Baseline Ecological Inventory for Three Bays National Park, Haiti

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Report for the Inter-American Development Bank (IDB)

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Table of Contents

Summary **8**
Introduction **11**
Physical Setting of Three Bays National Park **12**
Previous Ecological Studies in Haiti **20**
Assessing Biodiversity of 3BNP **22**
I. Terrestrial Vegetation 29
Description of Terrestrial Habitats 29
Comparisons to Previous Studies 34
Conclusion 36
II. Mangroves and Coastal Wetlands 37
Description of Mangrove and Wetland Habitats 38
Threats to Mangrove and Coastal Wetlands 50
Conclusion 55
III. Birds and Terrestrial Vertebrates 56
Description of Terrestrial Vertebrate Habitats 57
Threats to Terrestrial Vertebrates and Birds 66
Conclusion 67
IV. Freshwater Fauna 68
Description of Freshwater Habitats 69
Comparisons to Previous Studies 83
Threats to Freshwater Fauna 86
Conclusion 86
V. Marine Benthic Invertebrates 87
Description of Marine Benthic Habitats 88
Comparisons to Previous Studies 99
Conclusion 100
VI. Marine Fish 101
Description of Marine Fish Habitats 102
Comparisons to Previous Studies 108
Conclusion 112
Synthesis and Recommendations **113**
Management Recommendations 113
1. Recommendations for large-scale physical and ecological processes 113
2. Recommendations for habitats 115
3. Recommendations for species 117
Scientific gaps of 3BNP 119
Conclusion 121
References **122**
Appendices **128**
Appendix 1. Detailed Materials and Methods for biodiversity assessments 128
I. Terrestrial Vegetation 129

II. Mangroves and Coastal Wetlands 130
III. Birds and Terrestrial Vertebrates 133
IV. Freshwater Fauna 134
V. Marine Benthic Invertebrates 135
VI. Marine Fish 136
Appendix 2. Vascular plants observed in 3BNP 138
Appendix 3 List of IUCN Redlisted botanical species in Haiti 143
Appendix 4 List of vegetation waypoints taken during botanical assessments in 3BNP 145
Appendix 5 Comparison of pore water parameters for mangrove areas of 3BNP measured in 2015, reporting mean and standard error 147
Appendix 6 Summary of flora observed within coastal wetlands in 3BNP, including halophytes from saline, brackish, and other tidal freshwater habitats 148
Appendix 7 Checklist of birds recorded in 3BNP 150
Appendix 8 Relative abundance of birds in each of the major habitat types surveyed in 3BNP 153
Appendix 9 List of amphibians and reptiles recorded in 3BNP 156
Appendix 10 Coordinates for sampling sites of freshwater fauna species in 3BNP 157
Appendix 11 Complete freshwater fauna list organized by sampling date and site in 3BNP 158
Appendix 12 Freshwater fauna from each of the four habitat types, and ranked by number of sites from which each was collected in 3BNP 161
Appendix 13 Sampling design of the freshwater surveys 163
Appendix 14 Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Caracol within 3BNP 165
Appendix 15 Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Fort Liberté within 3BNP 173
Appendix 16 Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Limonade withing 3BNP 182
Appendix 17 Species list of coral reef fish identified at the different sites surveyed in Caracol within 3BNP 188
Appendix 18 Species list of coral reef fish identified at the different sites surveyed in Fort Liberté within 3BNP 193
Appendix 19 Species list of coral reef fish identified at the different sites surveyed in Limonade within 3BNP 199

Figures

Figure 1 Map of Three Bays National Park..12
Figure 3 Regional plate tectonics.....14
Figure 4 Principle geological units 14
Figure 5 *4-months Water temperature data*.15
Figure 6 Entire watershed boundary.....16
Figure 7 *Water Level time series data* 17
Figure 8 Schematic diagram Geologic events 19
Figure 9 Geomorphologic Subregions 23
Figure 10 Map of terrestrial land cover 25
Figure 11 Landscape photograghs 30
Figure 12 Riverine area.....31
Figure 13 *Acacia farnesiana* Shrubland.....31
Figure 14 Dry Broadleaf Evergreen 32
Figure 15 Photograph IUCN Redlisted species 34
Figure 16 Charcoal prod. Broadleaf Shrubland 35
Figure 17 sampling sites for coastal wetland 37
Figure 18 Dominant mangrove associates ..38
Figure 19 common mangrove habitat classif. 40
Figure 20 Basin and fringe mangrove habitats 41
Figure 21 mangrove crabs and oysters 41
Figure 22 Brackish tidal habitat in Grande Riv 43
Figure 23 Canopy height & percent cover ...45
Figure 24 Pore water conditions by site.....46
Figure 25 Tidal fresh and brackish habitats.47
Figure 26 Fringe habitats at Fort Liberté cliffs 47
Figure 27 Plantations & rounded leaf mangle 48
Figure 28Traditional fishers Lagon aux Boeufs 48
Figure 29 Dense nuisance algae 49
Figure 30 Forest cutting at Lagon aux Boeufs 50
Figure 31 fishers at the nearshore waters ...51
Figure 32 Wood harvest, salt, and trash.....52
Figure 33 Grazing cattle, barren lands, cutting 53
Figure 34 Evidence of cutting in Caracol area 54
Figure 35 Evidence of cutting in Ft Liberte ..54
Figure 36 Areas of terrestrial faunal surveys 56
Figure 37 Fruit trees & Morne Deux Mamelles 58
Figure 38 Mudflat and Saline area.....58
Figure 39 coastal mangroves & clear cutting 59
Figure 40 Landscape photo Lagon de Phaeton 59
Figure 41 Salt pond near Jacquezyl 60
Figure 42 Aerial photographs of salt ponds.61
Figure 43 Scrub savannas of bayahonda....61
Figure 44 Riparian vegetation.....62
Figure 45 Pastures and annual crops.....63
Figure 46 Birds species accumulation curve63
Figure 47 Recently killed Anas discors.....67
Figure 48 Fish & invertebrate sampling sites 68
Figure 49 Sites sampled Trou du Nord River 70
Figure 50 Freshwater sites sampled.....71
Figure 51 Ecologically important fish species 73
Figure 52 Ecolog. important invertebrates...75
Figure 53 Invert. of public health significance 76
Figure 54 Lagon aux Boeufs.....78
Figure 55 Estuarine habitats at mouth of TDN 80
Figure 56 Human uses of the rivers/streams 85
Figure 57 Benthic sites surveyed.....88
Figure 58 Benthic invertebrate richness 89
Figure 59 Richness of all benthic organisms 91
Figure 60 Most common hard corals in 3BNP 92
Figure 61 Most common benthic invertebrates 93
Figure 62 Most common benthic invertebrates 94
Figure 63 Hard corals Endangered Species Act 95
Figure 64 A new cup coral for Haiti.....96
Figure 65 Panoramic photo of Orbicella reef 97
Figure 66 *Small recruits of sea urchins,* 98
Figure 67 Sponge and tunicate species 99
Figure 68 Doris verrucosa 100
Figure 69 Mean fish biomass (g/100m^2) 102
Figure 70 Densities of reef fish assemblages 103
Figure 71 Most frequent coral reef fishes 104
Figure 72 Richness of coral reef fish 105
Figure 73 Average biomass and density 106
Figure 74 Frequent fish at seagrass mangrove 107
Figure 75 A possible new species of hamlet 108
Figure 76 Top predators in 3BNP 109

