COASTAL WETLAND PRELIMINARY ASSESSMENT FOR VULNERABLE AREAS AND RESTORATION OPPORTUNITIES AT PORTLAND BIGHT PROTECTED AREA, JAMAICA

Caribbean Community Climate Change Centre (CCCCC)

1/19/2018

Recommendations for Climate Change Sustainability of Coastal Habitats

Prepared for

Caribbean Coastal Area Management Foundation (C-CAM)
P.O. Box 33
Lionel Town, Clarendon
Jamaica

Prepared by

Lewis Environmental Services, Inc.
11449 Calhoun Ct.
Venice, FL 34293 USA

TABLE OF CONTENTS

TABLE OF FIGURES

INTRODUCTION

Portland Bight Protected Area (PBPA) and the Cays Ramsar Site, established in 1999, are located along the coastal plain within the southwest quadrant of Jamaica and is comprised of a mosaic of saltwater and brackish water wetland types including, mangrove, scrub mangrove, salinas, beaches and marshland (Figure 1). The area represents the largest remaining mangrove system in Jamaica, encompassing 48 km^2. These areas provide valuable nesting for several endangered and threatened species including the Hawksbill sea turtle (*Eretmochelys imbricata*), Green sea turtle (*Chelonia mydas*), West Indian Whistling duck *(Dendrocygna arborea),* and American crocodile (*Crocodylus acutus*). In particular, the Salt River, Rolling Bay and West Harbour are three of the most important areas in Jamaica for crocodile nesting. Suitable nest sites are one of the most important limiting factors for crocodile populations. Additionally, PBPA provides nursery and shelter habitat to a large variety of crab, shrimp, and mollusk species and for many fish species, including coral reef fish, which support important local and commercial fisheries. Wading birds foraging along the shorelines and open lagoons also benefit from plentiful invertebrate and fish found within these areas. Vast areas of mangrove and marshland also provide important attenuation of storm energy by protecting shorelines and inland areas from wave erosion and storm surge energy.

Although under protection, some areas remain vulnerable to both anthropogenic, socio-economic and natural stressors that have resulted in a decline of wetland functions. In particular, mangrove forests have suffered from ongoing human encroachment, hydrologic alterations, harvesting, grazing, and impacts from severe storm, hurricane and drought events. Such activities and events that alter the landscape, creating blockages in the natural paths for tidal exchange, will increase the frequency and prolonged periods of flooded conditions within portions of the forest. The state of increased frequency and prolonged periods of flooding will eventually cause acute die off areas of the forest (Lewis 2005, Lewis et al. 2016). These areas tend to increase in size over time and without restoration will persist as dead areas providing little to no ecological benefit. Effects from drought, when occasioned by unseasonably extended high winds which prevents cloud formation and precipitation from occurring on lowland coastal areas cause desiccation of coastal vegetation. This was observed within nearshore Cays during 2016 severe drought, where some of the vegetation on the nearshore Cays became so desiccated that it looked as though it had been scorched by fire.

Lewis Environmental Services, Inc. (LES) was contracted by the Caribbean Coastal Area Management Foundation (C-CAM) to provide a preliminary status assessment of the coastal wetlands, primarily mangrove forest, and provide recommendations for priority management and restoration. This assessment supports the overall project “Climate Change Adaption in the Portland Bight Protected Area, Jamaica”, whereas the overall objective of the project at the local level is to implement local adaption measures to reduce vulnerability and increase resilience to the impacts of climate change and human impacts in PBPA. Project funding is graciously provided by the Caribbean Community Climate Change Center (5Cs) with co-financing from the Federal Republic of Germany through the German Development Bank (KfW).

LES has worked closely with the Science Officer, C-CAM staff, NEPA staff and the Manchester Parish Council Planning Department to gather and evaluate existing information, complete on site evaluations of target locations, and assess the current status and potential threats to the long term sustainability of the mangrove forest and associated wetland types. This information is further used to identify specific coastal areas suitable for restoration and in general, feasible approaches to restoration including long-term conservation measures to address climate change and hydrologic restoration opportunities. C-CAM's overall objective for coastal restoration is to restore optimal wetland functions supporting a variety of wetland habitats to capture different community types. This includes restoring mangrove, mangrove scrub, salt flats/salinas, lagoon, mudflats and tidal marshes and the connectivity between these communities. In recent years, NEPA and C-CAM have worked to restore these areas with projects such as the Portland Cottage mangrove planting project that implemented hydrologic restoration to support planted mangroves and encourage natural recruitment.

