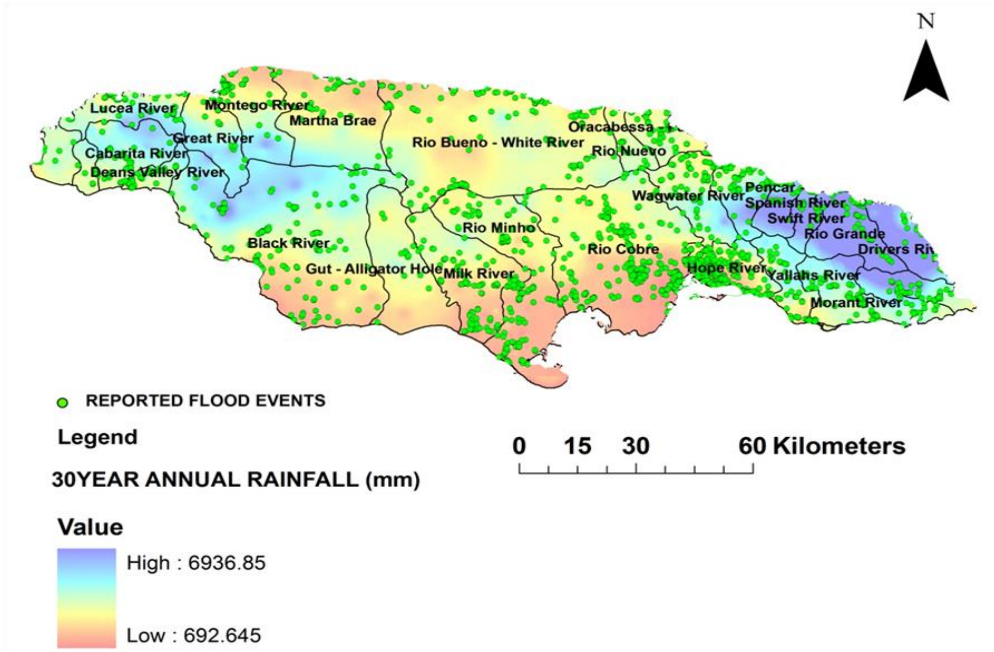


Figure 17 Map of Jamaica showing the watersheds and flood prone communities with relation to the rainfall pattern. Dots are communities reporting floods from 1904 to present. Source: Taylor et al. (2013).

Flooding will remain a climate change risk for the PBPA, notwithstanding that the region is projected to become drier under climate change by the end of the century under climate change (see again section 2.2.2). As noted in Table 7, it is projected that for the immediate future the rainfall regime will be highly variable (through to the middle of the century), with the drying signal dominating in the years thereafter. Even under the drier regime, rainfall extremes will still occur, though perhaps less frequently.

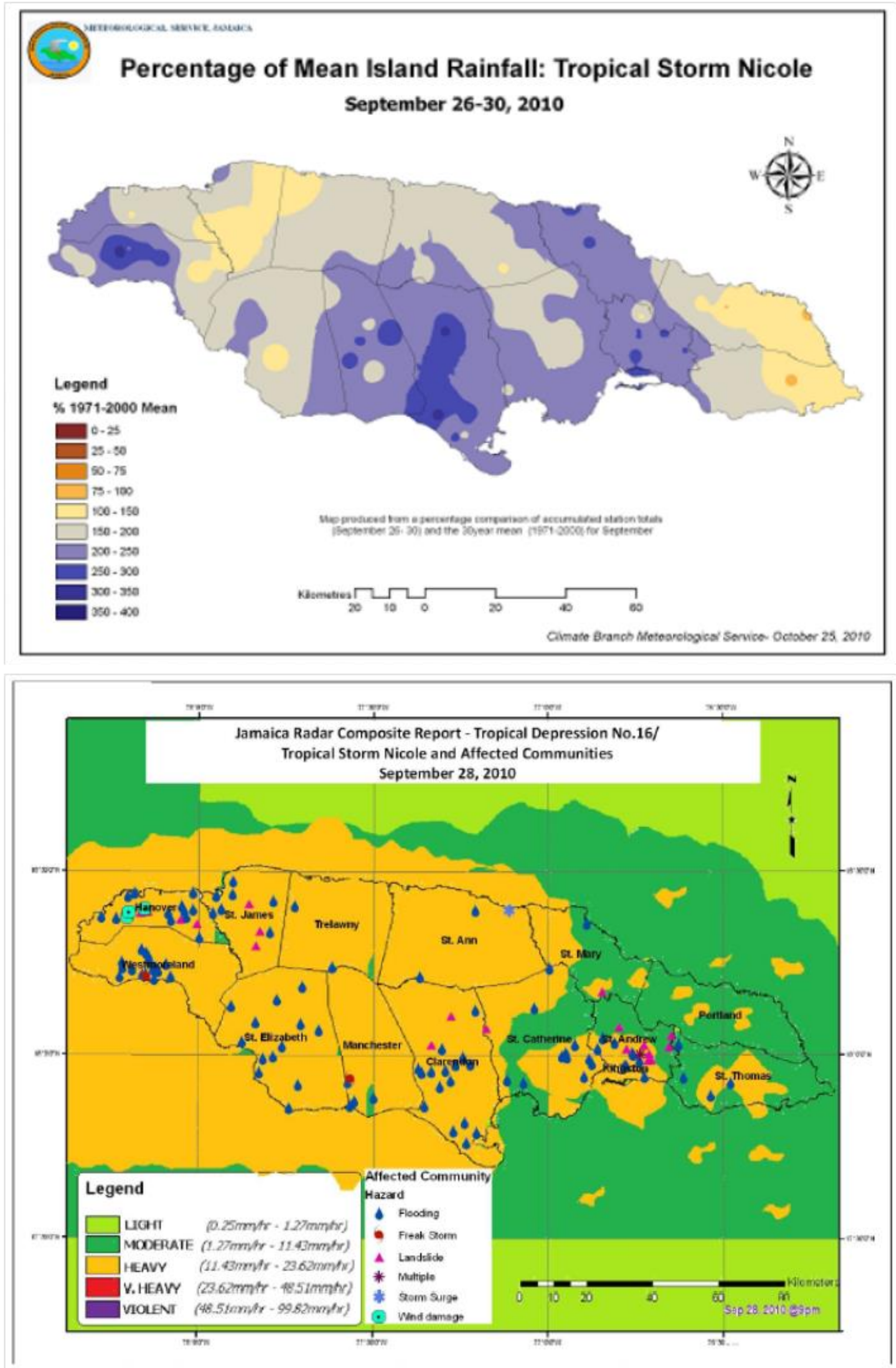


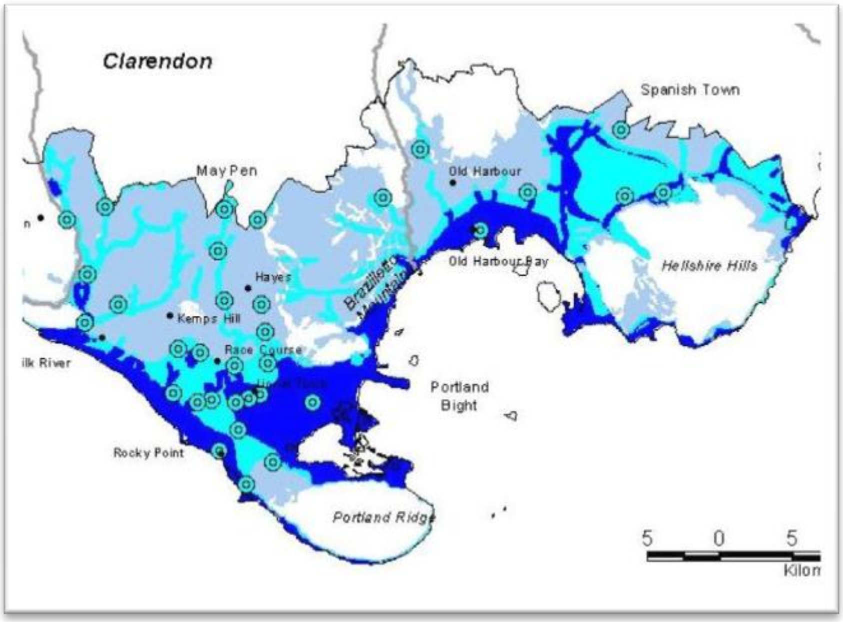
Figure 18: Top: Percentage of mean island rainfall for September due to Tropical Storm Nicole. Bottom: Rainfall on September 28, 20120 due to Hurricane Nicole and affected communities. Source: PIOJ (2010).

2.3.2 Storm Surge

In addition to being vulnerable to flooding associated with extreme rainfall from hurricanes, the PBPA exhibits present vulnerability to storm surge caused by the tropical systems. The bathymetry and general configuration of the Portland Bight, makes the area susceptible to storm surges from hurricanes, especially if the eye of a hurricane passes very close to or over the Bight. The low-lying coastal plains at the south of the PBPA cause the coast of the protected area to be particularly sensitive to increases in the mean sea level (Figure 19a). The areas in blue in Figure 19a largely mirror those areas below 10 m which have the potential for flooding (Figure 19b). The communities of Hellshire Hills and Portland Cottage are particularly vulnerable based on their physical characteristics (sub-tropical dry forest, mangroves and swamps) and their proximity to the coast. In the coastal community bordering the Hellshire Hills the soil is described as 'terra rosa' and is generally impermeable. The Portland Cottage community operates on the borders of the Portland Ridge and can be primarily described as flat and dry.

Hurricane Ivan (2004), Dean (2007) and more recently Hurricane Sandy (2012) have emphasized the susceptibility of the PBPA to weather induced damage, particularly damage due to storm surge. After Dean severe flooding in Old Harbour Bay forced people to retreat to the upper floors of the few houses that had two stories (CEAC, 2009). In Portland Cottage, a community previously devastated by Hurricane Ivan in 2004, surges and flooding due to Dean were accompanied by water logging of the ground and downed power lines (PIOJ 2007). From survey reports, CEAC (2009) estimates that hurricane Dean (2004) caused storm surges of 4.2 m in sections of the PBPA while hurricane Ivan (2003) caused storm surge of 2.2 m. Table 9 shows estimated storm surge effects caused by Hurricane Dean as extracted from data produced by the Marine Geology Unit, UWI. The estimates are in line with previous studies which suggest that hurricanes which track south of Jamaica but in close proximity to its coastline (e.g. Hurricane Charlie in 1951) can cause storm surges of greater than 1 m (Portland Bight around to Old Harbour or in excess of 4 m (Hellshire) (Figure 20). Recall from Figure 10 that just over two-thirds of all storms which pass within 200 km of Jamaica track south of the island, with a tendency to come from the east or southeast. CEAC's (2009) analysis further notes that that there is a deep-water wave height of 7.8 m for eastern waves and 7.0 m for northeast or western waves over a 100-year return period. “These are relatively large waves capable of wreaking severe damage on coastal infrastructure” (CEAC, 2009).

(a)



(b)

Figure 19 (a) Flood hazard map for Portland Bight. Dark blue indicates areas of highest risk, circles indicate where floods were recorded up to 2002 (Halcrow, 2002). (b) Potential flood areas of Jamaica below 10 m. (PIOJ, 2007).

The CARIBSAVE Climate Change Risk Atlas for Jamaica (Simpson et al., 2012) notes that there will likely be changes to the frequency or magnitude of storm surges experienced at coastal locations in Jamaica “as a result of the combined effects of: (a) Increased mean sea level in the region, which raises the base sea level over which a given storm surge height is superimposed. (b) Changes in storm surge height, or frequency of occurrence, resulting from changes in the severity or frequency of storms. (c) Physical characteristics of the region (bathymetry and topography) which determine the sensitivity of the region to storm surge by influencing the height of the storm surge generated by a given storm.” Given that projections are for more intense hurricanes under climate change, there is an enhanced risk to the PBPA due to this climate hazard. The risk is further enhanced by the prospect of higher sea levels (see previous discussion in section 2.2.4).

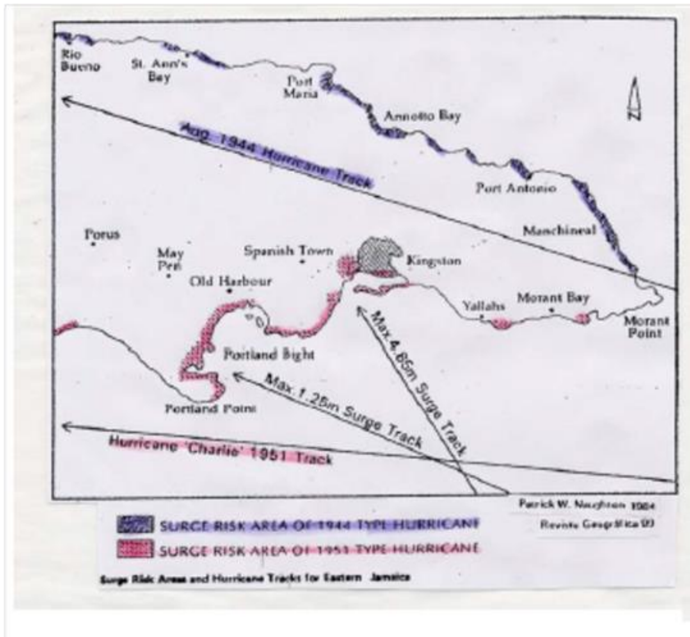


Figure 20 Storm surge for different hurricane tracks. Source: Noughton (1984).