Figure 77 Comparison average fish biomass 110
Figure 78 Spatial range (in km) requirements 111
Figure 79 Fisherman at 3BNP 111
Figure A1-1Regional subdivision within 3BNP110.....128
Figure A1-2 coastal wetland sampling sites 131
Figure A1-3 Birds & Terr. Vertebrates sites.133

Tables

Table 1 Areas of different habitats..... 11
Table 2 Four principle watersheds of 3BNP 16
Table 3 Land cover and distribution..... 26
Table 4 Marine benthic classes and habitats 27
Table 5 IUCN Redlisted species in 3BNP ... 33
Table 6 Expected birds not observed 64
Table 7 Expected Species of amphibians ... 65
Table 8 Expected species of reptiles..... 65
Table A1-1 Land cover and distribution..... 130
Table A1-2 Braun Blanquet density scores . 136

Summary

In 2013, the Haitian government designated a new Marine Protected Area (MPA) in the northeast coast of Haiti, called the Three Bays National Park (3BNP). The protected area encompasses three bays: Limonade, Caracol, and Fort Liberté, as well as one of the largest inland brackish water lagoons – the Important Bird Area (IBA) of Lagon aux Boeufs – covering an area of 75,618ha. To date, there are very few peer-reviewed papers or gray literature describing the ecosystems within 3BNP. The Nature Conservancy was contracted by the Inter-American Development Bank (IDB) to conduct an ecological assessment of 3BNP. The main objective of this consultation is to provide assistance to the Ministry of Environment by conducting a detailed biological inventory of the marine and coastal resources of the Park and developing a biodiversity database.

The Three Bays National Park (both shallow marine and coastal terrestrial areas) was mapped from recent high resolution satellite imagery and ArcGIS to provide a detailed and up-to-date characterization of the spatial extent and distribution of the different terrestrial and marine benthic habitats. The Park was further subdivided into 8 sub-regions which separate watersheds, bays, and offshore areas. Extensive surveys by scientific specialists were then carried out across these different habitats and sub-regions to characterize the terrestrial flora and fauna, freshwater fauna, and marine flora and fauna.

Although there have been significant human interventions within 3BNP over the years, there remains biologically significant flora and fauna within the Park. Extensive land clearing and deforestation over many centuries have greatly reduced the extent and qualiliy of terrestrial and freshwater riparian habitats. Despite this, we documented one hundred and seventy-nine (179) native vascular plant species throughout the Park including five (5) IUCN Redlisted (endangered) plant species. Plant diversity was the lowest in Human Altered areas, which was characterized by weedy, non-native species including a number of invasives. In contrast, most of the native species, including the Redlisted plant species, were observed in portions of the Fort Liberté Peninsula with relatively intact Dry Broadleaf Evergreen-Shrubland habitat. The third class, *Acacia farnesiana* Shrubland, is essentially a monoculture of a single species with remnant populations of other weedy and invasive species. *Acacia farnesiana* is considered a an invasive species here as it aggressivley spreads into other vegetation types, reducing the biodiversity of those areas.

Three Bays National Park contains one of the largest intact stands of mangrove forest and coastal wetlands in the country of Haiti (Aube and Caron 2001) comprising some 4,274ha of mangroves. A total of 37 wetland plant taxa were observed within the Park's coastal mangrove systems. The mangrove system of the Caracol Bay was the largest and most structurally complex in 3BNP. The highest wetland plant diversity occurred at the western boundary of the Park near the mouth of Grande Riviere du Nord.

The terrestrial fauna of 3BNP has also been affected by the human habitat conversion but also directly by the introduction of predators. Invasive species which are well established and widespread in 3BNP include the Small Indian Mongoose (*Herpestes auropunctatus*), the Feral Cat (*Felis catus*), rats (*Rattus* spp.), the Cane Toad (*Rhinella marina*) and the Bullfrog (*Lithobates catesbeianus*).

Surveys of the coastal land areas documented ninety-five (95) species of birds with 22 of these being non-breeding migrants. Resident rare birds observed included the Hispaniolan Parrots (*Amazona ventralis*), flamingoes (*Phoenicopterus ruber*), Roseate Spoonbills (*Platalea ajaja*) and White Ibises (*Eudocimus albus*). The amphibian community, once rich with native skinks and geckos is now dominated by introduced species. Surveys found only four (4) species of amphibians, and eleven (11) species of reptiles many of which were not native.