This report is not intended to provide detailed restoration design, as additional work would need to be completed to ensure a successful restoration project. This report is intended as a starting point to identify areas of concern, evaluate issues of vulnerability and consider management options for the long term sustainability and climate change resilience of the PBPA. Impacts from climate change, in particular an increase in sea level rise and the increased precipitation and storm strength, will inevitably affect these coastal areas. The degree to which these changes will affect coastal communities largely depends on topographical, climatic and anthropological influences (Field 1995). Management and restoration decisions should consider all aspects of climate change to ensure the long term sustainability of these areas.

Figure 1. Location and Major Areas of Consideration at Portland Bight Protected Area.

SITE ASSESSMENT AND STATUS REPORT

LES completed a site visit on October 17-18, 2017 and areas were accessed by both boat and land. Areas evaluated include the Salt River and Cockpit Wetlands, Rocky Point and Burial Grounds Point, Peake Bay, and West Harbour. In addition, specific locations of interest at Dolphin Point, outer barrier islands and Jackson Bay Beach were visited.

The Cockpit Wetlands Area (CSM) is located in the northern portion of the PBPA and is comprised of brackish water wetlands inshore and mangrove forest seaward (Figure 1). Cockpit River to the north, is a spring fed river that is a source of ongoing freshwater flows. A portion of the Cockpit River water is diverted through a canal system that runs the parallel to Salt River Road (Figures 2 and 3). The canal system separates the road and small development areas from the expansive brackish wetland area comprised largely of Phragmites (*Phragmites australis*), cattail (*Typha domingensis*) and sawgrass (*Cladium jamaicense*). Mangrove forests, are expansive in this area and comprised of all three regional species; red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and white mangrove (*Laguncularia racemosa*). Higher elevations support the mangrove associate buttonwood (*Conocarpus erectus*). Three mangrove and beach islands; Long Island, Short Island and Salt Island are located offshore and likely provide benefit to the mainland by attenuating some wave energy during storm events (Figure 3). Long Island and Short Island are surrounded by a vast area of seagrass and coral outcroppings to the east, however, both islands have suffered erosion on the eastern side. Short Island is small with little vegetation and likely to disappear with continued storm events. Salt Island is the largest of the three islands and supports a large interior lagoon. Recent decline of coral reef in this area and the onset of strong storms has produced a phenomenon where dead coral has been piled on the east side of the island creating a natural breakwater.

Review of historical 1950 aerials (Photographic Survey Corp. LTD, for the West Indies Sugar Company LTD) (Figure 2) and recent Google Earth imagery indicates this area has largely supported coastal ecological functions and has shown some expansion into the adjacent marshlands. The historical impacts on the area of the damming of the mouth of the Cockpit River, which would have increased the amount of freshwater retained in the wetland, and the more recent partial breach of the dam, have not been documented. However, the diversion of freshwater flows from the canal, a drainage canal located near the center of the area and a road blocking connections to the south have likely have induced some degree of sustained stress on the system (Figure 3). Recent greater than normal rainy seasons and hurricane activity (Charlie and Ivan in 2004 and Dennis, and Emily in 2005, Dean 2007 and Sandy 2012) and severe drought in 2016 have damaged some of the larger trees and evidence of a forest decline is seen in the 2017 Google Earth image (Figure 3). The role of hurricanes in changing the composition of the CSM is undoubtedly significant, however, the marsh areas are also frequently subjected to fires which regularly burn large sections of the wetland and are also likely causes for the expanding area of marsh relative to mangrove or coastal scrub as the grasses recover much faster from fires than the forests and therefore they increase their territory. Fires are frequently deliberately set by persons who fish in the CSM to create and maintain access and possibly to drive out threats from territorial crocodiles.

This area, is still largely intact and is a priority for further investigation to determine specific reasons for the decline and the feasibility of rehabilitation. The ability to intervene and rehabilitate a mangrove forest before a die off not only saves resources, but is more cost effective, has a greater chance for success and prevents large scale loss of stored carbon, helping reduce the effects of climate change (Lewis et. al. 2016).

Figure 2. 1950 Aerial of Cockpit Wetlands and Canal System, Photographic Survey Company LTD.