Table 9 Extent of storm surges caused by Hurricane Dean.

2.3.3 Location	2.3.4 Maximum Surge Height (m)	2.3.5 Run-Up Distance (m)
Port Henderson Beach	3	80
Port Henderson Road	4	54
Hellshire Beach	3	383
Old Harbour Bay	3.5	573
Portland Cottage	3	1000
Rocky Point	¼	20

2.3.6 Forest Fires

The hot-dry climate of the PBPA makes the forested regions susceptible to forest (‘bush’) fires. Forest fires are linked to extended dry periods and warm temperatures. Given that Jamaica’s mean temperatures are warm year round, forest fires in Jamaica are linked to the climatological dry periods i.e. December through April and June/July. No studies could be found which analysed the occurrence of forest fires for Jamaica or for the PBPA though anecdotally and from newspaper reports the association of forest fires and the dry months is apparent for the country as a whole. Figure 21 shows the number of bush fires reports received and logged by the May Pen Fires Station for January to May 2011 and March to December 2012. No distinction is made for the reported location of the fire and the cause of the fire (if determined) was not noted in the log. The plots seemingly confirm a robust climate-bush fire link for the parish, as the number of reported fires peaks in the dry periods and falls of significantly during the wet seasons.

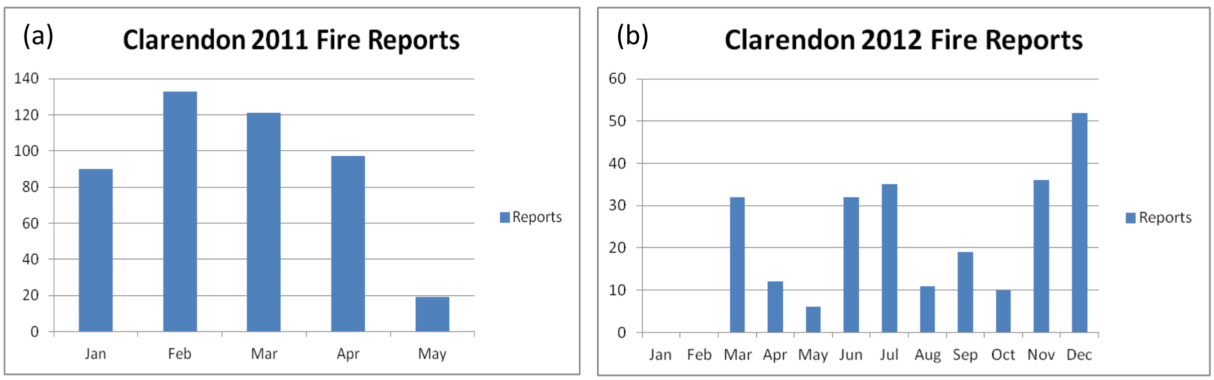


Figure 21 Number of reported bush fires per month logged by May Pen Fire Station, Clarendon. (a) 2011 (data available only for January to May) (b) 2012 (data available March to December). Data Source: May Pen Fire Station.

The Jamaica National Fire Management Plan (2002) notes that "The threat of bush fires is further increased during drought conditions." The Plan further states that "reports from the Jamaica Fire Brigade indicated that 2599 bush fires occurred during the period January to June 2000. These increased figures were attributed to the conditions caused by meteorological drought from December 1999 – August 2000." The increased frequency of occurrence of drought conditions in the recent past (see again Figure 14), and the likelihood of increased variability in rainfall conditions through mid century means that the PBPA will likely be under repeated threat of forest fires for some time to come. The projection for significantly drier and hotter conditions by the end of the century means further suggests significantly enhanced risk from forest fires and the possibility of an extended forest-fire season beyond April.

2.3.7 Sea Level Rise (Inundation)

Low lying coastal areas of the PBPA are vulnerable to inundation under projected sea level rise of up to 2 metres. Figure 22 depicts the regions of inundation under sea level rise of up to 5 feet (1.5 metres). Vulnerable areas include Portland Cottage, sections of Old Harbour Bay, Goat Island and Carbarita Point.

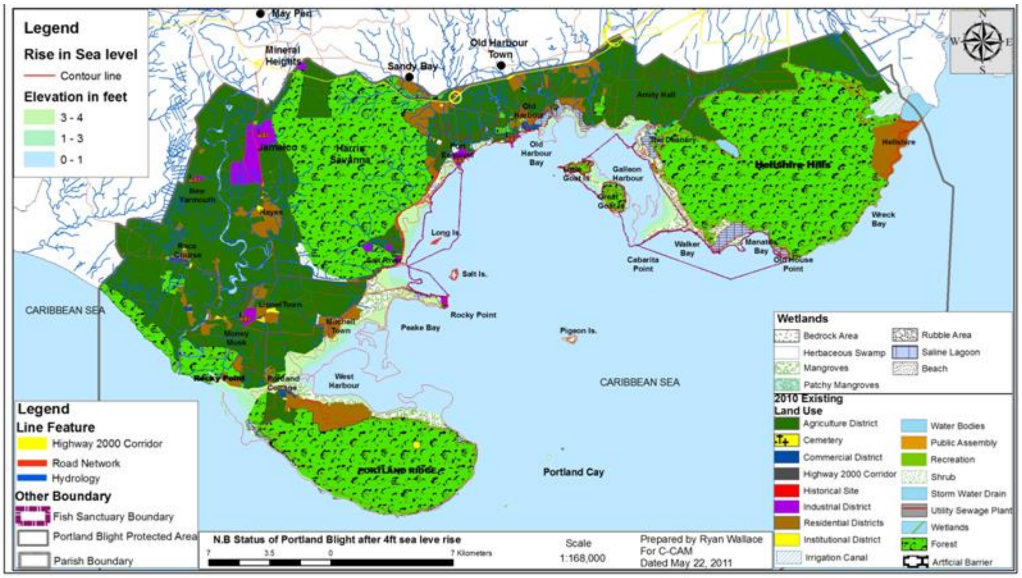


Figure 22 Impact of sea level rise up to 1.5 metres on the PBPA.

2.3.8 Summary of Impact of climate change on Climate Hazards

Table 10 below summarizes how the climate hazards for the PBPA are likely to be altered under climate change.

Table 10 Summary of climate change impact on climate hazards to which the PBPA is prone.

Hazard	Projected climate change Impact
Flooding (Rainfall)	Risk enhanced at least through middle of century due to projected variability in rainfall extremes.
Storm Surge	Higher surge and farther fetch likely due to stronger hurricanes and higher sea levels.
Forest Fires	Increased incidence due to projected variability in rainfall extremes through middle of century. Extension of forest-fire season likely by end of century due to significant projected drying.
Inundation (Sea Level Rise)	Loss of low lying coastal land area due to higher projected sea levels.

3. CLIMATE RISKS

Focus: Summary of the risk posed to the biodiversity of the Portland Bight Protected Area by climate change.

3.1 Introduction

The PBPA consists of sensitive ecosystems which are rich in biodiversity. The balance that ensures species survival in these ecosystems is being threatened under climate change. There are very few studies exclusively documenting the impact of climate variations on any timescales on the biodiversity of the PBPA. The climate risk to the biodiversity of the PBPA's is deduced from wider studies and from the evidence provided by the impact of recent extreme weather events. The examination is done for the ecosystems identified in Chapter 1 and for landmark species endemic to the PBPA.

3.2 Mangrove Wetlands

Most of the mangroves in the PBPA fringe the coastline. Approximately 16% of the land area is wetlands with continuous mangroves (including the Great Salt Pond, Galleon Harbour, West Harbour, the Goat Islands and almost all areas between). The PBPA has the longest area of contiguous mangrove coastline in Jamaica. The mangrove wetlands are part of the Portland Bight Wetlands and Cays Ramsar Site.

The main mangrove strands are the black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and red mangrove (*Rhizophora mangle*).

Upland debris and sediments are carried into some of the coastal mangrove wetlands of the PBPA through the lower halves of Rio Minho and Rio Cobre watershed units. These watersheds carry sediments and debris responsible for sedimentation within the coastal mangroves.

3.2.1 Climate Risks

Physical Damage

Hurricanes are usually at their greatest overland strength at initial landfall having been fuelled by warm sea temperatures (Doyle et al., 1995). Mangroves are particularly sensitive to storm and hurricane winds because of their exposed location within the intertidal zone, their shallow root systems and the noncohesive nature of the forest soils (Cahoon et al., 2006). The mangroves which fringe the coast of PBPA are particularly exposed to hurricane impacts due to their location on the south coast and the preferred track of hurricanes impacting Jamaica (see previous section). During hurricanes they are exposed to increases in wind shear which can cause physical damage such as windthrow, branch loss and defoliation. Sites within the hurricane's eye path can experience blowdowns of 50-100% of the standing biomass (Doyle et al., 1995). Figure 23 depicts typical physical damage to mangrove forests by hurricane winds.

Figure 23 Typical physical damage to mangrove forests by hurricane winds.

Hurricane Gilbert in 1988 resulted in mangroves across Jamaica being severely damaged, with losses of up to 60% of trees in some areas (UNEP/CEP, 1989). In the PBPA, the large red mangroves between Great and Little Goat islands were badly damaged in hurricanes Ivan (2004) and Dean (2007) (PIOJ, 2004; PIOJ, 2007). Ivan and Dean also highlighted the vulnerability of the mangroves to event frequency i.e. mangroves reach maturity in 20-25 years and the ability to regenerate is limited between two events occurring ‘back-to-back’.

There is enhanced risk of increased physical damage to mangrove forests in PBPA due to more intense hurricanes under climate change. The extent of damage will, however, depend on the forest's proximity to the path of the storm.

Species Vulnerability - Mangrove Stands

Doyle et al. (1995) indicates that *Laguncularia racemosa* may be more susceptible to wind damage than *Avicennia germinans* and *Rhizophora mangle* at wind speeds around 40 ms^{-1}.

Model projections of South Florida mangroves suggest that an increase in hurricane wind intensity over the next century is likely to result in a decrease in the average height of mangroves (Ning, et al., 2003) The red mangrove *(Rhizophora mangle)* and black mangrove *(Avicennia germinans)* used in the study are the same species found in the PBPA. There is the possibility of changes in the structure and species composition of the mangrove forests in the PBPA in response to future severe hurricane winds.

Species Vulnerability - West Indian Whistling Duck (Dendrocygna arborea)

The West Indian Whistling Duck *(Dendrocygna arborea)* is a globally threatened species which relies on the mangrove wetland for food sources, protection and breeding. It nests on a branch or in a tree cavity (BirdLife International, 2003). Canopy trees will sustain significantly greater direct wind damage than subcanopy trees (Doyle et al. 1995). This will directly affect the nesting habitats of the West Indian Whistling Duck *(Dendrocygna arborea).*

Increased Sedimentation

Increased flooding on the alluvial and coastal plains of the PBPA may cause increases in erosion, landslides, and debris flow into the coastal mangrove wetlands. Too much sedimentation will lead to mangrove mortality as the sediments asphyxiate the respiratory structures that allow for gas exchange within the roots (lenticels, aerenchyma) (Ellison, 1999).

Coastal Erosion

Hurricane winds produce strong waves and near-shore currents that can mobilize sediments, causing both erosion and sediment deposition. Mangrove forests within the eroded zone will be destroyed or drowned and the remaining mangroves buried with coastal sediments. The extent of mangrove inundation may increase due to projected accelerated increases in mean sea level and hurricane peak wind intensity.

Mangrove forests develop between mean sea level and high water level. Geological records reveal that mangrove habitats shift or stay according to the speed of sea level rise (Miyagi, 1998). When the speed of sea level rise is greater than the limit of sediment accumulation, mangrove forests will submerge in the sea and will die. Land loss of mangrove forests is also directly related to mean sea level. Projected increase in the rate of sea level could increase inundation stress on mangroves.

While mangroves can adapt to sea-level if the rate of sea level rise does not exceed the rate at which the mangroves trap sediment, mangrove communities in carbonate islands such as Jamaica are considered extremely vulnerable to sea-level rise where landward migration to escape the effects of sea-level rise is not possible and sediments are often limited (UNEP,1994). The mangroves in West Harbour are a possible target for "coastal squeeze" since their mobility inward is limited by the settlements of Mitchell Town and Portland Cottage behind the forests.

Saltwater Intrusion

There is a delicate balance between salt water and fresh water in most coastal mangrove wetlands. There is risk of intrusion of saltwater into mangrove wetlands through mean sea level rise which could change the salinity of the wetland and the elevation of the freshwater-saltwater interface. This would in turn impact the fish nurseries found within the mangroves.

Decreased rainfall and increased evaporation may also increase the salinity of water available to mangroves thus decreasing their net primary productivity, growth and seedling survival. The long-term effect would be a reduction in the diversity of mangrove zones (Duke et al., 1998).

3.3 Dry Forests

Much of the land area of the PBPA is occupied by the dry limestone forests of Hellshire Hills, Portland Ridge, Brazilletto Mountains and Kemps Hill. Plants in the Rubiaceae, the *Euphorbiaceae* and the *Myrtaceae* family dominate the Jamaican dry forests and in this regard they are similar to Puerto Rican dry forests.

3.3.1 Climate Risks

Physical Damage to trees

Hurricanes have been found to change the structure of the Caribbean dry forest ecosystem, though not the function (Imbert and Portecop, 2008).