The freshwater drainages that pass through the Park have been frequently utilized for fishing, bathing, and sand mining, and waste disposal. Unlike other large-river systems in the Caribbean, freshwater flows remain fairly intact though dynamic and polluted. There are no major dams and hydrological diversions for agriculture or flood control are not commonplace within the four principal watersheds. Our surveys documented a total of forty-seven (47) animal taxa, including fourteen (14) species of fish and thirty-three (33) species of invertebrates. Fishes included one endemic limia *(Limia pauciradiata)* thought to only occur within the Park. Among the invertebrates, all were native species except three (3) invasive snails. Management efforts within 3BNP should prioritize reducing impacts such as water pollution and restoring native riparian habitat structure within these highly threatened freshwater systems.

The highest animal and plant species diversity was found within the shallow marine waters of 3BNP. A total of three hundred and one (301) different species of marine sessile- and motile-benthic organisms were identified including one hundred and forty-nine (149) species of sponges, fifty-one (51) species of hard coral, forty-three (43) species of octocorals, and twenty-one (21) species of echinoderms. For marine fishes, a total of one hundred and eighty-three (183) different species of fish were identified within the Park waters including 1 endemic serrandae (*Hypoplectrus)* found only in Fort Liberté bay. The marine species richness documented in 3BNP is similar to what has been found on other Greater Antillian islands of the Caribbean. The outer forereefs exhibited the greatest species diversity of benthic invertebrates and fish while the isolated mangrove embayments of western Caracol Bay displayed the lowest.

Despite the moderately high overall species diversity occuring within the waters of 3BNP, the area is strikingly depauperate of marine mammals (manatees, dolphins, whales), sea turtles, elasmobranchs (sharks), and larger-bodied groupers and snappers. None of these species were directly documented during hundreds of cummulative observer hours under water. These slow growing and large-bodies species are likely now ecologically extinct (e.g., non breeding populations) within the Park. However, fisherman reports and anecdotal evidence do suggest that individuals sea turtles, dolphins, and whales and some large-bodied fishes (e.g., Nassau grouper, Black

grouper, Tarpon) do show up from time to time within 3BNP and are occasionally caught by local fishermen (ReefCheck 2015; FoProBiM 2015, 2016). Severe and chronic fishing pressure within and around the Park over many decades has eliminated them functionally from the foodweb. As a result, the trophic structure of the reef fishes has shifted towards smaller-bodied, quickly reproducing species. With management and regulated enforcement, there is a high likelihood that these absent species could be recovered within a decade or less.

In summary, the biodiversity inventories of 3BNP have revealed that significant species richness remains in each of the three major ecosystems including a large number of total species, as well as some that are rare and endemic to the area. These species and their habitats provide essential services to the communities around the Park and have the potential to be the basis for future ecotourism developments. Extensive human use going back hundreds of years has removed or seriously depleted a number of native species from the area, while threats put the remaining species and their intact habitats at risk (see separate 3BNP Threat Assessment report). Essential to the continued persistence of the remaining biodiversity is the preservation of remaining intact habitats and the establishment of a functioning park with a management plan, zoning, and enforcement to regulate human use within the Park boundaries.

The information developed as part of this baseline ecological assessment is designed to inform the management planning and zoning plan for 3BNP. All of the information will be made available in standardized digital format. GIS maps of terrestrial and benthic habitats along with mapped and modeled threats (Kramer et al. 2016) provide a standardized and up-to-date baseline for the Park. All documented species occurences encountered during the field surveys have been published into a standardized biodiversity systematics database (Darwin Core Archive) (http://tools.gbif.org/dwca-assistant/). It is our hope that this information will form the beginning of a comprehensive ecological database for 3BNP that can be used to guide decision making as well as future scientific studies for the area.

Introduction

In 2013, the Haitian government designated a a Marine Protected Area (MPA) in the northeast coast of Haiti, called “Three Bays National Park (3BNP)”. The northeast coast of Haiti is part of a marine ecosystem of regional importance and a high priority for biological resource conservation. It is a zone with elevated indices of biodiversity centered on the bays of Caracol, Limonade, and Fort Liberté (Figure 1). The three large bays together with the brackish lagoon, Lagon aux Boeufs, form the core of Haiti’s biggest marine protected area. The Park boundary extends from the Western edge of Grande Rivière du Nord east for over 40km to the border with the Dominican Republic. The seaward edge of the Park extends from the 12-mile territorial sea limit inland up to the 10m topographic contour line. The Park encompasses one of the largest mangrove forests in Haiti(approximately 4,274ha) and represents about 18% of Haiti’s remaining mangroves. The Park also includes the largest barrier coral reef on the north coast of Haiti stretching for over 20km mainly along the seaward edge of Caracol Bay. In addition, a rich 20 km length of fringing reef occurs on either side of the mouth of Fort Liberté Bay to the Haitian/Dominican border. The total coral reef complex (Holocene reef build-ups) of 3BNP is estimated at 1,100ha or about 10% of the shallow (<30m) shelf area. The protected bays, mangroves, sea grass beds, and reefs of 3BNP are important spawning and nursery areas for fish, mollusks, and crustaceans; many of these species serve as important sources of protein for local communities. These habitats also protect the northern shoreline from erosion, wave action, and storm surges. Three Bays National Park provides an important habitat for endangered and rare species including turtles and manatees, and provides important inputs for offshore marine ecosystems because organic productivity is high. The main habitats of the Park surveyed included terrestrial, mangroves, inland fresh water, and marine environments (Table 1).

Table 1. Land area (ha) of different habitats surveyed within Three Bays National Park.