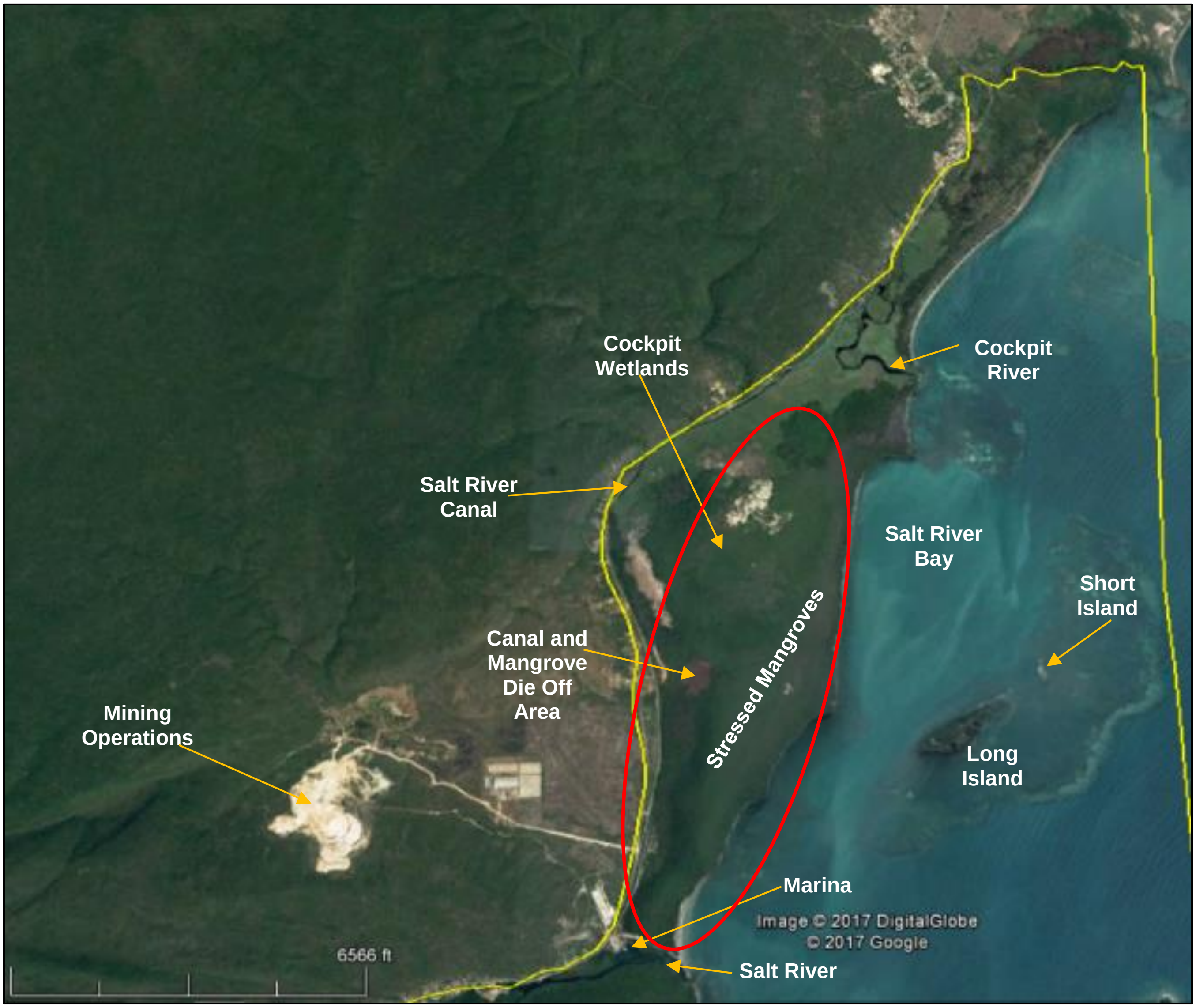

Figure 3. Cockpit Wetlands Major Landscape Features and Stressed Mangrove Area.

ROCKY POINT AND BURIAL GROUND POINT

The Rocky Point and Burial Ground Point areas include primarily basin mangrove (all three species and buttonwood), scrub mangrove and salinas, adjacent to the north side of Rocky Point Road and rail road tracks. The Salt River and its tributaries border the northern side of the area where the newly constructed C-CAM Discovery Center for wetlands and wildlife interpretation is located. The Burial Grounds Point peninsula and Rocky Point bauxite storage and shipping facilities protrude along the east side of the shoreline and Rocky Point Road and rail tracks border the southern edge of the wetlands (Figure 4).

The construction of Rocky Point Road and rail tracks did not include drainage systems to allow natural flows from Burial Ground south to Peake Bay, therefore, tidal flow and freshwater runoff discharge are forced through tidal connections at Salt River Bay and another into Colon Bay (Figure 4). These tidal connections are likely in some state of closure, reducing tidal exchange to the interior. In addition, storm events and erosion have breached portions of the coastal berm north of Rocky Point, leading to opening of coastal lagoons to the sea. This combined with sea level rise, is contributing to coastal erosion in some places and has resulted in the loss of important shorebird habitats. The importance of the PBPA for shorebirds was one of the criteria that were used when the Portland Bight and Cays Ramsar site was declared. Since shorebird habitats are increasingly rare in Jamaica and the rest of the Caribbean, a great deal of importance is given to preserving and restoring these areas.