There is a bias towards larger stems and shrubs in the resulting damage, and the long term outcome is typically a reduction in overall stem density and basal area within the forest (Pascarella et al., 2004; Bloem et al., 2006; Imbert and Portecop, 2008). Hurricane winds impact dry forests by uprooting, snapping, breaking large branches, leaning and defoliating trees (Foster and Boose 1995). Falling limbs or stems cause structural damage to stems. For example, tree crowns in the coastal dry limestone forests in Clarendon were moderately (26-50%) damaged following Hurricane Dean (2004) (PIOJ, 2004). Though several tree species had broken branches and trunks, the damage was most pronounced in the Red Birch (*Bersera simaruba*) and Burnwood (*Metopium brownie*) which have little resistance to strong winds due to their brittleness.

The loss of leaves also leads to canopy thinning and the transferring of substantial biomass and nutrients to the forest floor. These large inputs of litter change spatial and temporal resource availability and serve as important nutrient pulses (Lodge et al., 1979).

Sprouting is also a common response of tropical dry forest trees to stressors such as hurricanes, which indicates that the high frequency of multiple stemmed trees in these ecosystems is largely a natural occurrence and not solely under anthropogenic influence (Dunphy et al., 2000; Bloem et al., 2006). Sprouting has been found to be an indicator of hurricane influence on trees that have shown no other visible sign of damage. A substantial increase in new sprouts occurs on trees that have been exposed to hurricanes, even those that have shown no clear defoliation (Bloem et al., 2006).

An increase in the peak wind intensity of hurricanes under climate change increases the risk for physical damage of the forested regions of the PBPA, particularly in the periods immediately following hurricanes. In the long term more intense hurricanes may change some of the physical characteristics of the forest.

Decrease in Seed Germination

Soil moisture availability in dry forests is directly influenced by the amount of rainfall. The PBPA dry forests experience distinct seasonality (see again Figure 7 for the Hellshire Hills) and high inter-seasonal variability in rainfall. It can be expected that seed germination and early establishment in these forests will be primarily influenced by seasonal variation in rainfall. Seeds of a majority of dry tropical species mature in the dry season and are dispersed at the beginning of the rainy season when sufficient moisture is available for germination and seedling growth (Singh and Singh, 1992).

The significant reductions in rainfall and inter-seasonal rainfall variability projected by the end of the 2080's will be accompanied by projected increases in temperature over both the early and late wet seasons and during the mid-summer drought. These factors imply a transition by the dry forests to a much drier state by the end of the century. Insufficient saturation of the forest's soil during the wet seasons and increased rates of evapotranspiration will likely progressively reduce the soil moisture availability in the dry forests and impact seed germination. In a nursery experiment, in Hellshire Hills, McLaren (2003) found a high correlation between survivorship and monthly rainfall received among 4 plant species. The effect of the watering treatment in the experiment was an increased survival percentage of 8% among all species. The survival rates of seeds less adapted for the projected drought are at risk.

Fire

The transition of the PBPA to a much drier state in the future will alter the frequency and intensity of forest fires. Fire already poses a significant risk to plant species and animal species within the PBPA. For example in 2005 forest fires in Portland Ridge denuded significant sections of the forest and removed faunal food sources. Custodians of the area occupied by the PWD Hunting and Sporting Club reported a sharp decline in the bird population which affected the quantity of birds caught during bird shooting seasons since that year. A drier state facilitates the rapid spread of the fires irrespective of the source of ignition – natural or otherwise. Exacerbated fire loss is likely under climate change.

Alteration of Fauna Composition

An immediate threat, to regions with sensitive ecosystems such as the PBPA occurs when climate varies outside of the bioclimatic norms. For fairly pristine areas such as the interiors of the dry forests of the PBPA, it is assumed that endemic species are in equilibrium with the abiotic factors in their habitat, and will remain in equilibrium with all factors external to the climate of the area over time. As climate changes, however, the bioclimatic envelope may change and impact species composition.

Table 11 provides some insight into how variable rainfall conditions and a warmer-drier climate may impact species composition.

Table 11 Sensitivity of dry topical forest fauna to climate variation. Summarised from Stephenson (2012).

Arthropods
• Moisture is an important factor in the life cycle of an arthropod, both in the form of free water and atmospheric water vapour (Brusca and Brusca, 2003). Low relative humidity can retard the life cycle of the organism, slowing oviposition, growth, development and physiology, while high relative humidity can drown young individuals or increase pathogen infection (Gullan, 2005). • Studies assessing the variability of arthropod populations with rainfall seasonality in Grenada in 1977 showed that arthropod populations were 2.3 times larger and 3.1 times greater in biomass during the wet season (June-December) than during the dry season (January-May) (Tanaka and Tanaka, 1982). • Drying favours a shift in feeding group dominance towards detritivores (which feed on decaying organic material) and scavengers (Holmgren et al., 2001). • Rainy events can allow for a shift in dominance among plant species in otherwise dry environments. There is often also an associated rise in arthropod abundance with increased moisture and foliage, particularly of herbivores (Holmgren et al., 2001). • Populations will vary in size due to variations among different feeding groups based on how each species is adapted to deal with an affected food source (Andrew and Hughes, 2004). • Extreme events such as hurricanes can change the composition of a community, since regeneration and success are dependent on species-specific persistence (Kennard et al., 2002). • Increased temperatures increase the rate of development for many arthropods, possibly causing spikes in pest infestations (Kiritani, 2006; IPCC, 2002). Kiritani (2005) found that the life cycles of many species change during periods of unusually high temperatures, which can result in adults appearing earlier in the year and more generations occurring per year. • There is generally a temperature threshold for growth and development of arthropods, and above or below this optimum temperature, development is hindered (Thornwaite, 1948). • Climate shifts can spur migration and result in the expansion of species range.
Tropical Lizards
• Tropical lizards, due to the continuously warm nature of their habitats, are less likely to be affected by a rise in temperatures than their higher latitude counterparts. Huey et. al (2008), however, found that living in a warm habitat does not remove the possibility of intolerance to high temperatures as the relatively narrow annual temperature range to which tropical groups are accustomed puts them at risk to substantive rises in ambient temperature outside of their preferred temperature ranges, particularly during summer months. • Breeding patterns of anoline lizards are influenced by rainfall being a driving factor. Anoles lizards produce many single egg clutches throughout the wetter months of the year at a high cost to females (Gorman and Licht, 1974; Cox and Calsbeek, 2009). Licht and Gorman (1970) showed this seasonality using seven species of *Anolis* across the Caribbean.

3.4 Cays and Sandy Beaches

The Portland Bight Cays are mostly sand cays. The cays are a part of the Portland Bight Wetland and Cays Ramsar site. Sandy beaches and cays are of importance for nesting sea turtles and crocodiles. Some of the cays have mangrove forests.

3.4.1 Climate Risks

Erosion of beaches and nesting habitats

The mean sea level determines the position of the actual shoreline of the cays and sandy beaches of the PBPA. Natural erosion occurs when the mean sea level exceeds the elevation of the shoreline. Climate change models predict an accelerated increase in the rate of mean sea level rise. This may result in a significant increase in land loss through submergence and erosion of beaches and cays by the end of the 2100's. The amount of land retreat will depend on if the shoreline is steeply rising or very flat. On very flat lying shores the rate of retreat could be very high. Preliminary estimates by the Marine Geology Unit of the University of the West Indies suggest there will be at least a 30 m retreat of some of the flatter lying Jamaican beaches by the end of the century due to mean sea level rise alone.

Storm waves also erode the beach and either deposit the eroded sand offshore or move it inland, out of the beach area. For example, Manatee Bay showed substantial beach recession after the passing of Dean in 2007 (Marine Geology Unit, 2007). During Hurricane Ivan (2004) there was significant accretion of sand and debris on some beaches in Old Harbour Bay and Rocky Point (up to 30 m inland) (PIOJ, 2004). On an eroded beach or cay, the position of the actual shoreline may recede, or the erosion may only involve the removal of the top layer of sand from the beach area. Projected increases in mean sea levels and the peak wind intensity of hurricanes and cyclones suggest an increase in the storm surges associated with these events. This will likely cause more severe coastal erosion of cays and beaches due to hurricanes than at present.

Erosive processes and the resulting nest loss have long been presumed to be a hindrance to clutch survival. Many sea-turtles, seabirds and crocodiles rely on the cays and sandy beaches nesting and feeding purposes. Natural erosion of these coastline nesting habitats due to mean sea level directly decreases the available nesting grounds.

Some species may attempt to shift their habitat inward in response to the increase in mean sea level. The changing conditions in nesting and foraging areas of these species could limit growth and reproductive potential for these populations that are already under stress due to non-climatic factors such as the illegal harvest of their eggs and invasive alien species and plants.

Species Vulnerability - The Hawksbill sea turtle (Eretmochelys imbricata)

The Hawksbill sea turtle *(Eretmochelys imbricata)* is an endangered species and one of the few sea turtles that still nests in Jamaica. The months July through November are the traditional nesting months for the *E. imbricata*. This overlaps with the Atlantic Hurricane season. E. *imbricata* eggs would face increased danger of full or partial mortality due to disturbance from enhanced coastal hurricane activity coupled with possibly enhanced beach erosion. It is estimated that beach erosion as a result of 0.5 m rise in sea level in the Caribbean would cause a decrease in sea turtle nesting habitats by up to 35% (Simpson et al., 2010). Increases in temperature will also likely affect the reproduction of turtles since sex is determined by temperature.

Physical Damage to vegetation

The increase in peak wind intensity could cause an increase in the damage of coastal mangroves and vegetation on the cays. A reduction in mangroves, which act as natural protection from hurricane winds, could allow storm waves to penetrate greater distances inland exacerbating erosion.

3.5 Coral Reefs

The marine area of the PBPA has widespread coral reefs associated with the 16 cays and several shoals. Between 8 and 13 coral species have been identified in the PBPA and the most common species were those of *Porities spp* and *Montastrea spp*.

3.5.1 Climate Risks

Coral Bleaching

The preservation of coral reefs is highly dependent on the presence of the species that build their physical structure. One such species is the zooxanthellae *(Symbiodinium)* algae which is needed by coral reefs for photosynthesis and in turn coral reef construction. This symbiosis is destroyed by small increases in temperature. The susceptibility of symbionts to temperature increases is related to the thermal properties of their internal membrane lipids, whose composition varies among different strains. Stressed, overheated corals expel the algae ("coral bleaching") and there is an uncoupling of symbiosis among coral and their symbiotic dinoflagellate algae. Biochemical analyses of the bleaching response show that the photosynthetic mechanism in these algae fails after small increases in temperature (Nybakken, 1993).

Caribbean coral reef ecosystems are vulnerable to thermal stress because they live very close to their upper tolerance limit for temperature. A popular model (Hoegh-Guldberg, 1999) shows an invariant bleaching "threshold" at ~ 1°C above mean summer maximum temperatures. Under the projected accelerated rate of sea temperature rise, there is likely to be an increase in the frequency of bleaching events for the coral reefs of the PBPA. The expulsion of zooxanthellae will leave corals more susceptible to disease and, if continued, partial or full mortality. Once bleached, corals are unable to grow a skeleton, reproduce, or defend themselves against natural predators.

One of the most common species of coral reefs in the PBPA are and *Montastraea spp* (Creary, 2008). Published reports of individual bleaching surveys have consistently indicated that *Montastraea* is highly-to-moderately susceptible to bleaching (Brandt, 2009). Studies of Jamaica's coral reefs note coral mortality due to temperature increases in coastal waters in 1988, 1990 and 2005 (Anderson, 2000; Kane, 2005).

Ocean Acidification

Carbon dioxide (CO2) solubility in water decreases as temperature increases. With ocean acidification, corals cannot absorb the calcium carbonate they need to maintain their skeletons and the stony skeletons that support corals and reefs will dissolve. Corals are already living near, at, or occasionally beyond their maximum tolerance limit for temperature, but they are still far from having reached any acidity limit. Therefore, the impact of ocean acidificiation is projected to be minimal.

Diminished light conditions

The first requirement for active coral reef development and growth is light. Light is necessary to promote photosynthesis within the corals symbiotic zooxanthallae. Corals require water depth where light intensity is at least 1-2% of surface intensity (Nybakken, 1993). No species of coral has been found to develop in waters deeper than 70 meters, with most corals growing in waters less than 25 meters (Nybakken, 1993). A rise in sea level will cause reef ecosystems at the depth limit of coral growth to experience diminished light conditions that will no longer sustain their growth and will most likely result in death (Hoegh-Guldberg, 1999). Slow growing corals will be particularly affected by the rapid increase in sea levels. *Porites spp*, one of the most common corals in the PBPA, has a very slow growth rate, perhaps only nine millimetres a year (Veron, 1986). Therefore, it will be particularly vulnerable to dramatic sea level rises in the PBPA.

Destruction of corals

Major damage was reported to free standing corals at Portland Bight following Hurricane Ivan (2007) (PIOJ, 2007). The corals were tossed about and branching forms were broken. Massive coral heads which were more secure were, however, not badly affected. Some coral disease resulting from stress was reported following the hurricane's passage (PIOJ, 2007). Damage and disease may be exacerbated under climate change due to more intense storms.

3.6 Seagrass

Seagrass is important as fish nurseries and to stabilize the shoreline. They also contribute to nitrogen fixation, reducing the turbidity of water by being a sediment sink, serving as a food source for some marine species, and in the recycling of nutrients.

3.6.1 Climate Risks

Mortality

Seagrasses will not survive above a 2-3^{o}C increase in sea surface temperature during the summer months. In addition the proximity of seagrass beds to coral reefs exposes them to similar climatic change impacts (see previous section). As for corals, sea level rise may reduce the available sunlight to sea grass beds and hence reduce their productivity. On the other hand, carbon dioxide enrichment of the ocean may have a positive effect on photosynthesis and growth of seagrass.