Category	Hectares
Terrestrial	16,677
Mangroves	4,274
Freshwater	412
Shallow Marine (<30m)	10,657
Deep Marine (>30m)	43,386
TOTAL	**75,406**

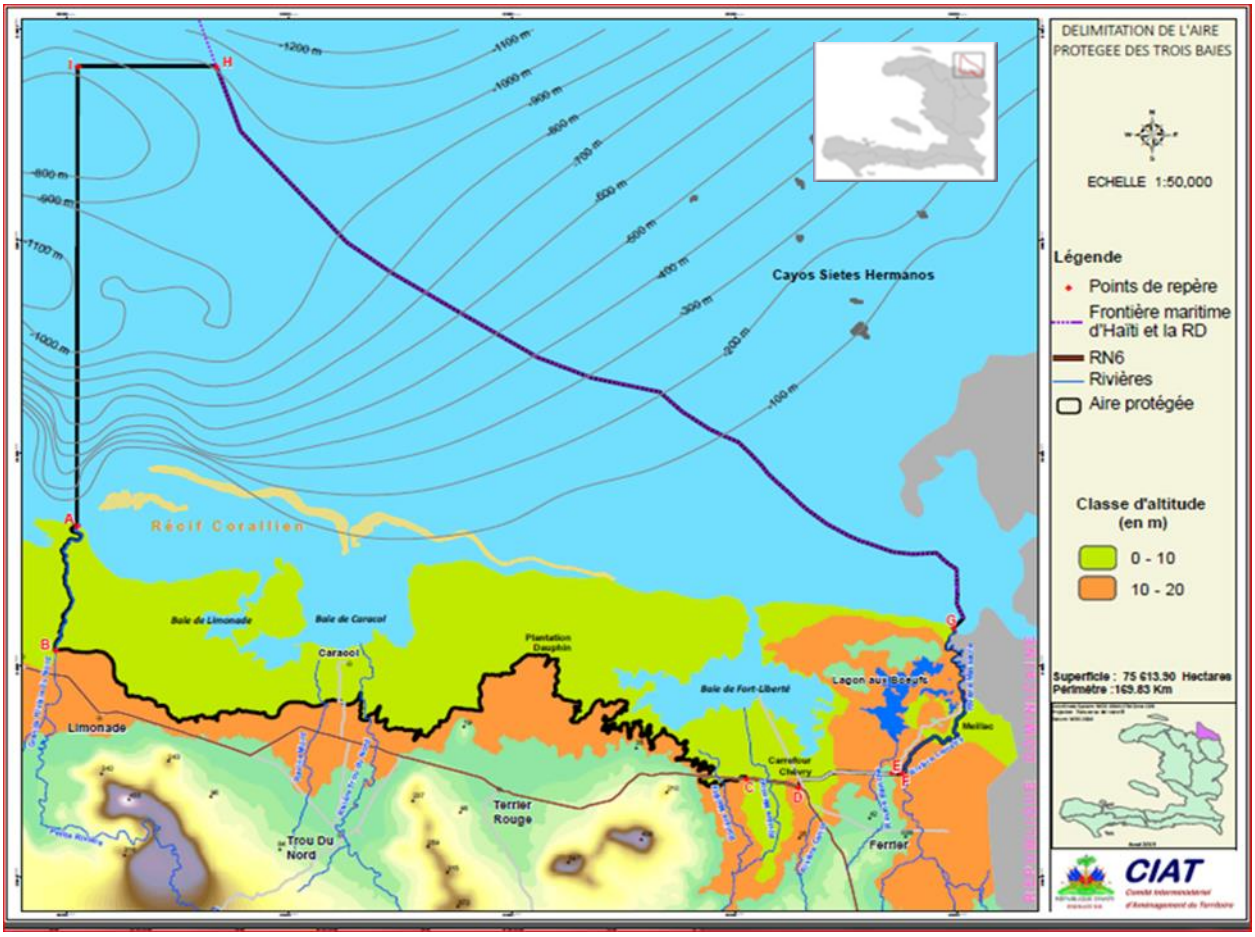

Figure 1. Map of Three Bays National Park (3BNP)

The Nature Conservancy has been contracted by the Inter-American Development Bank (IDB) to conduct an ecological assessment of the Three Bays National Park. The main objective of this consultation is to provide assistance to the Ministry of Environment by developing a database of terrestrial, marine, and coastal resources.

Physical Setting of Three Bays National Park

Three Bays National Park is situated in the north central coast of the island of Hispaniola, commencing in the west at the national border between the countries of Haiti and the Dominican Republic and extending east to the Grande Rivière du Nord. The heart of the Park consists of the extensive mangrove forests and highly productive waters of Limonade, Caracol, and Fort Liberté Bays which support extensive artisanal fishing in the area. The Park also includes a coastal land strip (3-10km wide) that encompasses the lowermost drainages of four watersheds carrying water and sediment from the adjacent Massif du Nord Mountains. Offshore, the Park boundary follows the exclusive economic zone (EEZ) boundary (5-40km off the coastline) of the Windward

Passage and includes deep canyons with depths in excess of 1,000m associated with the tectonically active Septentrional fault (Figure 2).

Geology: Since the late Miocene period, the island of Hispaniola has been strongly influenced by the boundary between the North American and Caribbean plates (Figure 3). Much of Hispaniola sits on the Hispaniola Micro Plate marked in the north by the Septentrional fault. The ongoing strike slip movement along the Septentrional fault, measured at rates of 8-10mm/year (Mann et al. 2002), has heavily influenced the geomorphology of Haiti's north coast and continues to create significant seismic hazards for the area. Numerous earthquakes have been recorded in the area. As recently as 1842, a major earthquake destroyed most of the structures in Cap-Haïtien along with half its population at the time. Folding and upthrust associated with the Septentrional fault has produced an extensive mountain chain all along the northern coast of Hispaniola. In Haiti, these mountains are known as the rugged Massif du Nord Mountains, which rise up abruptly from the coast to elevations in excess of 1,000m. Over millions of years, runoff and erosion from these mountains has transported huge volumes of siliciclastic detritus down to the north coast forming a wide flat plain between the towns of Cap-Haïtien and Monte Christi called the Northern Plain.