Historical aerials from 1950 show the area pre-development and evidence that Rocky Point Road and rail tracks had blocked those flows to the northern tidal channel and likely impounded some of the mangroves directly to the south as seen in the "pockmarking" of the mangrove forest were the canopy has opened up due to trees dying (red circle) (Figure 5). Closer to the shoreline and roadside, mangroves are intermittent due to higher elevations from accumulations of sands and erosion from the roadside and fringe mangrove forest borders the shoreline.

The 2004 Google Earth image shows two tidal connections, with much of the area flooded and void of substantial vegetation (Figure 6). Later that year, Hurricanes Charley and Ivan in 2004, and Dennis and Emily in 2005, changed the hydrology, possibly further reducing tidal flows. By 2006, new mangrove colonization is evident in areas that were historically higher in elevation and represented scrub mangrove and salinas (Figure 7). By 2017, much of the historic scrub mangrove, salinas and mudflats areas that served as important bird foraging area, became colonized by mangrove and areas historically mangrove forest became zones of dead mangrove and impounded waters (Figure 4).

The areas where mangrove has migrated to have impacted important bird foraging areas. Long term documentation has shown species such as the globally vulnerable West Indian Whistling duck (*Dendrocygna arborea)* and many species of waterfowl, warblers and shorebirds routinely use the area, however, in recent years there appears to be a decline in the diversity and number of species present in this area. The area is also an important foraging area for columbids, including White-crowned pigeons (*Patagioenas leucocephala)* and White-winged doves (*Zenaida asiatica).* This area is also of recreational importance and is used by bird hunters during the shooting season.

The known potential major stressors on the hydrology of the area are the continued closure of the north and south tidal connections causing reduced tidal flow. Rehabilitation activities such as opening up the tidal channels and restoring coastal berms has the potential to restore enough tidal exchange to reestablish a healthy mangrove forest while allowing higher elevations to continue as marginal mangrove habitat allowing bird foraging habitat to persist. Important bird areas, such as the narrow belt between the road and the western end of Colon Bay, should a priority to restore both bird and crocodile habitats. Additional information to verify our professional opinion and develop such a plan will need to be collected prior to any major restoration activity being considered.

Burial Ground Point has in recent years suffered from severe erosion where storms have impacted the eastern and most vulnerable side of the peninsula. The peninsula has lost approximately 10% - 15% of its 1950 area, based on aerial interpretation (Figures 4 and 5). C-CAM has worked to restore the eroded degraded areas with mangrove plantings. With the work of C-CAM and natural regeneration, the area has developed into a small embayment with mud flats and seagrass meadows providing a mosaic of tidal habitats to support fisheries and foraging for wading birds. However, these areas are very vulnerable to further erosion. It is recommended that continued mangrove restoration efforts and potentially armoring the shorelines with rip rap or constructing an offshore breakwater be considered to help reduce the rate of erosion to this area. It is noted, however, that seagrass meadows are dense and vast in this area and offshore breakwater may not be feasible. Further work to determine the best locations for protective barrier would need to be further investigated.

Figure 4. Rocky Point Area, Major Landscape Features, 2017 Google Earth.

Figure 5. 1950 Aerial Showing Pre-Development Conditions, Photographic Survey Company LTD.

Figure 6. 2004 Google Earth Image Showing Tidal Connections and Extensive Flooding.

Figure 7. 2007 Google Earth Image Showing Mangrove Recruitment into Higher Elevations.

PEAKE BAY

Peake Bay is located just south of Rocky Point has over time shown an overall decline of wetlands and in some cases, periods of mangrove death and recovery. The western side of the wetlands is bordered by Salt River Road and the outer reaches of Mitchell Town and the north side is bordered by Rocky Point Road and rail tracks. The general landscape is largely basin mangrove forest and natural lagoon areas. Higher elevations are found closer to the shoreline created by accumulation of sands (beach bars) from storm events, and currently is an expansive area of dead mangrove of approximately 154 ha (Figures 8 and 9). An impervious coastal berm along the eastern shoreline prevents routine tidal exchange to the majority of the area. The large lagoon system that borders the south end does not appear to have major influence on the area (Figure 8).

Based on photointerpretation of the 1950 aerial, Peake Bay tidal exchange was contiguous with the Rocky Point/Burial Ground system and represented a well-developed high canopy mangrove forest. Three significant points of tidal connections were present, all of which are now blocked by Rocky Point Road and rail tracks.