Increased storm events, flooding or high intensity rainfall will likely exacerbate existing stressors for seagrass by increasing the volume of polluted runoff from upstream sources. Sea grass beds are also vulnerable to extreme weather events as often after a hurricane beaches are strewn with mats of dead seagrass. Hurricane Dean uprooted large mats of seagrass beds as seen in Figure 24. This is likely to lead to a reduction in fisheries catch in the ensuing months. After Hurricane Gilbert (1988) observers in Rocky Point, St. Thomas, Discovery Bay, Ocho Rios and Falmouth reported significantly reduced abundance of juvenile fish in those areas which suffered damage to seagrass beds and coral reefs (UNEP/CEP, 1989).

Such storms may also cause massive sedimentation increasing the turbidity of waters surrounding sea grass beds. High turbidity affects the productivity of coastal ecosystems by lowering the amount of sunlight entering the water, disrupting photosynthesis and reducing the amount of food available for marine organisms.

Figure 24 Large mats of seagrass uprooted in Rocky Point, Clarendon during Hurricane Dean. From PIOJ (2007).

3.7 Freshwater Ecosystems

Freshwater supplies to support rivers, aquifers and springs in the PBPA are supported by flows from the upper watersheds of the Rio Minho and Rio Cobre. Many of the streams, springs, gullies and rivers in this protected area run through the broad low-lying coastal plains and empty into the Portland Bight. As a result, there are many coastal freshwater systems. These freshwater systems serve as habitats to many freshwater fish, pond turtles and plants. These systems are also affected by invasive alien plants and crustaceans.

3.7.1 Climate Risks

Decrease in water levels and coastal sedimentation

Rainfall controls the water regime of the freshwater ecosystems in the PBPA. The projected significant reduction in rainfall and increase in temperatures suggests a possible decrease in the water level of the two river systems, as well as, greater frequency of drought within the PBPA. These changes suggest a decreased volume of freshwater supply from the upper parts of the watershed into the PBPA's rivers, springs and aquifers and possible drying of ephemeral ponds such as those in Harris Savanna. In addition, there may be a decrease in the flow of upper sediments to the coast. The upper sediments are responsible for mangrove sedimentation and beach formation.

Saline Intrusion

While some of the contiguous coastline of the PBPA is protected by the steep hills of the Hellshire Hills and the south side of Portland Ridge, the majority of the shoreline of the Portland Bight is broad low-lying coastal plains and therefore coastal springs, ponds and streams are also susceptible to flooding from elevated sea levels. Some parts of the coastal plain have elevation as low as 5-10 feet (1.5 to 3 m) above mean sea level increasing to 20-25 feet (6 to 7.6 m) in the alluvial plains. Permanent inundation of these low lying coastal lands may occur as the sea level simply exceeds the elevation at the coast.

Coastal flooding would facilitate an increase in estuary salinisation through the increased influx of salt water into coastal freshwater ecosystems. The combination of the increased influx of ocean water with the decrease in freshwater flow due to significant decreases in rainfall could increase the salinity of coastal freshwater systems beyond its typical levels. This can destroy these water bodies as habitats for freshwater organisms that have a low saline tolerance or require a specialized environment.

An increase in mean sea level would also result in salt-water inundation of coastal lands which may prompt saline intrusion into coastal aquifers. This can reduce freshwater sources, and further compound water shortages.

Species Vulnerability - Australian Red Claw (Cherax quadricarinatus)

The invasive Australian Red Claw, *Cherax quadricarinatus,* found in the freshwater ecosystems of the PBPA is adversely affected by increases in salinity of their habitat. Studies show hatching rate and post-hatch survival of the *C. quadricarinatus* decreases with an increase in seawater salinity (Anson et al., 1994).

Species Vulnerability - Hydrilla (Hydrilla verticilate)

The Cockpit Canal is particularly affected by the invasive Hydrilla *Hydrilla verticilate* weed. There is a significant negative correlation between germination of *H. Verticilate* and salinity. In a laboratory environment, Carter et al, (1987) found 92-97% of *H. verticilate* propagules germinated at salinities of 0 parts per thousand (ppt), 4-20 % germinated at 5 to 9 ppt and no germination occurred at salinities higher than 9 ppt.

3.8 Jamaican Iguana (*Cyclura colei*)

At one point thought to be extinct, the Jamaican Iguana *(Cyclura colei)* is one of the two most endangered lizards in the world.

3.8.1 Climate Risks

Habitat Loss

Hellshire Hills serves as the only habitat for *C. colei* and therefore the climate change risks that may affect *C. colei* are directly related to those likely to cause disturbance and loss of its dry forest habitat. Some of the climate change risks faced by the dry forests of the PBPA are:

- Increased physical damage to trees from hurricanes due to projected increases in both peak precipitation and wind intensity of hurricanes by the end of the century.
- Lower survival rates of seeds due to a decrease in soil moisture availability moving to the 2080's. This decrease in soil moisture is expected because of the projected decrease in wet season precipitation and the projected increase in dry period temperatures.

3.9 American Crocodile (*Crocodylus acutus*)

The American Crocodile *(Crocodylus acutus)* is considered an endangered species by the International Union for Conservation of Nature (IUCN). It is protected in Jamaica through listing in the First Schedule of the Trade in Endangered Species and Schedule Three of the Wildlife Protection Act. It is the largest reptile and only crocodilian present in Jamaica. The *C. acutus* is important in its ecosystem both as a scavenger and a top predator. It helps to maintain healthy biological diversity through the removal of slow or diseased individuals from prey (e.g. fish) populations.

The American Crocodile inhabit brackish and saltwater habitats and are typically in coastal mangrove wetlands and ponds. The optimal nesting habitat for these crocodile includes sandy banks or beaches close to mangroves and to freshwater pools for the young. These nesting sites have well-drained soil adjacent to water, which prevents flooding and allows for direct access to water.

3.9.1 Climate Risks

Loss of nesting areas

An accelerated increase in mean sea level and/or more intense hurricanes could increase the disturbance, reduction and loss of suitable sandy bank and beaches for nesting due to increased coastal erosion.

Loss of Hatchlings

Coastal or saltwater flooding could affect the salinity in crocodile habitats close to the coast due to saltwater intrusion. Hatchlings have a much lower salt tolerance than adults. Hatchlings face rapid salt gain and water loss as a consequence of their surface to volume ratio (Dunson, 1970) and so an increase in hatchling mortality is likely.

Dramatic switch in sex ratio

The sex determination of *C. acutus* hatchlings is temperature dependent with high temperatures likely to produce males. A possible consequence of the projected mean increase in temperature in the PBPA is a dramatic switch up in sex ratio with more male crocodiles and fewer females. This ratio could adversely affect the capability of the existing crocodile to reproduce.

4. COMMUNITIES, BIODIVERSITY and CLIMATE VULNERABILITY

Focus: Overview of socio-economic profile of area, demographics, livelihood options and sustainable development potential as well as unsustainable practices that affect/impact on the biodiversity.

4.1 Socio-economic Overview

4.1.1 Communities

The PBPA includes about forty-nine residential communities. These include three large towns (Old Harbour Bay, Lionel Town and Hayes) and large housing estates (Hellshire, Longville and New Harbour). About nineteen communities are directly on the coast. The 1991 census estimated that the population was about 48,000 for the entire PBPA. Except for Hayes, the 2011 census showed an increase in the population of the large towns (Table 12). The 1991 census also indicated more males than females and more young people.

Table 12 Population of large towns in the PBPA. Data source: (STATIN 2012).

	1991	2001	2011	% Change from 1991 to 2011
Hayes	8,447	10,098	10,639	25.9
Lionel Town	4,664	3,568	3,609	-22.6
Old Harbour	17,778	23,823	28,912	62.6
Old Harbour Bay	---	6,344	5,872	---

The Social Development Commission's community profiles provide socio-economic 'snapshots' for communities across Jamaica. Table 13 provides, as example, the SDC profiles for three communities within the PBPA communities - Portland Cottage, Old Harbour Bay and Hellshire. The Table shows both a commonality of socio-economic characteristics especially among coastal communities as well the diversity of community structures present within the PBPA.

Table 13 Community profiles for three communities within the PBPA. Source: SDC.

Old Harbour Bay
The Community of Old Harbour Bay is a geographic area comprised of twenty one (21) districts. The districts within the Community are Old Harbour Bay Proper and Blackwood Gardens. The area is bordered to the north by Old Harbour, south by Sea, east by Lloyd's Pen and west by Port Esquivel. The predominant terrain of the community is flat. The climate is predominately dry but experiences periods of heavy rain fall. There are storm reliefs systems present in the community which remove flood waters from the area in these times. The natural resources present within the community are ponds, rivers and forested areas. The Community of Old Harbour Bay has an estimated population of 7,388 and an educational institution enrolment rate of 70.9% of school aged residents. The household head employment rate was 61.6%. The most common employment category was full time employment which accounted for 51% of all employed persons. The highest rate of unemployed males was 20-24 years accounting for 9.6% of unemployed males while for females the highest level of unemployment could be seen in the 60+ age cohort accounting for 12.8% of unemployed females. A significant amount of the respondents involved in this project reported the presence of a longstanding health problem within their household (35.5%). Among household heads and family members, hypertension was the most common illness. There are no health care facilities present within the Community as such residents usually travel to Old Harbour to access these services. The main difficulty to accessing health care reported by respondents was financial constraints (40%). The top five developmental challenges reported by the respondents are; high levels of unemployment and youth unemployment, limited/no opportunity for training, poor drainage facilities, poor roads and poor representation by elected leaders. The community of Old Harbour Bay has twenty one (21) Districts. They are Old Harbour Bay Proper and Blackwood Gardens. The Old Harbour Bay community is located in the South Westerly section of the parish and is located 29km from the capital town of Spanish Town. The main economic activities of the area are farming and fishing.
Hellshire
The community of Hellshire) has fourteen districts, including Hellshire Heights, Cave Hill, Edgehill, Johnson Hill, Sand Hill, Upperfort A and B, St. George's Street, St. George's Cliff, Hellshire Park, Sand Hill Bay, Half moon Bay, Cannon Ridge, Seafort, and Hellshire Glades I and 2. These districts are all located within the Portland Bight Protected Area. Hellshire is a dormitory suburb of Kingston. 32.1% percent of the household heads have attained tertiary level education and another 73% of the heads of the households within the community are engaged in professional occupations. Infrastructural development is coastal. There is a single access point to the community. A deficient water supply is also listed as a major environmental issue for the community.

15.3% of the population suffers from chronic illnesses like diabetes, musculoskeletal diseases, and eye disease.
Portland Cottage
Portland Cottage is located in southern Clarendon. It is predominantly flat land bordered by swamps and mangroves, and dotted with few hilly areas. The community is vulnerable to hurricanes, flooding and high tides. Hurricane Ivan in 2004 dislocated many residents in Salt Pond, a coastal settlement within the community, and resulted in five drowning deaths. It is estimated that 60% of the adult population is illiterate, and lack of nutrition may be inhibiting their learning (Social Development Commission, 2010). Heads of households are generally male and many residents are unemployed and illiterate. Unemployment is particularly acute among youth. Income generation is otherwise linked to fishing directly or indirectly. Almost half of all residents are afflicted with chronic illnesses (hypertension, diabetes, asthma, and arthritis). The residents of the community attribute hypertension to their environment i.e. salty air and sodium laden piped water. An estimated 40% of the dwellings are wooden structures which have previously been blown down in hurricanes, and 51.7% of the community uses pit latrines. Other waste matter is disposed of by incineration.

4.2 Livelihoods

Many residents of the PBPA are particularly dependent on the natural ecosystems of the area. Some livelihood activities of the PBPA with direct links to the PBPA ecosystems are discussed below. Table 12 summarizes other economic activities located within the PBPA

Fishing

The fish industry is a significant contributor to livelihoods in the PBPA, especially amongst its coastal communities. C-CAMF (2013) notes that they are 3,000-4,000 fishers in the PBPA, with an additional unknown number from Kingston, Port Royal and the North Coast also using the area. There are nine designated fishing beaches and 16 landing beaches in the area. Old Harbour Bay and Rocky Point are among the largest landing beaches in Jamaica. In 2010 the Fisheries Division established three Special Fisheries Management Areas (SFMAs) in the PBPA to help manage fish stocks. The SFMAs are located at Salt Harbour, Galleon Harbour and Three Bays and are managed by C-CAM. A derivative from the fishing communities is that a large number of persons are engaged in related small scale services and trading activities, including fish vendors, fish cleaners, cook shops and restaurants.

Agriculture

Small farmers cultivate flat lands near Raymonds in the Brazilletto Mountains and near Salt River (C-CAMF 2013). Crops grown include sugar and fruit trees. C-CAMF (2013) also note that there are a few areas where sheep, cattle and goats are grazed but that livestock rearing is not a major economic contributor to the area. Cattle and goats are grazed informally on the abandoned cane lands. Goats are also grazed on Goat Island and in Portland Cottage. There are a few large and small chicken farms.