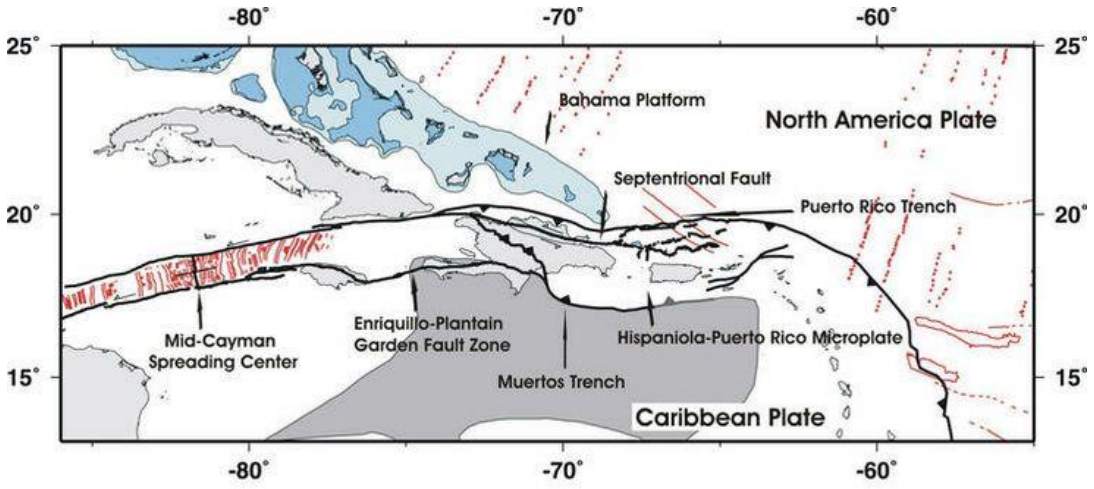

Figure 3. Regional plate tectonics affecting Hispaniola.

The geology of the majority of 3BNP land area consists of alluvial detritus which form particularly rich farming soils in and around the present day rivers. Around Fort Liberté and Lagon aux Boeufs, an uplifted terrace (up to 10m above MSL) of coral reef limestone occurs which is distinctly different than the detrital sediments found across most of the Northern Plain. This Plio-Pleistocene limestone reef terrace is composed of coral fragments that are loosely cemented and in places are mixed with fine red siliciclastic clay. Two distinctive low hills (named Morne Deux Mamelles by Columbus) represent post-Eocene intrusions of andesite and granite that occur along a secondary fault line that trends NW-SE (Figure 4). These igneous intrusions are much harder than the surrounding limestone and are thought to have had a major influence on the recent erosional and depositional history of the area.

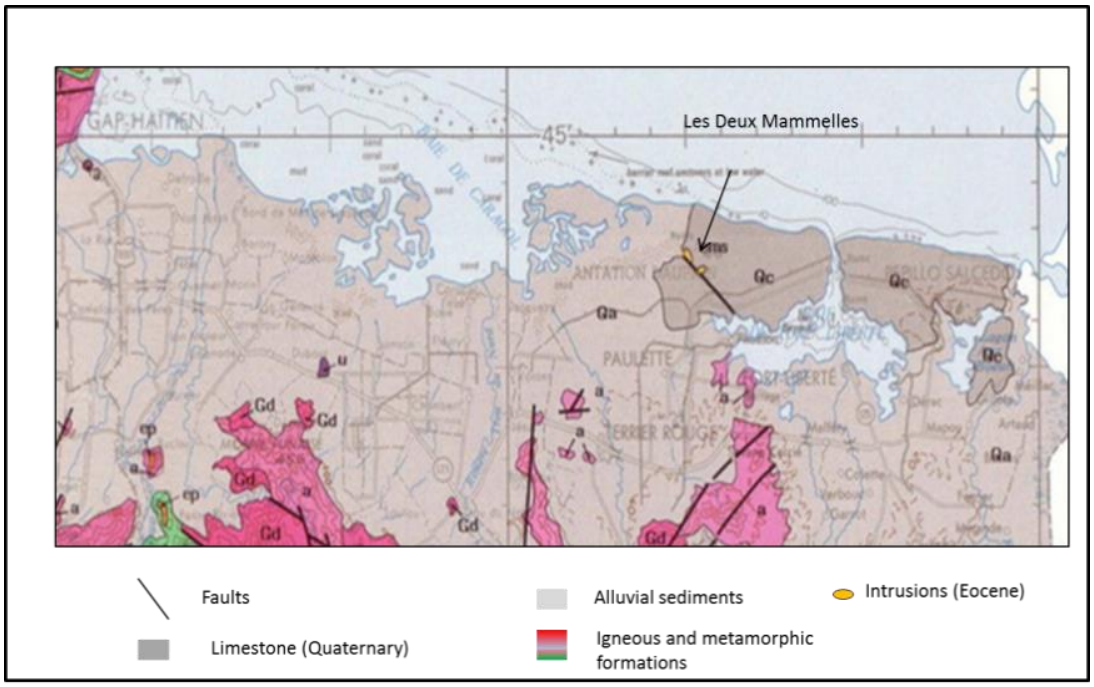

Figure 4. Principal geological units of Northeastern Haiti.

Climatology: Northern Haiti enjoys a warm and humid tropical climate year round with temperatures ranging from 23°C to 35°C, with January being the coolest month and July the warmest. Shallow lagoons like Lagon aux Boeufs will closely track air temperatures whereas coastal bays show significantly less daily and annual variation (Figure 5). Winds are strongly influenced by the local mountainous terrain, creating daily anabatic winds that begin around 10:00am and die down after 9:00pm. Year round wind direction is almost always from the north to north east with an average speed of 3.3m/s. Rainfall averages about 1,600mm per year with two distinct wet periods from May-June and October-December, accounting for about two-thirds of the annual amount. The west side of the Park receives about 25% more rainfall than the east side resulting a two distinct climates.