Although culverts are shown on topographic surveys, no culverts or drainage pathways were identified during the field inspection. The reduced number of tidal connections resulting in a decrease of tidal exchange, primarily the ability for the wetland to naturally drain with falling tides, has created at a minimum, a heightened level of stress on the wetland system. The addition of extreme wet seasons and devastating storm events further increased the frequency and duration of flooded conditions unsustainable for the mangrove forest. In 2004, Hurricane Ivan severely damaged the forest and opened up the canopy such that the forest floor was now subject to drying. This has led to the current series of partial regeneration and die off that the area is now experiencing. Additionally, the old Abner gully canal running roughly west to east directly through the Peake Bay mangroves (Figure 8) was a source of fresh water. This canal was reported to have been important in taking large volumes of excess flow from the sugar cane fields to the west. During the high periods of sugar production on the Vere Plains, fields were irrigated by periodic flooding and excess water was channeled to the sea in an extensive system of earthen canals. Since the decline of sugar cultivation (1970s) the canals have not been properly maintained and the Abner gully fell into disrepair. However, excess freshwater and rainwater runoff would have continued to supply the Peake Bay mangroves via this route presumably until it became completely blocked likely somewhere in the middle of the Peake Bay wetland. Today there is almost no evidence of the end of the canal where it once entered the sea.

There are opportunities for restoring this area by re-establishing historic tidal connections. This would include the installation of culverts under Rocky Point Road and allowing freshwater drainage from the old Abner gully canal to be redirected to a purposeful location. It should also be noted that it is possible that the mangroves along the western shoreline of Peake Bay present a unique situation where they may also have a natural cycle of die off and recovery from major storm events.

The 1950 aerial shows this area sparsely vegetated, however it cannot be interpreted if this is due to dead mangroves not visible in the image, or is in fact less mangrove (Figure 10). It is possible that the area suffered damage from the 1951 Hurricane Charlie followed by Hurricane Hazel 1954 and Hurricane Janet 1955. The Google Earth image from 2004 (Figure 11) shows this area mostly revegetated prior to impacts from Hurricane Ivan. The area again shows areas of major die off in 2006 after four major hurricanes (Charley and Ivan in 2004 and Dennis and Emily in 2005) (Figure 12). Recently Hurricane Dean in 2007 and Sandy in 2012 passed over the area and leaving little time for any significant recovery (Figure 8).

Figure 8. 2017 Google Earth Image Showing Major Landscape Features of Peake Bay Coastal Habitats.

Figure 9. Photographs of Peake Bay Dead Mangrove Area, October 18, 2017.

Figure 10. 1950 Aerial Showing Historic Conditions and Major Tidal Connections, Photographic Survey Company LTD.

Figure 11. 2004 Google Earth Image Showing Recovery of Mangroves.

Figure 12. 2006 Google Earth Image Showing Major Mangrove Die Off.

WEST HARBOUR

West Harbour encompasses the southern portion of the PBPA. Mitchell Town and Portland Cottage border the northwest and southwestern outer boundaries. Barrier islands to the east provide some protection from wind driven storms. The entirety of the shoreline is a mosaic of extensive salinas, mangrove forest and natural lagoons with most of the major tidal channels seemingly intact and functioning. The mangrove forest is intertwined with connecting open lagoons providing important nursery habitat for fisheries, bird foraging and crocodiles (Figures 13 and 14). However, some areas now open are the result of mangrove loss, possibly a combination of storm damage, recent greater than normal rainy seasons, and anthropogenic influences.

Anthropogenic alterations to the hydrology, encroachment into the interior wetlands and wood harvesting has introduced stress on the system resulting in areas of mangrove and salinas loss (Figure 15). The dependence on fishing, access to fishing areas, harvesting of mangrove for wood, grazing and dredging of drainage canals are challenging socio-economic influences that are difficult to address.

The 2002 Google Earth image (Figure 16) shows conditions of two areas of interest during active salt/fish pond activity and pre-filling of the Portland Cottage fishing beach. These areas were significantly altered by cutting of canals and ponds and casting material aside creating berms and blockages to the natural hydrology. This is evident in the die off of mangroves adjacent to these activities. In 2004, the Portland Cottage fishing beach was filled to allow better access to open waters of West Harbour (Figure 17). This exacerbated the problem by further blocking tidal exchange. In addition, hurricane damage and continued wood harvesting continues to thin the forest.