Forest Use

Some residents of communities adjacent to the dry forests of the PBPA (Hellshire, Brazilletto Mountains and Portland Ridge) derive all or part of their income from illegally harvesting lumber, fuelwood, pot sticks, and thatch or from charcoal burning. Recently concluded surveys of Forest users suggest that users of Portland Ridge originate from the bordering communities including Portland Cottage, Wildman Town and Dry Hill (CSGM 2013a, 2013b). Communities from which users of Hellshire Hills originate include Hill Run, Braeton, Half-Moon Bay, Dunbeholden and Spanish Town. The surveys also found that persons travel from as far as St James, St Ann and Trelawny to use the Hellshire Hills. Charcoal burning and the gathering of firewood accounted for the main activities of the forest users of the Hellshire Hills and Portland Ridge. Other activities included hunting and logging. As with fishing there are derivative services and trading activities from forest activities, including charcoal vending, cook shops and restaurants.

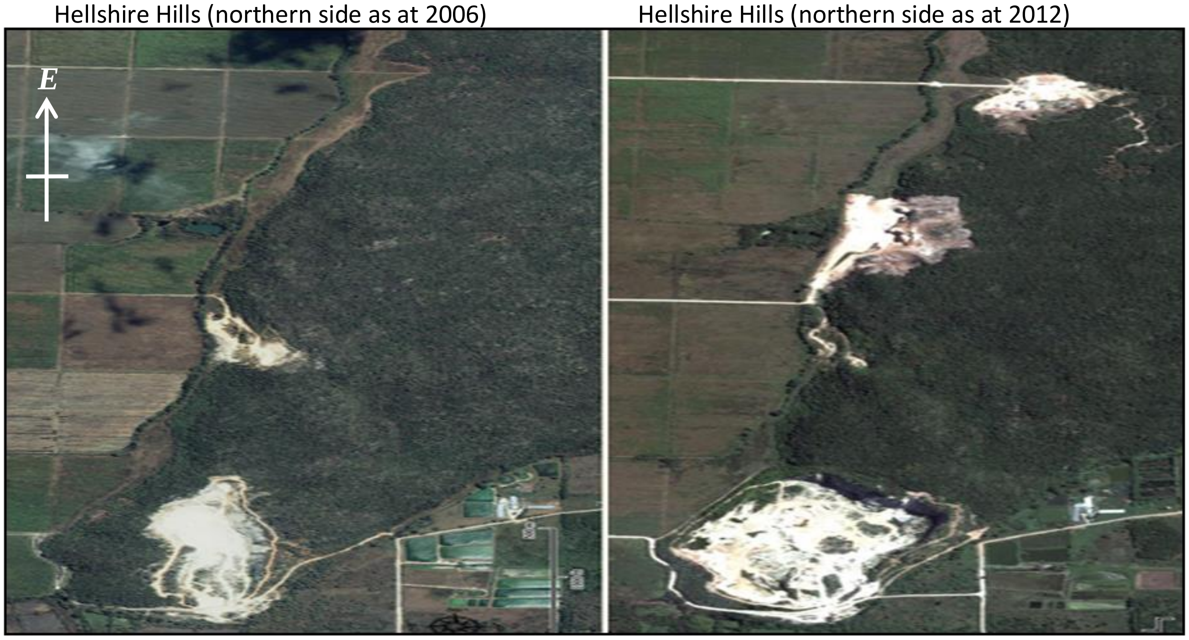
Quarrying

There are three declared quarry zones in the PBPA. These are located in the Brazilletto Mountains, Hellshire and in the bed of the Rio Minho. These include quarries for limestone and aggregate (including at Hill Run, Free People, Tarrentum and western Brazillettos). Figure 20 shows quarrying locations on the periphery of the Hellshire Hills.

Table 14 Other Economic Activities in the PBPA related to Livelihoods. Summarized from CCAM (2013).

Livelihood	Note
Sugar	Many large sugar estates were established on the deep, well-watered soils of the plains of Vere and St Dorothy, including Bernard Lodge, Monymusk and New Yarmouth. The only one that is currently operating is Monymusk factory. The aquifers in lower part of the Vere plains have become too salty (due to over-pumping) for sugar cane and there are large areas of ruinate, abandoned cane land. Monymusk and Bernard Lodge have recently been leased to the Chinese company Pan-Caribbean Sugar.
Fish farming	In the 1980s and 1990s fish farms proliferated in the area, with many large and small farms being excavated mainly in mangroves. Most have since been abandoned for a variety of reasons, including most recently a large shrimp farm near the mouth of the Rio Minho. Some fish farms in survive in the Hill Run area.
Industry and Industry Related Infrastructure	Some large industry and industry related infrastructure in the BPA include: Spirit Pool Distillery JB Ethanol Plant Rocky Point Port Bauxite-alumina plant at Hayes Master Blend Feed Mills Protein recovery plant, Longville Park Solar Salt Factory, Portland Cottage Jamaica Public Service Co. Old Harbour Bay Hummingbird Power Barge
Small businesses and service industries	Many people derive part of their income from providing services such hair dressing, mechanical work and other similar activities.
Tourism	Tourism in the area is mainly related to recreational bathing (e.g. beaches at Hellshire, Welcome Beach and Salt River Spa), recreational fishing and boating. There are two small private marinas operated by Monymusk Gun Rod and Tiller Club and PWD Gun Club. A small number of people also visit cultural sites such as Alley Church. Sports fishers and yachtsmen also come from Kingston.

Hellshire Hills (northern side as at 2006) Hellshire Hills (northern side as at 2012)



Source: National Land Agency (2012) *Source*: Google maps (2012)

Figure 25 Limestone quarrying along the periphery of Hellshire Hills 2006 and 2012.

4.3 Biodiversity-Community Interaction

4.3.1 Anthropogenic threats and compounding climate risk

The proximity of the natural ecosystems of the PBPA to human settlements makes them also vulnerable to large-scale anthropogenic disturbances (e.g. charcoal burning, animal grazing, quarrying, over-fishing and wood gathering). Consequently climate-driven impacts on biodiversity, as discussed in the previous chapter, pose even greater threat to species and ecosystems because of the coupling with non-climate anthropogenic stressors The Bight's status as a protected area should provide the protection needed to address the threats to biodiversity and support sustainable development. However the necessary legislation has not been enacted and the resources for enforcement have not been provided.

For example, the PBPA as noted above is a production centre for charcoal that is supplied to Kingston and St. Catherine (CSGM, 2013a; CSGM, 2013b). The activities of charcoal burners in the last 10-20 years have resulted in a reduction in forest cover in the northern section of the Hellshire Hills (McLaren and McDonald, 2002b). Removal of mature forest decreases soil stability and increases sediment runoff following storms. Additionally, seedlings need moisture and shade for growth and development (McLaren and McDonald, 2003b). Most seedlings in Hellshire mature during the dry season and germinate at the beginning of the rainy season. Therefore seedling density tends to be higher in well-shaded areas than in areas where forest cover is reduced by activities such as charcoal burning (McLaren and McDonald, 2002b). Charcoal burning compounds stresses already present due to changing rainfall and temperature patterns and severe tropical events.

Other anthropogenic stresses to the biodiversity of the PBPA, which if not adequately regulated, will exacerbate some of the already noted vulnerabilities to climate change, include:

- Limestone mining, particularly around Hill Run and in the Brazilletto Mountains. Forests are totally removed in limestone mining and the landscape is scarred (see again Figure 25). The gaps in forest cover reduce humidity in the surrounding forests.
- Declining forest cover in the PBPA and the upper watersheds of the Rio Minho and Rio Cobre. This increases vulnerability of coastal communities and ecosystems to flooding.
- Sand mining in the Rio Minho. This damages the river bed and affects the freshwater ecosystem.
- The encroachment of new human settlements into previously forested areas. This brings additional stresses to the area e.g. the new housing developments on the south-eastern side of the Hellshire forest (since 2006). Invasive alien mammals including mongoose, cats, dogs, pigs, goats, and rats move into the area where they threaten ground nesting species, and limit seed distribution, seedling development and forest regeneration in general. Human settlements are also associated with poor garbage disposal and increased pollution of groundwater due to poor sewage disposal.
- Declines in the quality and extent of protective coral reefs and mangroves in part due to direct removal. The mangroves protect the coastline and the infrastructure behind it while providing nursery habitat for fishable resources. Coral reefs and seagrass beds also protect the coastline and support fisheries. Removal of the coral reefs and mangroves

contribute to coastal erosion and reduced fish stock and threatens coastal woodlands, beaches and cays.

- Proposed industrial developments. There are proposals for industrial development including those for a cement factory at Port Esqivel, a limestone export port beside Rocky Point port with a beltway from Brazilletto Peak to deliver the limestone to the port (by CEMEX), and new power generation facilities at Port Esquivel and Old Harbour.
- Overfishing (especially through poor fishing practices such as dynamiting and trawling) of near shore reefs. This contributes to the decline of the coral reefs and makes fishing communities more vulnerable to storm surge and loss of livelihoods.

Table 15 below reiterates some of the climate risk posed to the PBPA ecosystems and also notes how the risk may be further compounded by anthropogenic factors.

Table 15 Examples of climate vulnerable features of the PBPA and compounding anthropogenic factors.

Vulnerable feature of PBPA	Climate Threat	Compounding Anthropogenic Factor
Forests and associated terrestrial biodiversity	Rainfall and temperature extremes, intense storms, drought induced fires.	Exacerbated by charcoal burning; settlement encroachment; quarrying.
Coastal wetlands	Storm surge, sea level rise, saline intrusion and changes in precipitation	Exacerbated by changes inland e.g. to forests; removal of mangroves.
Beaches and cays	Storm surge, increased wave action from intense hurricane and storm events, erosion	Loss and degradation of protective coral reefs and mangroves is leading to coastal erosion, threatening beaches. Several cays have already been lost.
Coral reefs	Sea temperature rise, storm surge, ocean acidification, intensified storms	Severely stressed by pollution, overfishing and bad fishing practices such as dynamiting.
Sea Grass beds	Storm surges and intensified storms,	Stressed by pollution.
Fisheries	Storm surge, intense wave action form intense hurricane or storm events and sea surface temperature increases all may damage/threaten reef fisheries.	Overfishing of near shore reefs, degradation of nurseries and habitats (mangroves, sea grass beds, coral reefs),

4.3.2 Climate Threats and Resource Dependent Livelihoods

A downstream effect of enhanced climate threat on the biodiversity of the PBPA is the impact on the livelihoods that depend on the natural resources.

Table 16 summarizes how community members perceive that climate change is impacting their resource-dependent livelihoods either directly or through its impact on the natural resource on which they rely. The information was obtained through a survey of residents of communities adjoining Hellshire Hills (CSGM 2013a).

Table 16 How climate impact on biodiversity is impacting main livelihoods that depend on the natural resources of the PBPA.

Livelihood	Climate Variable	Perceived Climate Change Impact	Compounding Anthropogenic activity
Fishing	Hurricanes, Tropical storms	During storms and hurricanes, fishermen lose productive time at sea and lose fishing equipment	Removal of mangroves affects coastal protection and makes storm impact on the community worse and loss greater.
	Increasing temperature	Due to increasing sea surface temperatures, fish stock decreases and so the fishermen have to spend a longer time out at sea and have to go a farther distance.	
Farming	Rainfall patterns	Due to the inadequate and unpredictable rainfall patterns, farmers no longer plant according to the rainy season. Farmers also say they no longer plant in the daytime due to the increasing temperature in the forests. They now plant before dawn and after sunset. Water from heavy rainfall in areas with impermeable clay soil settles around the plants and kills them.	Indiscriminate logging for agricultural purposes within the forest reduces shade cover and increases exposure of forest users to direct sunlight.
Coal burning	Heavy rainfall	Rainy conditions associated with more frequent storms prevent accessing the site to harvest the wood for coal production.	

		Drought increases risk of accidental fire.	
Crab hunting		Prior to the 1970s, the residents of Portland Cottage were able to predict the rainy season as occurring in May and October. Unpredictable rainy season is seen as a threat to these people's livelihoods.	Too many people now catching the crab reduces the length of the crab season from 3 weeks to lasting not longer than about 3 days
Fish farming		According to freshwater fish farmers in Hill Run, cloud cover affects their ability to catch their fish.	
Hunting	Droughts Increasing temperature	Due to longer 'dry periods' the mud baths or 'watering holes' that the wild hogs would bathe in have evaporated, making it significantly more difficult for the hunters to catch them	In Hellshire Hills, it was reported that there were no longer any wild pigs due to consumption.
Workers at the Quarry	Heavy rainfall	Heavy rainfall prevents them from going to work	

The survey also provided information on the residents' general perceptions about climate change its impact on their lives and livelihoods, and its impact on the Hellshire Hills forests. The methodology employed and the main results of the survey are included in Appendices A through D. The information obtained is consistent with previous vulnerability surveys conducted by the C-CAM, for example that published in the stakeholder workshop report on "Increasing Community Adaptation and Ecosystem Resilience to Climate Change in Portland Bight" (Haynes-Sutton, 2009). In both instances responders cited storm associated surges and flooding as well as droughts as direct threats to the community.

Some main findings of the survey are summarised below:

- The respondents are aware of climate change due to media coverage (radio and television) and sensitisation by NEPA and other environmental organisations during seminars held within the community.

- Residents identified climate change as a major threat to their livelihoods, health, and to infrastructure in the PBPA. Storms were viewed as being particularly hazardous, in addition to flooding and droughts. This is in a large part due to the geographic vulnerability of the area compounded by badly sited housing, vulnerable livelihoods (such as fishing) the lack of adequate shelters or widely circulated evacuation plans. This mirrors results from previous survey work done in the PBPA (Haynes-Sutton, 2009).

- The majority of users consider that the forest has been visibly degraded over time and feel that the effects have had an impact on climate and livelihood. The majority of respondents (60%) thought that the Hellshire Hills dry forest has undergone a negative change over the years, compared to 9% who saw no change and 31% who saw positive change. The majority noted that warmer temperatures and less rainfall have resulted in reduced tree growth and loss of wildlife.