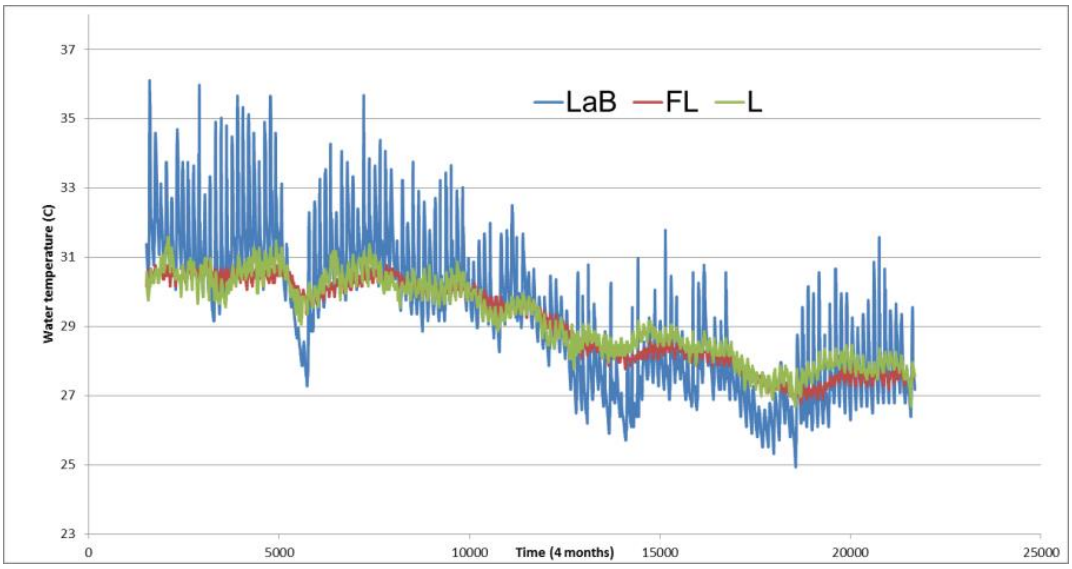

Figure 5. Water temperature time series data for 4 months (Sept-Dec 2015) for Lagon aux Boeufs (LaB), Fort Liberté (FL), and Limonade (L)

Hydrology: There are four principle watersheds that drain into the Park: Grande Rivière du Nord, Rivière Trou du Nord, Rivière Marion, and Rivière Jassa (Figure 6).

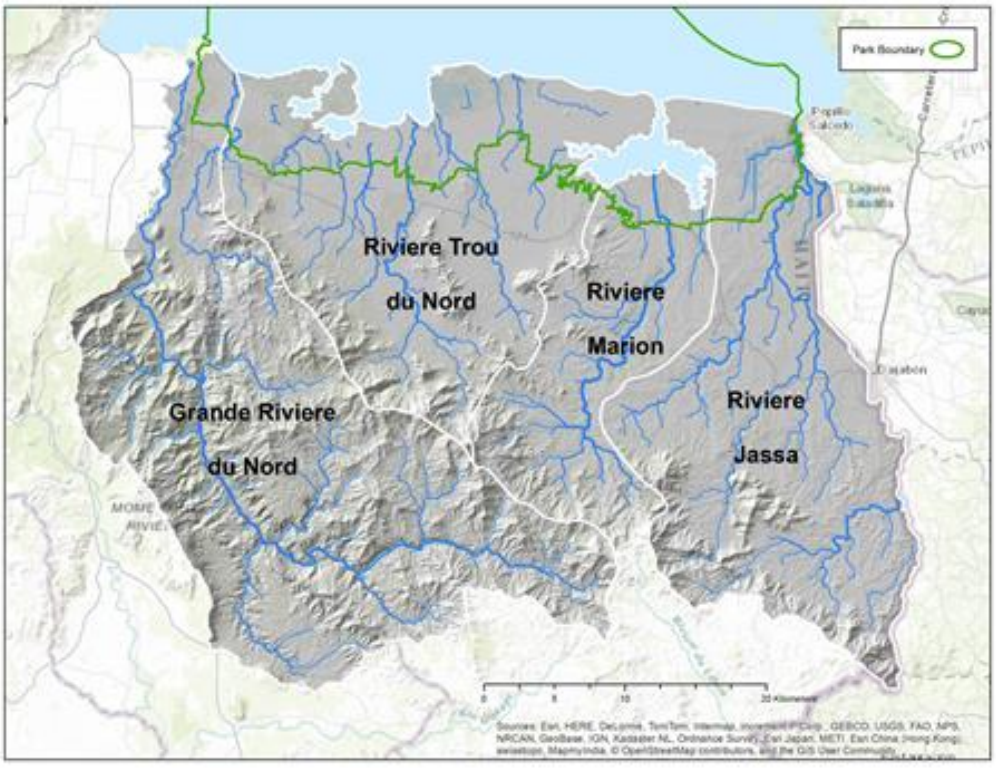

Figure 6. Entire watershed boundary of four principle water drainage basins, including Three Bays National Park.

The area, mean annual precipitation, and approximate rate of discharge for each of the four watersheds are shown in Table 2. The Grande Rivière du Nord accounts for nearly

two-thirds of the total freshwater discharge and is large enough to flow year round, including the dry season. In contrast, the other watersheds are smaller and during extended periods without precipitation may run completely dry in their lower reaches. The steep deforested slopes of the upper portions of all the watersheds allow for very rapid and high flow discharges following storm events. High rainfall events cause hazardous flash flooding conditions and the movement of large volumes of sediment. In the lower reaches of the watersheds that cross the Northern Plain, the riverbeds and river mouths may shift around from year to year building deltas where they enter the bays.

Table 2. Four principle watersheds of 3BNP and their characteristics: area (ha), annual precipitation (mm), and approximate average annual discharge (m^3/sec).

Watershed	Area (ha)	Mean Annual Precipitation (mm)	Average Discharge (m^3/sec)*
Grande Rivière du Nord	62,746	1,743	17
Rivière Marion	21,803	1,361	5
Rivière Trou du Nord	42,830	1,217	8
Rivière Jassa	43,421	1,350	9

**Relative discharge calculated with a fixed infiltration/evapotranspiration coefficient of 0.5.*

Tides and Currents: The tidal range for 3BNP averages 0.5m and occurs as a mixed semidiurnal frequency every 24 hours (Figure 7). The first tide is about 30% higher and lower than the second tide. Water levels are highest during the fall months (October-November) associated with the warmest water temperatures, and are lowest in the spring (March-April). Offshore, the Windward Passage acts as an important gateway between the northern Atlantic and Caribbean seas. Hydrography studies have found that surface waters (0-600m) generally move at low to moderate speeds of 10-20cm/s, with net transport from east to west. Meanwhile, lower layers of the water column (>600m) have been shown to move the opposite direction at speeds of 20-40cm/s (John et al., 2004). Within Caracol Bay, circulation is mainly influenced by tides and the daily onshore wind out of the northeast. Along shore movement occurs to the west near Limonade Bay, but further to the east flow shifts eastward and out through the Caracol Channel. In Fort Liberté, circulation is mainly driven by the daily tides. Water visibility is generally less than 15m within the bays of Fort Liberté and Caracol. In Lagon aux Boeufs, a brackish water lake connected intermittently to the sea, visibility is less than 1m due to high concentrations of chlorophyll in the water column. Tides in Lagon aux Boeufs are nearly absent (~10 cm daily variation) due to the distance from the Massacre river mouth (~4 km) and lag behind the coastal areas by 2-3 hours (Figure 7).