Recent efforts by NEPA and C-CAM to educate residents at Portland Cottage fishing beach and implement a local mangrove restoration projects by re-establishing the hydrology has proven successful in the revegetation (both planted and natural recruitment) of approximately 5 ha of mangrove (Figures 18). Additional work to remove blockages in the system will further increase the area of recovery. However, other stressors such as grazing by goats and socio-economic needs of wood harvesting, encroachment and filling of paths continues to be a difficult challenge that will require ongoing education and support of the community.

The second area of interest is an area highly disturbed by the construction of salt/fish ponds and canals. The disturbance has resulted in an area of mangrove die off and disturbance of salinas providing little to no habitat function (Figures 17 and 19). Removal of barriers and re-grading of the site would be necessary for restoration. Since this area is entirely open, many options are available to restore habitat for specific species such as crocodile nesting areas or hypersaline areas suitable for brine shrimp to encourage Flamingo use. Additional investigations and survey work would need to be completed to evaluate the complete restoration feasibility of this area.

Other areas of interest that were visited were Dolphin Point, the outer barrier islands and Jackson Bay Beach (Figures 1, 13, 20 and 21). After further historical review of Dolphin Point, the mangrove die off area appears to be a natural feature, where during times of drought, mangroves will re-colonize and then die off during rainy years and storm events. The size, shape, persistence and lack of any obvious stressor indicates this is a natural phenomenon of this area. Other areas nearshore and similar to Dolphin Point may be present, however without additional field investigations this cannot be verified.

The outer barrier islands are important to the sustained health of the harbor (Figure 13). The barrier islands help attenuate wave energy during high winds and provide important sanctuaries for a variety of shorebird species. Although the majority of the barrier islands are intact, the outer most islands are currently void of vegetation and are vulnerable to degradation. It is recommended that these islands be evaluated for the possibility of reinforcement using rip rap or something similar and planted if possible. C-CAM has worked to plant the outer islands, however strong waves and winds impede successful plantings. Potentially adding rip rap to help attenuate wave energy with continued plantings may provide benefit to the islands.

Jackson Bay Beach is experiencing massive mangrove die off from road construction blocking natural flows and drainage. In particular, the area to east of the main road to the beach is completely dead (Figure 21). Installation of culverts under the roads and potentially some clearing of channels that have accumulated sediments and debris from reduced flushing will likely facilitate natural recovery to the area. This area is a priority for restoration efforts.

Figure 13. 2017 Google Earth Image Showing West Harbour Major Landscape Features.

Figure 14. Photographs of Natural Lagoon Areas, West Harbour, October 18, 2017.

Figure 15. Photograph of Encroachment into West Harbour Wetlands, October 18, 2017.

Figure 16. 2002 Google Earth Image Showing Areas of Interest.