- Despite visible forest decline and resulting negative effects on climate, more than half of all respondents showed no intention of lessening their use of forest resources. This was because they depend on the forests for income, and there is a steady demand for charcoal in commercial food preparation. It is unclear, however, whether or not the work of the forest users has become more or less difficult as a result of these changes (see Appendix A for full survey report).

4.3.3 Threatened Communities

Finally, it bears noting that climate change is likely to directly impact the communities within the PBPA. The vulnerability of the communities and in particular any lack of capacity to adapt to enhanced climate hazards can have a cascading impact on biodiversity. For example, post disaster recovery for affected communities can enhance or greatly diminish interaction with the natural resources e.g. through limited physical access to the resource or to tools to access the resource, or through greater temporary need for the resource (e.g. for water or for wood to use as fuel for cooking or to provide temporary income) during recovery.

Limited resources do not facilitate an examination of either the vulnerability or adaptive capacity of all the communities within the PBPA for inclusion in this report. In addition there have been some assessments already done particularly as a part of the ODPEM's efforts to come up with disaster management plans for communities. The following points are noted, however, for the PBPA in general.

- The PBPA region has a recent history of being affected by floods and hurricanes including Hurricanes Ivan and Dean in 2004 and 2007. A number of studies have been done following both hurricanes assessing the impact on and recovery of the most impacted communities. These include assessments of the characteristics that made them most vulnerable.

- Community vulnerability to climate change is generally a function of geography, socio-economic conditions, and linkages to the environment. For different communities a given factor may predominate, but all three generally come into play. For example, many of the most vulnerable settlements in the PBPA are low lying, mostly carved out of mangrove swamps and wetlands, include residents whose main livelihoods depend directly or indirectly on fishing, sugar or bauxite, and are areas which are already economically depressed i.e. even before the hurricanes or climatic hazard negatively impacts sources of revenue and/or employment. Using the previously presented SDC profiles (Table 13), this would generally describe Portland Cottage whose location puts it at high and direct risk from climate extremes especially flooding from storm surges, hurricanes and high tides. Additionally, however, the community had high numbers of wooden dwellings (which were destroyed during Hurricane Ivan) and a strong dependence on fishing as a livelihood. As another example, the residential community of Hellshire is also very vulnerable to climate hazards (notwithstanding its more robust infrastructure and relative affluence) as a result of a single point of access to the community which is blocked when there is flooding from high tides or hurricanes. This severely restricts movement of the residents, including access to work, schools, hospitals and supermarkets and can lead to health and food security issues. An already deficient water supply also represents a vulnerability which is likely to be exacerbated by climate extremes.

- There are social sub-groupings in communities that may be more vulnerable than others to climate change. Special consideration should be given to identifying these individuals. Table 17 provides an example of some of the social groups estimated to have the highest vulnerability within the PBPA.

- The community could also be positively impacted in the aftermath of a climate event through increased social cohesion and awareness e.g. of the need for proper building regulations (Haynes-Sutton, 2009).

- A community's adaptive capacity and/or the ability to withstand hazard and/or easily and quickly recover from risk or threat can influence, for example, post disaster stresses on biodiversity. Adaptive capacity is not evenly spread across communities. For example, though both Hellshire and Portland Cottage communities exhibit vulnerability to climate hazards as noted above, the adaptive capacity of Hellshire appears much greater than that of Portland Cottage.

- The adaptive strategy chosen can itself impact the biodiversity and so should be well thought out. For example, drought events are a threat to individual welfare and livelihoods through loss of crops and livestock, in addition to a lack of water availability. An increase in drought events could lead to a rise in food costs, loss of investment in the community, and an increase in respiratory digestive illnesses. Coping with these stresses would require steps such as increased monetary resources for the implementation of water storage options, regulations for the management of watersheds which play a role in water availability, management of forested or agricultural lands, as well as increased awareness and planning (Haynes-Sutton, 2009).

Table 17 Matrix of vulnerability showing exposure to and ability to cope with climate related hazards depending on livelihood and socio-economic standing.

Livelihood Group	Vulnerability	
	Exposure to Hazard	**Ability to Cope**
Women	Water shortage, emergency evacuation	Increased workload due to location and transportation of additional water, low mobility in event of emergency due to children
Ill Residents	Some residents have chronic illnesses (hypertension, asthma, limited potable water, drier conditions, higher temperatures, lack of sanitation, poor road networks, limited access to health care	Susceptible to respiratory complications, spread of pathogens, limited access to health care, low chance of reaching medical help in emergency

Farmers	Extreme rainfall leads to the flooding of agricultural lands Water settles around crops and destroys them Drought conditions lead to livestock fatalities and crop decline	Livelihoods threatened due to disasters, trickledown effect through impacts on some occupations
Fishermen	Extreme sea surface temperatures affect the quantity of fish harvested Hurricanes interrupt time on the sea harvesting Damage to boats Loss of pots	Longer periods of increasing temperature (in Portland Cottage) leads to the emergence of salt on the shoreline which residents, including fishermen, sell to supplement their income
Power Station and port Employees	More frequent hurricanes, tropical storms, storm surge will lead to damage of powerlines, substations and other infrastructure	
Unemployed	Most are young, illiterate	Low resources, minimal likelihood of adaptation

5. INITIATED AND PROPOSED ADAPTATION OPTIONS

Focus: Identify existing adaptation strategies and programmes within the Portland Bight protected Area.

5.1 Targeted Adaptation

Adaptation strategies are needed for the PBPA to protect its natural resources in the face of climate change. With respect to the biodiversity, the strategies must of necessity be targeted first and foremost at conservation of all the ecosystems of the PBPA (see again Table 2) since all display climate related vulnerabilities. The adaptation strategies must also target livelihoods that depend on the resources i.e. strategies to either ensure regulation of and/or restriction of access to the resource being exploited or strategies to facilitate alternative livelihood options. Public education and Awareness campaigns targeting behavioural change must also of necessity be a part of the adaptation strategy since anthropogenic influences compound the climate risk.

Table 18 provides a summary of ongoing adaptation and risk reduction activities in the PBPA grouped largely along the lines presented above. The table also lists the principal stakeholders in the PBPA who are undertaking these activities. The ensuing section adds some more details for selected key stakeholders.

Table 18 Summary of Key Activities and Function of Principal Stakeholders in the PBPA.

Focal Area	Principal Stakeholder(s)	Initiative Details
Climate Change Adaptation: Disaster Risk Reduction, Sustainable land management	National Environment & Planning Agency (NEPA) and the Planning Institute of Jamaica (PIOJ). EU/GOJ Project	Rehabilitation of Watersheds (Rio Minho and Rio Cobre). Increasing resilience of coastal ecosystems: installation of mooring buoys in Salt Harbour and Galleon Harbour fish sanctuaries as well as the installation of Wave Attenuation Devices (WADs) within Old Harbour. Mangrove replanting (Portland Cottage)
	Clarendon PDC and Mocho Development Council	Land restoration and reforestation in Pleasant Valley, greenhouse agriculture in Mocho.

Water Quality Management and Water Harvesting	NEPA, UDC, C-CAMF	Water quality monitoring: in Salt River, Milk River and Rio Cobre watersheds, and at Fort Clarence Beach. Collected data submitted to NEPA.
	Clarendon PDC and Mocho Development Council	Rainwater harvesting and water recycling.
Biodiversity Conservation	C-CAMF	Monitoring of Seabirds on Cays. Conservation of Gamebirds-Increasing coordination among stakeholders and between enforcement agencies, Habitat improvement
	WINDALCO	Artificial Reef Installation at Three Bays Fish Sanctuary- Structures built encourage growth of corals and ultimately fisheries
	C-CAMF, NEPA, ISF, Fire Brigade	Crocodile protection: Removal of reptiles from flooded communities of Portland Cottage, Salt River, Rocky Point, Hellshire and Portmore. Community awareness raising
	UWI and Forth Worth Zoo (Texas), UDC, NEPA	Crocodile Monitoring by tracking their movements of at Manatee Bay. Assessment of the Caymanas wetland and selected areas in Hellshire
	Portland Bight Fisheries Management Council (32 member multiple stakeholders)	Development of fisheries management including: management of coral reefs, seagrass beds, the Portland Bight Cays, turtles, manatees, crocodiles and the wetlands, and has made recommendations re how the marine space of the PBPA should be zoned
	Fisheries Division/C-CAMFF	Fish Sanctuaries (three): Management of sanctuareis and monitoring of catch to help recovery of fish stocks.
	NEPA-GEF Funded	Management of Alien Invasive Species: Control of mongoose and cats in Hellshire from preying on the Jamaican Iguana. Control population of lionfish in coastal waters.
Alternative Livelihoods	Local residents	Generation of value-added products: Manufacture of items of Craft and paper
	C-CAMF, residents nature interest groups e.g. Society for the Conservation and Study of Caribbean Birds's	The potential for a Portland Bight Heritage Trail being assessed under the Portland Bight Sustainable Wetland project . Work already started on the establishment of the Portland Bight Tourism Council. In 2012 C-CAM partnered with Society for the Conservation and Study of Caribbean Birds's for preliminary assessment of the options for nature based tourism .

Public Education and Outreach	C-CAMF	Awareness & Outreach: Climate change, Wetland Management (Including Mangrove replanting), lionfish control, bird and fisheries conservation
	Institute of Jamaica	Establishment of Biodiversity Centre-for Primary & Junior High level students
	NEPA	Faciliate First Responders Programme in PBPA, promote mangrove replanting
	UWI	Mainstream Conservation into School Curriculum
	Panos Institute Caribbean and other partners	Using non-traditional methods to communicate conservation and Climate Change
Policy & Enforcement	C-CAMFF	Delineation of zones: Three main zones-Core Areas, Buffer Zone, Transitional Zones. Advocate the designation of PBPA as a bisphere reserve. Enforce prohibition of fishing in Fish Sanctuaries and Wild life Protection Act
	NEPA	Monitor regulations of the Protected Area, Marine Park Rangers
	UDC/Forestry Department	Surveillance and Monitoring. Forest and other Ranger services-Enforcers of Wild life Protection Act, Fisheries Acts and Fishing Industry Act
	Marine Police, JDF Coast Guard, ISCF, JCF	Provide Security and surveillance services to enforcement agencies
	Ministry of Water, Land Environment & Climate Change	
	Ministry of Agriculture and Fisheries	Fisheries Management, licensing of fishers and fishing boats

5.2 Key Government and Non-Government Agencies

There are currently government initiatives underway in the Portland Bight Protected Area geared towards protection of the environment and capacity building for coping with natural disasters. Under the GOJ Climate Change and Disaster Risk Reduction Project, NEPA is engaged in monitoring changes in sea surface temperature from St. Catherine to Clarendon and replanting mangroves in the Portland Cottage area. The Office of Disaster Preparedness and Emergency Management (ODPEM) has focused on community development, specifically in Rocky Point and Old Harbour Bay. Some of their activities have included designing community disaster risk management plans, conducting training programmes as a part of the CERT (Community Emergency Response Teams), and mangrove replanting in Portland Cottage and Rocky Point.

NEPA is also assisting in the development of new strategies. They are funding C-CAM to implement demarcation of the boundaries of the fish sanctuaries in the PBPA; they are implementing an Alternative Livelihoods Programme beginning with workshops promoting bee farming, ecotourism and heritage programmes, organic farming and value added products; and they are engaged in shoreline protection in old Harbour Bay.

Non-governmental organizations (NGOs) have been actively involved in raising awareness. These include:

PANOS Caribbean

PANOS Caribbean and the NEEC (National Environmental Education Committee) have jointly formed a *Voices for Climate Change Educational Project* locally as part of PANOS Caribbean's Environmental Programme activities. The Voices for Climate Change Educational Project falls under the national climate change education strategy, and utilises the talents and expertise of local performing artistes to increase awareness about climate change issues and promote environmentally friendly behaviour.

In Clarendon, PANOS Caribbean embarked on a GEF funded biodiversity and climate change awareness programme for the 2010-2012 period entitled "Communicating Climate Change and Biodiversity". This program has a community level focus on the communities of Mocho and Portland Cottage in particular, with the purposes of building capacity, and raising awareness about issues related to climate change and the importance of biodiversity within those communities. Both communities have expressed concern about the potential effects of climate change on biodiversity and livelihoods. The program has facilitated climate change awareness workshops and a *Voices for Climate Change* concert in 2011, which commenced with a tree planting exercise.

Caribbean Coastal Area Management Foundation

C-CAM has been involved in activities aimed at promoting environmental conservation, livelihood diversification and awareness raising. The Foundation's philosophy is to promote sustainable development in the PBPA and thereby to improve the quality of life of all citizens and stakeholders, through conservation and appropriate use of natural and heritage resources. They list as their overall goals for the PBPA to provide:

- Clean land, water and air
- Sustainable use of natural resources contributing to improved quality of life of residents
- Conservation of species and ecosystems
- Support for participation of informed residents, resource users and other stakeholders in decision-making and implementation based on the best available information.

Their efforts are well known in the PBPA and they have produced many documents aimed at sensitizing and building the adaptive capacity of the surrounding communities in Clarendon in response to climate change. These include pamphlets about Climate Change impacts and adaptation, documents such as "Working Together to Conserve Portland Bight" and a student's manual entitled "Climate Change in Portland Bight: Making a Change".