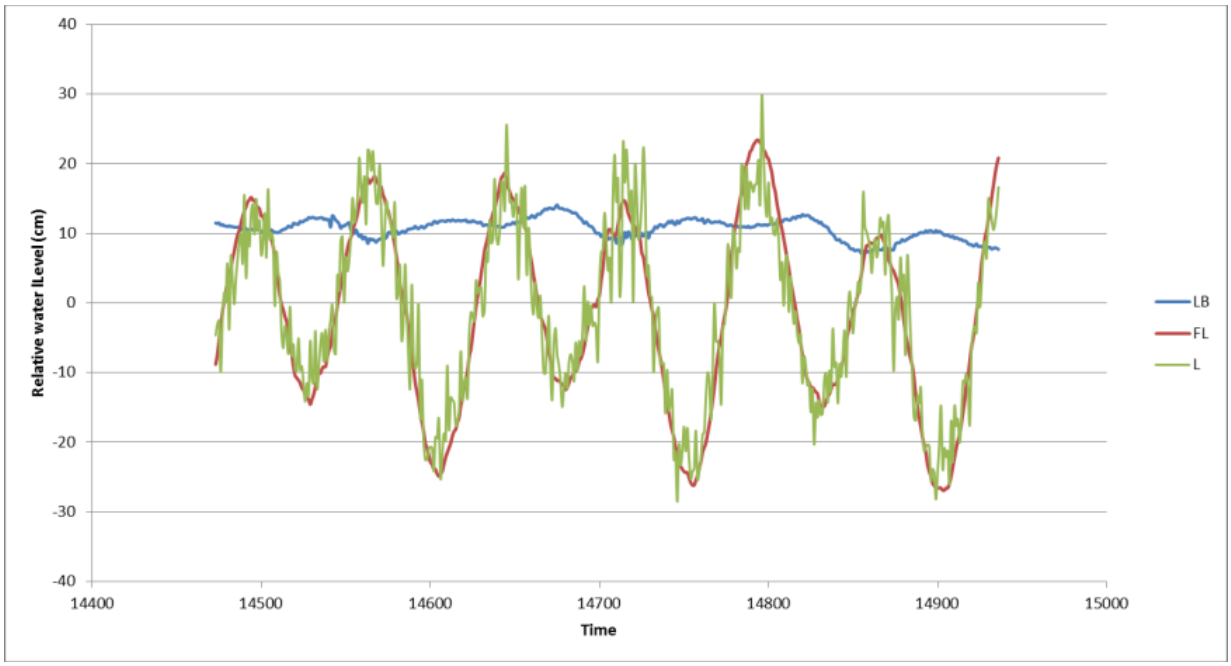

Figure 7. Water Level time series data for 4 days December, 2015) for Lagon aux Boeufs (LaB), Fort Liberte (FL), and Limonade (L)

The Caracol barrier reef and the evolution of the bays of 3BNP: The Caracol barrier reef runs along the outer edge of Caracol Bay for ~20km and is bisected by a deep paleoriver channel (Caracol Channel). As the longest, most continuous barrier reef on the north coast of Hispaniola, it stands out distinctly from the fringing and intermittent reefs found elsewhere in the area. The Caracol barrier reef is postulated to have once been a fringing reef similar to that found along the coast of Fort Liberté and that fluvial erosional processes coupled with continued coral growth along the margin are largely responsible for its present shape. The Fort Liberté limestone reef terrace may have once extended much further west towards Cap-Haïtien and provided the seaward foundation for the fringing reef. During periods when sea level fell up to 100m, a destructional phase was established (Figure 8). Extensive alluvial erosion particularly during the Pliocene is thought to have removed much of the original limestone terrace and carved out Caracol and Fort Liberté Bays, and also east of Lagon aux Boeufs around the Massacre river drainage. Discharges and erosion were considerably higher in the western portions of Caracol Bay due to the greater precipitation and size of the watersheds. Eocene aged igneous intrusions underlying Morne Les Deux Mammelles along the western edge of Fort Liberté Bay likely influenced fluvial pathways and reduced erosion on the eastern side of Lagon aux Boeufs. The resulting the degree of limestone removal in Fort Liberté and around the western side of Lagon aux Boeufs is substantially less than Caracol Bay. The outer edge of Caracol Bay, now marked by a barrier reef, remained largely intact during erosional periods due to the greater degree of cementation and hardness associated with reef growth on the margin during sea level high stands.