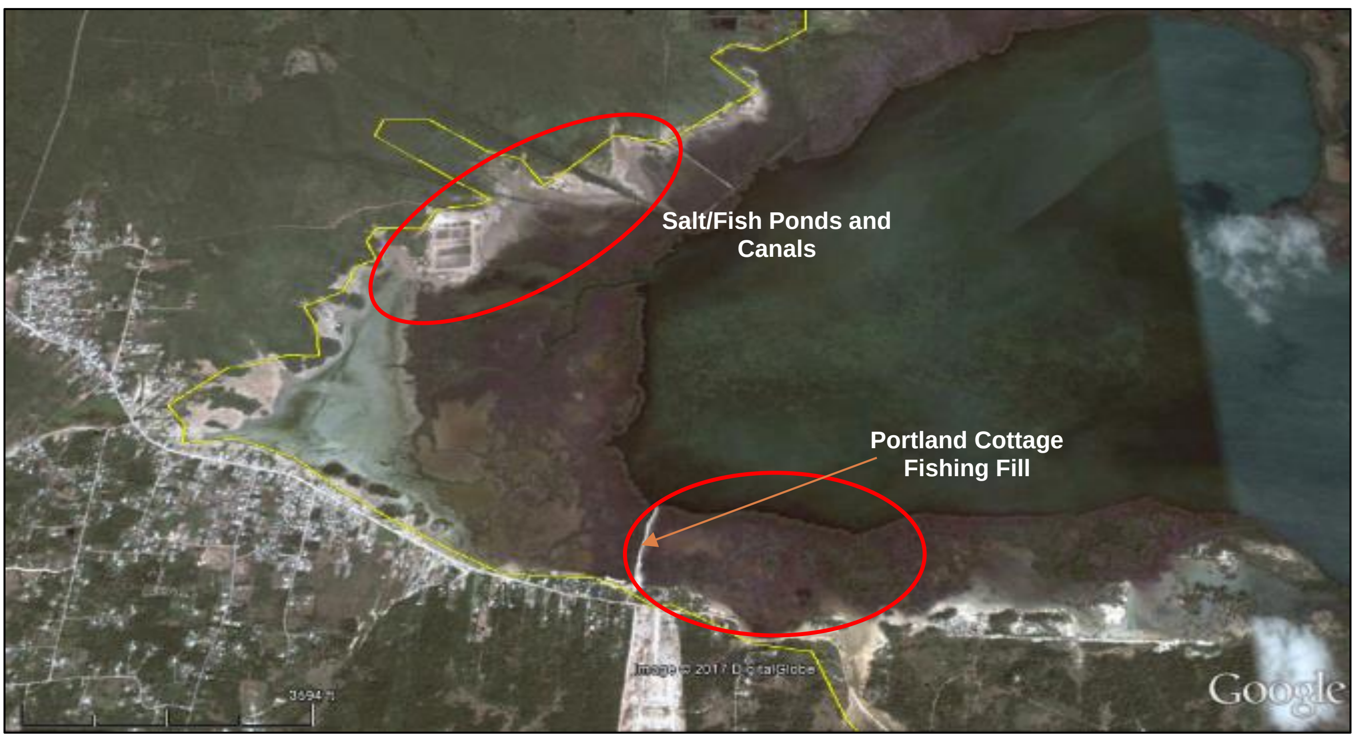

Figure 17. 2005 Google Earth Image Showing Areas of Interest and Severely Stressed and Dead Mangrove Forest.

Figure 18. Photographs of Portland Cottage Hydrologic Restoration and Recovery, October 18, 2017.

Figure 19. Photographs of Dead Mangrove and Salt/Fish Ponds at West Harbour, October 18, 2017.

Figure 20. Photographs of Dolphin Point Natural Mangrove Die Off, October 17, 2017.

Figure 21. Location of Jackson Bay Beach and Mangrove Die-Off Area.

RECOMMENDATIONS FOR PRIORITY RESTORATION PROJECTS

The provided recommendations for priority restoration projects are based on criteria we feel is necessary to implement a cost effective and successful project. The following criteria were considered for each of the proposed priority areas:

1. Need for habitat restoration (e.g. dead mangroves vs. stressed mangroves)
2. Potential for restoration of diverse wildlife habitat, especially for globally threatened species, species of economic importance and importance for eco-tourism, including crocodiles, ducks, columbids, shorebirds, herons and egrets and flamingoes
3. Availability of background data
4. Accessibility to site including ownership issues
5. Feasibility of implementing the project

6. Potential costs for restoration on a dollars per hectare restored basis including five years minimum of monitoring and reporting
7. Likelihood of success
8. Climate change influences and long – term sustainability

It is important to emphasize that in all cases, additional investigations into historic conditions, hydrologic data collection, topographic survey, field verification of potential stressors and vegetation baseline data collections are at a minimum necessary to implement a successful project (Lewis and Brown 2014). Although predictions of the effects of climate change to mangrove forests vary, it is generally agreed that a healthy mangrove forest has a greater ability to adapt to the changing environment versus a mangrove forest under stressful conditions. Therefore, rehabilitating a stressed mangrove forest prevents total loss of the forest and the ecosystem services it provides. Finally, rehabilitating an existing, but stressed forest also prevents the loss of sequestered carbon into the atmosphere that would further contribute to the overall climate change system.

Based on the criteria above, it is our professional opinion, that the following areas would be good candidates for rehabilitation and restoration and are listed in general order of priority.

1. **Rocky Point/Burial Ground Point** (Rehabilitation/Restoration) – Tidal clearing, fill removal, restoring natural hydrologic flows, possibly installing a culvert under Rocky Point Road and conservation and restoration of berms in other areas. Continued work at Burial Ground Point and protective measures considered. Potential New Fortress pipeline impacts/mitigation may affect the hydrology and coordination with C-CAM is critical to ensure the area is not further degraded.
2. **Jackson Bay Beach –** Install culverts under road and potential channel clearing.
3. **West Harbour Salt/Fish Pond** (Restoration) – Regrading and removing blockages to restore natural hydrology. Reinforcement and continued planting of the outer islands.
4. **Portland Cottage Fishing Beach** (Rehabilitation/Restoration) – In progress -Continued removal of blockages for restoration of areas to the south
5. **Cockpit Wetlands** (Rehabilitation) – Tidal clearing, restoring natural hydrologic flows to the north
6. **Peake Bay** (Restoration) – Restoring natural tidal connections, installation of culverts under Rocky Point Road. This area appears to be uniquely sensitive to storm events and restoration may be limited by an increase in storm intensity. A significant amount of investigation will need to be completed prior to finalizing any restoration plan.