C-CAMF has partnered with PANOS Caribbean in the promotion of climate change through the Voices for Climate Change campaign. Their joint efforts include the International Fisherman's Day Regatta, the replanting of mangroves in the Portland Bight area for World Wetlands Day 2012 and mangrove restoration in Portland Cottage & Rocky Point. The mangrove replanting effort also included partnerships with the Mocho Community Development Association, Christian Aid, the National Environmental Education Committee and the National Environment and Planning Agency, and through funding from the GEF Small Grants Programme (SGP).

C-CAMF work in conjunction with several co-management councils in the PBPA, including Portland Bight Fisheries Management Council (PBFMC), Portland Bight Tourism Council (PBTC) and Portland Bight Citizens Council (PBCC). The Councils are designed to allow collaborations and partnerships with community groups, NGOs, business people, government departments and agencies to manage the area.

5.3 Residents' Proposals

During the survey previously mentioned, respondents in the Portland Cottage community expressed ideas about sustainable management of the nearby forested areas. These include:

- The establishment of community based tourism. Respondents highlighted areas that could be used as attractions, such as caves and forested areas for bird or swallowtail butterfly watching. The residents expressed interest in being employed as tour guides.
- Employment of community members as forest rangers to protect and sustainably manage forest use.
- Building of a broom factory in the community. This would provide gainful employment for many people from the community. Land could be leased by C-CAM for a broom plantation to support the effort. This would also reduce pressure on forest use.
- HEART training programme. It was suggested that HEART could enlist 50 young people from the community per year in programmes including welding, building construction, electrical work and plumbing. This would provide them with certification and open up opportunities for a steady income, thereby reducing their forest use and reducing petty theft within the community.

6. CONCLUSIONS

6.1 Seven Things to Note

The purpose of this report is to examine the vulnerabilities and risks posed by present and projected climate change on the biodiversity of the Portland Bight Protected Area – with special emphasis on the two forested areas (Hellshire Hills and Portland Ridge). The intention is to help clarify the potential risks so that a robust long term and sustainable adaptation management plan for the PBPA can be established.

The following points are noted:

1. The PBPA represents the largest protected area in Jamaica. It includes the Portland Bight Wetlands and Cays Ramsar Site and is the proposed site for the Portland Bight Biosphere Reserve. It encompasses diverse ecosystems including dry limestone forests and hills, caves, coastland wetlands and mangroves, beaches, cays, sea grass and coral reefs as well as the anthropogenic lands and communities surrounding them. **Implication: The Bight's status as a protected area requires the implementation of diverse and innovative conservation initiatives given the diverse natural forms and systems and human activities and communities it encompasses. Adequate resources and personnel are needed to manage the extensive site and to enforce environmental legislation and zoning already in place or as may be required. The lack of resources contributes to the vulnerability of the region to climate and non-climatic stresses.**
2. The PBPA is one of high biological importance. The site is a habitat for more than 15 globally threatened species. Its mangroves are home to waterfowl and crocodiles as well as a nursery for fish and other marine wildlife. It is the site of one of the last remaining primary limestone forests in the Caribbean which is a habitat to over 300 species of standing plants (53 of which are endemic) and 11 endemic species of reptiles, including the critically endangered Jamaican Iguana. The species survive in the bioclimatic envelope unique to the region. **Implication: When climate varies outside of the bioclimatic norms sensitive ecosystems and species are threatened. There are, however, no studies of the direct and indirect sensitivity of species and ecosystems of**

the area to climate change. The magnitude of the impact of increasing climate extremes on flora and fauna can only be guessed at based on anecdotal evidence or research done on similar environments. The paucity of research including basic ecology and baseline information as well as data gathering/monitoring contributes to the vulnerability of the region to climate and non-climatic stresses.

3. The climate of the PBPA is warming, rainfall extremes (including droughts) and the frequency of intense storms and/or hurricane have increased in recent years. There is historical evidence of damage to coral reefs, mangroves and coastal infrastructure), with storm surge and flooding being particularly devastating. The projection is that climate change will lead to further warming, more rainfall extremes (floods and droughts), a mean drying, higher sea levels and more intense hurricanes**. Implication: There is inherent climate sensitivity of the physical and natural environments within the PBPA. The changing climate is already posing a real risk to the PBPA which will only be exacerbated by projected climatic change. Climate change must be planned for in the PBPA due to its inherent vulnerabilities to climate threats.**
4. The natural resources of the PBPA support livelihoods of associated or bordering communities. Livelihood activities include fishing and fishing related activities, harvesting of wood and lumber including for charcoal, and mining for limestone. There are also planned human settlements and industrial developments for areas within the PBPA. **Implication: (i) There is economic value associated with the PBPA. Previous economic valuations of the PBPA have noted this. Conservation of the PBPA will require sustainable use of its resources to facilitate livelihoods while conserving its natural resources. At present there is evidence of unsustainable livelihood practices related to the natural resources e.g. over fishing or removal of forest cover for charcoal in old growth forests. These practices represent non-climatic stresses which exacerbate vulnerabilities already existent due to climate. (ii) In addition to the physical and biophysical, livelihoods will be significantly impacted by climatic variations of the future.**
5. According to the Social Development Commission, within the community of Hellshire, a third of the household heads have attained tertiary level education while three quarters of the heads of the households are engaged in professional occupations. In Portland Cottage

it is estimated that 60% of the adult population is illiterate, and lack of nutrition may be inhibiting their learning. **Implication: There is variation in the socio-economic conditions of communities within or adjoining the PBPA. The existing socio-economic conditions point to different levels and/or manifestations of vulnerabilities to climatic threats in each community. The variation in socioeconomic conditions also point to different adaptive capacities to deal with climate change threat. Management plans being developed for differing communities must be tailored accordingly as vulnerabilities and risk to climatic threat differ due to socioeconomic conditions and 'one size' will not fit all.**

6. Community perception is that the forests of the PBPA have been visibly degraded over time and that the effects have had an impact on climate and livelihood. The majority of respondents (60%) to a survey undertaken thought that the Hellshire Hills dry forest has undergone a negative change over the years. **Implication: There is already a sensitivity amongst stakeholders to climate variability, associated risks and vulnerabilities. Finding ways to capitalize and leverage this knowledge is crucial to reducing vulnerability and handling the associated climate risk.**
7. The UDC, NEPA and ODPEM (and other government agencies) all have or had activities ongoing in the PBPA. There are non-governmental agencies actively involved in the region, including C-CAMFF and PANOS. **Implication: Some systems, agencies, groupings are already in place which can be called upon to address the challenges and risks of climatic and non-climatic threats to the PBPA. The cooperative management plan being proposed represents a wise strategy. It must clearly define roles and responsibilities for key stakeholders and collaborators.**

6.2 A Gap

As previously noted, the adaptation strategies and programmes aimed at protecting the natural resources of the PBPA must of necessity target conservation of all the ecosystems, livelihoods diversification, regulation and/or restriction, and public education and awareness. As shown in Table 18 some attempts exist to address of each of these areas within the PBPA. However, to appropriately target these options, to define their scope extent and reach, and to ensure their efficacy there is a need for supporting baseline data gathering and research, particularly with respect to the natural environment. For example, there are insufficient studies to adequately evaluate changes in forest ecology and to assess the need for and effectiveness of restoration and reintroduction of forests and associated biodiversity (Hammond, 1995; Khurana and Singh, 2000).

There is a gap with respect to monitoring, mapping, and modelling - including research associating climate with the ecosystems of the PBPA.

The following is noted about this gap:

- **Monitoring**. Recording and monitoring of atmospheric (rainfall, temperature, humidity, wind, etc.), terrestrial (soil moisture, pH, etc.), and marine (temperatures, salinity, etc.) variables, particularly within the most vulnerable ecosystems (e.g. the dry forests) is being done on a very limited scale, if at all. There is, for example, no meteorological station within the Portland Ridge forested area. This is important for defining the bioclimatic envelope for species survival and for establishing change as it is occurring. Relevant agencies including the Meteorological Service of Jamaica should be targeted for inclusion and review of the proposed Management Plan with respect to ensuring monitoring.

- **Mapping**. A comprehensive strategy for mapping and continuous monitoring of the ecosystems of the PBPA should be pursued, in particular for the fauna and flora of the forested hills. Maps are necessary for defining baselines and quickly identifying change. The strategy should identify and assign responsibilities to stakeholders with interest (including recognizing those who are already doing mapping and/or continuous species or resource monitoring). The strategy should identify specific gaps in mapping knowledge and outline strategies for filling them. Collaboration should include the Universities.

- **Modelling including climate-ecosystem research.** There are very few modelling related research efforts within the PBPA. This includes modelling of climate at the watershed or ecosystem scale, modelling climate species relationships, modelling of climatic hazards e.g. storm surge or fire potential. When coupled with monitoring, modelling provides the opportunity for instituting early warning systems (e.g. for onset of drought fire and exacerbation of fire potential) and for examining climate impact (e.g. on species composition or population) under hypothetical future scenarios. Modelling facilitates risk planning and the targeting of adaptation strategies. As for the mapping exercise a developed programme for modelling and research should identify specific gaps in knowledge and outline strategies for filling them. Collaboration should include the Universities.

6.3 Recommendation

It is proposed that a section of the management plan being drafted for the PBPA address explicitly the development of a strategy for addressing monitoring, mapping and modelling and research needs of the PBPA.

APPENDIX A – Climate Change Survey

A.1 Survey Methodology

For the purpose of this study, a "forest user" is taken to be any individual (or entity) that accesses the Hellshire Hills forest and/or utilizes its resources for leisure and/or for economic gains.

The survey design involved identifying forest users for inclusion in the sample by referrals from other subjects. The process began with a small number of persons who were themselves users of the Hellshire Hills forest (the desired requisite). These key individuals were then asked to identify and introduce to the survey team other persons who they knew were also using the area. As the process continued, the number of subjects increased significantly.

In support of the snowballing methodology, the survey team also patrolled sections of the Hellshire Hills' northern, eastern and southern margins in search of forest users to interview. Strategic points (three sites in total) were monitored in order to intercept and interview individuals who were either exiting or entering the forest at these points. If no individual was observed using the forest at a particular entry/exit point, the location was revisited at a later date.

For more on the survey methodology and results see CSGM (2013a).

A.2 Hellshire Hills Survey Results

An index measuring the extent to which the Hellshire Hills has changed overtime was also created to summarize the observations of the respondents. Table A1 below gives a basic idea of how the index was created.

Table A1 Index of the degree of change observed in the Hellshire Hills forest over time.

	Increased	***Decreased***	***No change***
1. Number of large trees	Positive change (+1)	Negative change (-1)	No effect (0)
2. Type of trees available	Positive change (+1)	Negative change (-1)	No effect (0)
3. Closed forest canopy (shaded areas)	Positive change (+1)	Negative change (-1)	No effect (0)
4. New plants in the area	Positive change (+1)	Negative change (-1)	No effect (0)

5. Number of wild pigs	Positive change (+1)	Negative change (-1)	No effect (0)
6. Number of birds	Positive change (+1)	Negative change (-1)	No effect (0)
7. Daytime temperatures	Negative change (-1)	Positive change (+1)	No effect (0)
8. Night-time temperatures	Negative change (-1)	Positive change (+1)	No effect (0)
9. Amount of rainfall	Positive change (+1)	Negative change (-1)	No effect (0)
10. Availability of roots, flowers & craft materials	Positive change (+1)	Negative change (-1)	No effect (0)

Essentially, all variables were recorded to reflect the values presented in Table A1. The responses of each respondent were then summed to create a single value termed the "Forest Progress Index". The index, which mathematically can range from -10 to 10, will give a composite measure of the changes (whether dominantly negative or dominantly positive) which have been observed overtime by each respondent.

Basic descriptive statistics of the Forest Progress Index reveals that on average, the respondents believe that the forest has slightly degraded over time (the index has a mean of -1.3). The maximum score on the index is 5 and the minimum is -8. This could be taken to mean that the most optimistic person gave the forest a score of 5 out of 10, whereas the most pessimistic individual gave the forest a -8 out of a -10.

Table A2 Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
CC_Index	35	-8.00	5.00	-1.2857	3.31282
Valid N (listwise)	35				

The Forest Progress Index was also grouped into five categories and then compared across locations.

A significant negative change was defined as an index score which records less than -5; a negative change means that the index values were between -5 and -1; no effect is when the index is identical to 0; a positive change occurs when the index valued between 1 and 5; and finally a significant positive change is when the index scores above 6. A summary of the results is presented in Table A3. Clearly, the majority of respondents (60%) think that the Hellshire Hills forest now is not what it used to be in the past, it has degraded.

Table A3 Forest Progress Index

Magnitude of change observed	Number of responses	Proportion
Significant negative change	4	11.4%
negative change	17	48.6%
no change	3	8.6%
positive change	11	31.4%
Total	35	100%

Table A4 Forest Progress Index by location.

	Forest Progress Index				
Location	**Significant negative change**	**Negative change**	**No change**	**Positive change**	**Total**
Dunbeholden District	2	1			3
Hellshire Beach	1	5	1	5	12
Hill Run	1	11	2	6	20
Total	4	17	3	11	35

At all three locations visited the number of respondents who perceived an overall negative change dominated the proportion that perceived largely positive changes in the Hellshire Hills. More specifically, about 60% of the interviewees in Hill Run, 50% along the Hellshire beach and all 100% in Dunbeholden agree that the forest now, when compared to times gone, is depleting, all things considered.