LONG TERM MANAGEMENT FOR CLIMATE CHANGE RESILIENCY

Climate Studies Group (2013) has prepared a climate change risk assessment report for the Portland Bight Protected Area (PBPA). They correctly note that future projections for climate change worldwide suggest that there will be changes in temperature, rainfall and the rate of sea level rise that may impact the survival into the future of mangrove forests within the PBPA due to increased wide swings in precipitation, more severe hurricanes, more flooding and increases in the rate of sea level change beyond what mangrove forests can be expected to adequately respond to and continue to exist.

Mangroves are noted to be particularly sensitive to storm and hurricane winds which can break the upper stems and trunks of larger trees, or blow trees over, and climate change can therefore be expected to damage more forests over time. However, mangroves have persisted for thousands of years along the south coast of Jamaica and recovered repeatedly from such damage without the intervention of humans, as presumed by review of recent historical aerials at Peake Bay.

Healthy mangroves can even keep up with sea level rise if they are not subjected to "coastal squeeze" where roads, seawalls or constructed human communities interfere with natural migration landward. The issue of "coastal squeeze" is mentioned in the Climate Studies Group Report (2013) on page 40 and is noted to likely be a major problem for landward mobility around the settlements of Mitchell Town and Portland Cottage. Also mentioned is the harvest of live mangrove wood for the manufacture and use and sale of charcoal in these same communities (p. 59). Likely fishery impacts with loss of mangrove habitat essential for nursery habitat for many species of fish and invertebrates harvested in the PBPA is a projected outcome if these impacts are not addressed.

Beginning on page 67 there are repeated references made to "replanting" of mangroves as a potential climate change adaption. We would note that the efforts to date that we are aware of, particular the hydrologic restoration project at Portland Cottage, included mangrove "planting" with some success, and that "replanting" is a term that should be reserved for the second or third planting effort after presumably the failure of the first effort (Lopez-Portillo et al. 2017). Mangrove planting as an attempt to restore or create mangrove habitat has a checkered past and does not work in most cases (Lopez-Portillo et al. 2017). Hydrologic restoration is generally required to restore tidal flows and allow for natural volunteer mangroves to colonize as they normally due under natural circumstances, with planting reserved for cases where natural recruitment of seedlings does not take place. Hydrologic restoration was implemented at Portland Cottage and successful plantings and natural of recruitment of mangroves has been documented.

Finally we would note that Lewis et al. (2016) and Feller et al. (2017) emphasize that with limited funds for any responses to climate change impacts to mangroves might best be focused on areas of existing but hydrologically stressed mangroves that typically have more problems keeping up with stronger hurricanes and accelerated sea level rise. The PBPA includes at least two of these areas that we suggest are the first priority for hydrologic restoration followed by monitoring to insure successful natural mangrove recruitment and/or prevention of death due to existing hydrologic stress. These are the mangroves at Rocky Point (a potential "mangrove heart attack" area – see Lewis et al. 2016) and the impounded mangroves west of West Harbour where abandoned aquaculture and salt production ponds exist.

LITERATURE CITED

Climate Studies Group. 2013. Climate Change Risk Assessment Report: Portland Bight Protected Area. Submitted to the Caribbean Coastal Areas Management Foundation (C-CAM). 111 p.

Feller, I. C., D. A. Friess, K. W. Krauss and R. R. Lewis III. 2017. The state of the world's mangroves in the 21st century under climate change. Hydrobiologia 803:1-12.

Field, C. D.1995 Impact of expected climate change on mangroves. Hydrobiologia 295: 75-81.

Lewis, R.R., E.C. Milbrandt, B. Brown, K.W. Krauss, A.S. Rovai, J.W. Beever III and L.L. Flynn. 2016. Stress in mangrove forests: early detection and preemptive rehabilitation are essential for future successful worldwide mangrove forest management. Mar. Poll. Bull. 109: 764-771.

Lewis, R.R. and B. Brown. 2014. Ecological mangrove rehabilitation – a field manual for practitioners. Mangrove Action Project, Canadian International Development Agency and OXFAM. 275 p.

Lopez-Portillo, J., R.R. Lewis III, P. Saenger, A. Rovai, N. Koedam, F. Dahdoubh-Guebas, C. Agraz-Hernandez, and V H. Rivera-Monroy. 2017. Chapter 10. Mangrove forest restoration and rehabilitation. Pages 301-345 In V.H. Rivera-Monroy et al. (eds). Mangrove ecosystems: A Global Biogeographic Perspective. Springer International Publishing AG 2017