Table A5 Effort getting harder

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	15	42.9	45.5	45.5
	No	15	42.9	45.5	90.9
	Not sure	3	8.6	9.1	100.0
	Total	33	94.3	100.0	
Total		35	100.0		

It is inconclusive as to whether or not each respondent's work or effort in the forest is getting harder. The number of persons who claimed that their effort was getting harder in the forest was equivalent to the amount that said it was not getting harder to work in the forest. Three understandably indicated that they were not sure. This is perhaps because any marginal increase in work load is too negligible to be noticed by the majority of individuals.

Table A6 Will continue working in the forest for the next five years.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	20	57.1	60.6	60.6
	No	13	37.1	39.4	100.0
	Total	33	94.3	100.0	
Total		35	100.0		

Over 60% of the sample indicated that they had no intention of discontinuing their work in the forest (Table A6) despite 71.4% claiming that the effects of climate change on the area is visible (Table A7).

Table A7 CC affects the forest.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	25	71.4	71.4	71.4
	No	10	28.6	28.6	100.0
	Total	35	100.0	100.0	

Table A8 How CC affects the forest as perceived by the respondents who claimed it would.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		9	25.7	25.7	25.7
	Causes the sea to rise and stopping persons who are digging pits to stop the work because the water tend to rise on them	1	2.9	2.9	28.6
	Cuts the growth of young plants, trees die	1	2.9	2.9	31.4
	Cutting down trees to burn coal results in less rain	1	2.9	2.9	34.3
	Does not know because he use to go when he was a boy	1	2.9	2.9	37.1
	Drought dry out peas and water saturate root and kill plants	1	2.9	2.9	40.0
	It does not rain often, but once it starts, flooding becomes a problem	1	2.9	2.9	42.9
	It is hotter now	1	2.9	2.9	45.7
	Less mud baths for pigs and temperature getting hotter	1	2.9	2.9	48.6
	Less rain so trees don’t grow	1	2.9	2.9	51.4

	Less tress growing because of dumping plastic	1	2.9	2.9	54.3
	makes the trees look greener when there is a lot of rainfall, however sometimes we have droughts	1	2.9	2.9	57.1
	Most of the time when it rains	1	2.9	2.9	60.0
	On the fish, when its cloudy a lot of the fishes die	1	2.9	2.9	62.9
	Plants and trees die	1	2.9	2.9	65.7
	Slow the growth of trees and animals	1	2.9	2.9	68.6
	Temperature changing	1	2.9	2.9	71.4
	The forest affects the climate because the cutting of trees results in less rainfall	1	2.9	2.9	74.3
	The temperature has increased compared to years ago	1	2.9	2.9	77.1
	There is a decrease in the number of rainfall	1	2.9	2.9	80.0
	Trees getting less water as the amount of rainfall is decreasing	1	2.9	2.9	82.9
	When it is too hot there is drought and the trees die	1	2.9	2.9	85.7
	When it rains a lot the trees tend to spring up more	1	2.9	2.9	88.6
	When persons cut the green trees it tend to reduce the amount of rainfall	1	2.9	2.9	91.4
	When the rain falls you can't go to work	1	2.9	2.9	94.3

	When the time gets hot it affects the growth of the trees.	1	2.9	2.9	97.1
	When the time is cooler, trees grow more rapidly	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

Table A9 Justification for wanting to continue operating in the Hellshire Hills for the next five years.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		4	11.4	11.4	11.4
	As long as he lives	1	2.9	2.9	14.3
	As long as I am alive	1	2.9	2.9	17.1
	Business is profitable	1	2.9	2.9	20.0
	Do not make a living from it	1	2.9	2.9	22.9
	Form of enjoyment	1	2.9	2.9	25.7
	Getting older	1	2.9	2.9	28.6
	Going into fishing industry next year	1	2.9	2.9	31.4
	Hobby	1	2.9	2.9	34.3
	Hobby and tradition	1	2.9	2.9	37.1
	If able to	1	2.9	2.9	40.0
	If I stop somebody will take over, need to earn money	1	2.9	2.9	42.9
	Its my job	1	2.9	2.9	45.7
	Limited	1	2.9	2.9	48.6
	Main living and loves it	1	2.9	2.9	51.4
	Main Source of income	1	2.9	2.9	54.3
	Mining business earns a lot	1	2.9	2.9	57.1

Need for my restaurant	1	2.9	2.9	60.0
Not sure	1	2.9	2.9	62.9
Not Sure	1	2.9	2.9	65.7
Not the dream job	1	2.9	2.9	68.6
Source of income	4	11.4	11.4	80.0
Source of income and ease of access	1	2.9	2.9	82.9
The demand for chicken is high	1	2.9	2.9	85.7
Too hard and dangerous	1	2.9	2.9	88.6
Tradition and a passion	1	2.9	2.9	91.4
want to improve	1	2.9	2.9	94.3
Wants to own the equipment	1	2.9	2.9	97.1
We will use it as long as pigs are available to hunt	1	2.9	2.9	100.0
Total	35	100.0	100.0	

APPENDIX B – Interviews residents (Portland Cottage)

Summary of Interview conducted with Focus Group in Portland Cottage on Friday November 9, 2012

The following summary is a collection of responses gathered by the Climate Studies Group in a focus group with eleven residents from the Portland Cottage community, on forest use, socioeconomic activity of the area and the impacts of climate change on well being and biodiversity.

How is the forest used by the community?

The forest is used mainly for agricultural purposes; harvesting of trees for coal and broom production. Both residents and outside persons cultivate gungo peas, tomato; cassava, pumpkin and marijuana in the forest.

NB: The term forest is defined by residents to not only include traditional definitions but also extends to areas of abandoned lands where vegetation grows wildly.

Kasha *Prosopis juliflora* is the plant used for coal production by knowledgeable coal burners. It is a fast growing plant species, taking two years to fully mature for harvesting. It grows wildly in the district of Portland Cottage. Coal production is a process that takes 4 days.

Why do people use the forest?

A lack of livelihood options coupled with a robust market for coal and broom products are the key socioeconomic conditions driving internal and external indiscriminate logging of wood.

How far do they go into the forest?

Forest users (from outside of the community) who harvest the trees for broom and coal production operate at the lower areas of the forest.

The more knowledgeable coal burners from within the community harvest wood for coal from anywhere in the community, where the kasha plant can be found.

Respondents felt that the demand for coal is due to not only obvious reasons but because food prepared on a coal stove is better tasting.

Have you noticed any changes in the forest?

The respondents have observed less rainfall in the forest, than in previous times. This was attributed to the death of trees as a result of "heat" or increasing temperature in the days and indiscriminate logging.

How old are the forest users and how often do they visit the forest?

They are middle aged (45-55 years) and visit the forest between 4 and 5 a.m. in the morning. They don't come at any particular day of the work week. Respondents witnessed an increase in forest use i.e. logging for coal and broom production since the year 2000, due to massive unemployment.

N.B: Respondents noted that it is people from outside the community who are using the forest for thatch harvesting more so than those living inside the community.

What are the main sources of income in the community?

Fishing, charcoal burning and agriculture were defined as the main sources of income in the community. Some persons work at the Monymusk factory.

How do you propose C-CAM improve the lives of people within the community?

- Community based tourism, is a venture that could be established in the community. Respondents highlighted areas that could be exploited like the caves and forested areas for bird watching; owls; swallowtail butterflies. The residents expressed interest in being used as tour guides.
- Community residents also indicated interest in being forest rangers to protect and sustainably manage forest use.
    - NB: Currently there are no forest rangers protecting the area from human disturbance.
- Respondents reacted positively to the idea of land that C-CAM could lease for a plantation. A plantation is a place where trees are planted for a specific purpose i.e broom

and coal production. This would be used to also sustainably manage and reduce pressure on forest use.

- A factory for broom production could be built in the community, which would provide gainful employment for many people from the community.

What could be done to address the high unemployment rate, especially among the youth in the community?

The youth of the community were described as generally unwilling to “get their hands dirty” in agriculture and “quick profit seeking”. Therefore, it was suggested that HEART training programme enlist about 50 young people from the community per year in programmes like welding, building construction, electrician and plumbing work. This would provide them with certification which could secure opportunities for a steady income, reduce their forest use and reduce petty theft within the community.

One respondent noted that near to Christmas time, more trees are logged in the area for coal production by the young people from Portland Cottage because they want “money to spend for the upcoming Christmas season”. Therefore in a very direct way, employment would reduce pressure on forest use.

Are you aware of the term “climate change”? How?

The respondents are aware of climate change due to media coverage (radio and television) and sensitisation by NEPA and other environmental organisations during their seminars within the community.

How is climate change affecting your livelihood?

- Every year the drought or “dry season” is getting longer and there is a reduction in rainfall. This dry season (March to June) with the increasing daytime temperatures dries out the crops, including the plants that the animals graze on, which eventually leads to death by starvation; and significant profit loss for the farmers.

- During heavy rainfall, flooding is restricted to low lying swampy areas. One respondent indicated during the passage of Hurricane Sandy, water settled around gungo peas, tomatoes in his backyard and killed them.
- When there is flooding, one respondent noted that some farmers in the community lost their livestock (pigs, goats and chickens) due to drowning. Other animals developed screwworm.
- Heavy rainfall disrupts the activity of the charcoal burners.
- The inconsistent rainfall patterns in the area has also disturbed the cultivation cycle of farmers who used to plant during times of predicted heavy rainfall (May and October).

How are the changes in climate affecting your health, productivity?

The dry and "hot" times (March to June) affect those residents who suffer from asthma.

Also during times of increasing daytime temperature or "hot times" respondents of the focus group reported that they have no energy to carry out their day to day activity. One respondent noted that she heard that one member of the community who was doing "bushing" recently collapsed in the midday heat.

The heat inside the forest is also affecting the farmers' routine. Currently they plant their crops in the early morning or in the evenings because they cannot bear the heat during the daytime.

How is climate change affecting the biodiversity?

The respondents indicated that climate change is affecting the biodiversity in the following ways:

a) Crab season has been affected by the reduction of rainfall. Portland Cottage used to have major rainy seasons in May and October, which was synonymous with "crab season" (a time when residents anticipated crabs for consumption and trade). However, since the 1970s, respondents have observed that Portland Cottage has experience a reduction in rainfall. So much so, that there was no rainfall in the area, this year except for that brought on by the passage of Hurricane Sandy, which meant that the crab season occurred once this year.

b) The respondents have observed an abundance of sweetsop in the area, which they have linked with the increasing heat; lack of water and seed dispersion by foraging birds.

c) Longer bearing season for guineps. Guineps usually bear from June to August, but respondents indicated that guineps are still bearing in the community. Also the mangoes which only bear in May have now been bearing the entire year.

d) The size of certain fruit (guinep, sweet sop, june plum) is smaller than it was in the past.

Forest biodiversity

Wild boar, yellow belly snake and wild goats are also found in the forest. Wild boars are hunted for consumption. They have a taste similar to pork and are perceived by the respondents to be of higher nutritional value, due to their diet of berries.

Environmental observations:

During dry season, salt emerges on the shoreline of Jackson Bay due to evaporation of seawater. The residents sell this salt to supplement their income.

Respondents explained that many people in the community live with the chronic illness of hypertension which they attributed to their “salty” area and water supply, which is high in sodium content.

APPENDIX C – Interview (PWD Club)

Interview with Mr. Miller at PWD Hunting and Sporting Club

What are the general activities observed in the forest?

People use the 3 mile boundary outside of the club forest for farming (outside the gate) and for harvesting thatch.

Is there any charcoal burning observed?

It is mostly people from the community who harvest trees to burn charcoal and they operate on private land. This activity happens beyond the gate.

There is no coal burning inside the forest.

Thatch: About 8 or 9 men and women come everyday in a little pickup to harvest the thatch for broomsticks. They come early morning and leave by midday. The people who cut the thatch use the whole leaves and the branches of trees, by cutting them with chain saws and machetes.

They don't live in the community, they come from as far as May Pen,

Pigs are hunted beyond the gate.

Fishermen use the beaches in the district.

What do you understand from the term climate change?

Rain only falls when depressions build up. The residents of the community used to be able to predict the seasons. Days gone by people used to use fireside and have to pack up when May is coming. When rain fell, it used to fall for 13 days.

There are warmer days and nights than years gone by.

Do you notice any changes in the number of large trees?

There are more large trees. It is a heavily shaded area because of Tropical Storm Sandy and also people who use the club plant a lot of trees.

APPENDIX D – Interviews (St. George's Cliff)

Interview in St George's Cliff with 2 residents (upscale community in Hellshire)

- The removal of trees for the construction of housing has reduced the level of rainfall in the area.
- Daytime and night time temperatures have also increased.
- During tamarind time, June and July, there is a high incidence of forest fires. This was also attributed to the presence of flint stones in the forest.
- The summer times are hotter and there is a lot less rainfall.
- 2012 has been extremely hot and the winter months are hotter and drier than years ago.
- Hellshire used to rain only when the island had rainfall, now it only happens when a depression is near.
- Charcoal burning in the area is not allowed because the Urban Development Corporation heavily enforces forest use in the community.
- It is the dead trees that are usually harvested for coal.
- Hellshire people use firewood to fry their fish.
- Consumption of wild pigs in the area led to their gradual extinction.
- Police and soldiers regulate and control the abandoned areas of the community because it is believed to be an area of heavy illegal activity.
- There is no specific use of the forest. Farming is discouraged in the community because the soil is too dry to grow anything of value and the chlorine in the water will kill the plant.
- The forest is also not used because it has very rugged terrain, too far to access the wood for coal burning and too many insects (wasps and red ants).

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