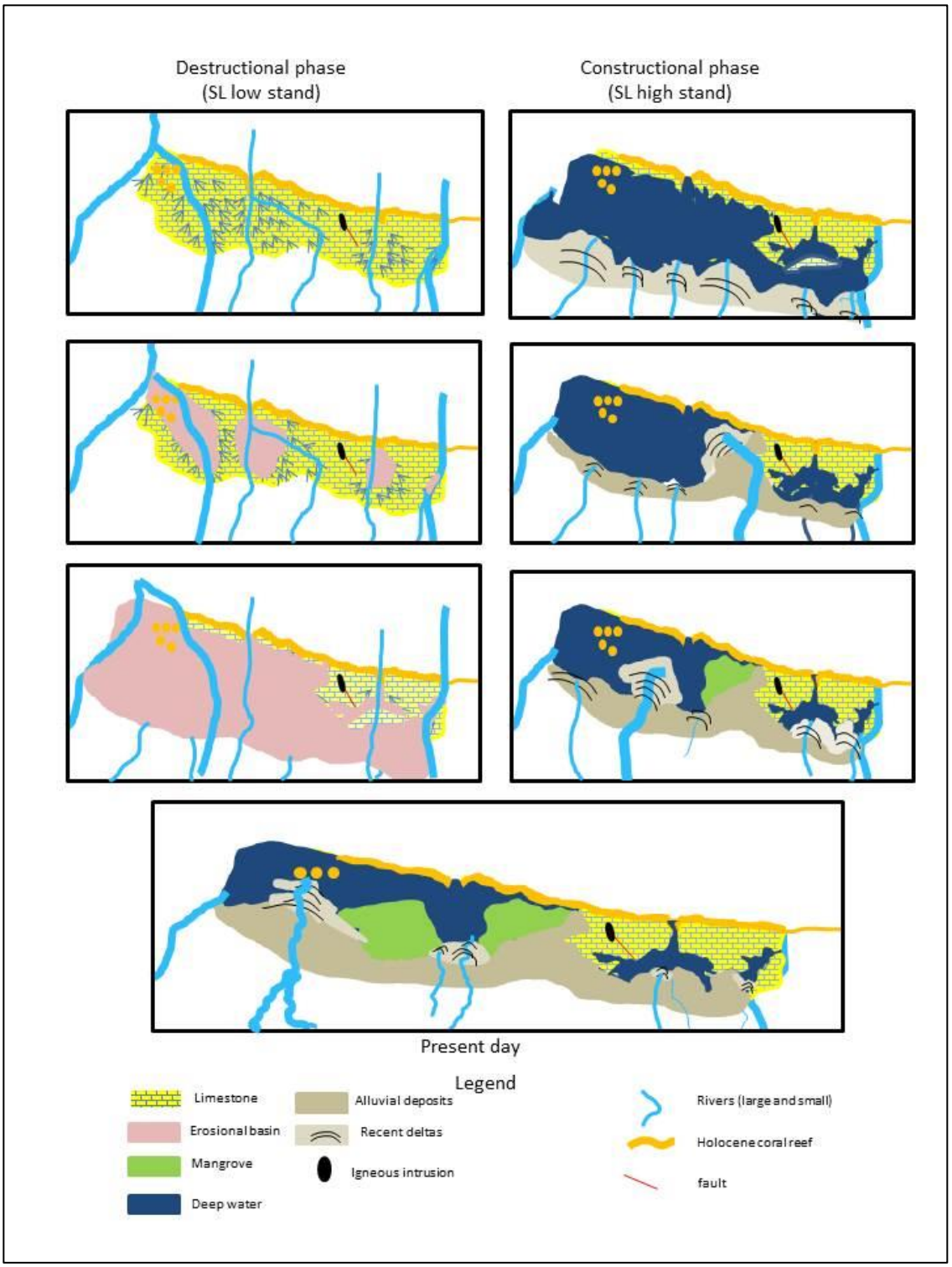

Figure 8. Schematic diagram showing destruction, (A) to (C), and construction, (D) to (F) of coastal features influenced by fluvial processes during sea level low stands (SL low stand) and high stands (SL high stand). The Caracol barrier reef is thought to represent the remnants of a once more extensive Pliocene-aged limestone reef terrace found today in front of Fort Liberté (G).

Previous Ecological Studies in Haiti

To date, there have only been limited peer-reviewed papers or gray literature on the different ecosystems within 3BNP. Thus, with the intention of better defining park resources, facilitating strategic planning, and mitigating the impacts of a new industrial park on the natural resources, an ecological baseline was commissioned by the Inter-American Development Bank (IDB). Wiener et al. (2013) conducted a rapid ecological assessment (also commissioned by IDB) of the lower reaches of the Rivière Trou du Nord within 3BNP boundaries that included sampling of fish and invertebrates. Other recent biological inventories (either direct observation or interviews of fisherman) include those of FoProBiM (2015) and ReefCheck (2014). To our knowledge, no additional studies have been conducted on aquatic animals in 3BNP. However, there is a substantial literature on collections of fish and invertebrates made in Haiti that are described in the rich taxonomic literature covering the Caribbean region. Much of this literature is exclusively taxonomic, but some studies contain useful ecological information.

Marine communities have been dramatically changing throughout the Caribbean. Magnitude of change is difficult to assess due to the lack of baseline and long-term data in the region. Haiti, part of the Greater Antilles region, is a country which lacks baseline data of marine ecosystems and the few qualitative and quantitative assessments conducted have focused only on coral reef habitats. Information is lacking for seagrass and mangrove communities. In 1927, William Beebe, the first ecologist to visit Haiti assessed the marine environments in the Bay of Port-au-Prince (Beebe 1928). This expedition was undertaken by the Department of Tropical Research of the New York Zoological Society. Beebe (1928) study was generally qualitative accounts of the coral reef ecosystems. Their main objectives were to prepare a list of fish species present in coastal waters and to obtain photographs of the coral reef life. They recorded the coral reefs to be full of life, with high abundances of fish and corals. They observed 270 different fish species in just the bay alone. Historically, Haitian people have heavily relied on natural resources, especially the resources from the sea and overfishing was evident in 1983 when Jacques Cousteau visited Haiti. In Cousteau's documentary, he recorded a low abundance of reef fish at all coral reef sites visited. Overfishing, especially of parrotfish, has been well documented at many other locations in Haiti (Hay 1984, Reef Check 2003).

Most quantitative studies on coral reefs have focused surveys around Navassa Island (Miller and Gerstner 2002, Miller 2003, Miller et al. 2003, 2007, 2008), which is a small (4.64km^2), uninhabited, offshore island (56km west of Haiti) under the jurisdiction of the U.S. Fish and Wildlife Service. In the past decade there have been many shifts occurring on the coral reefs around the island. The most prominent change has been the coral-macroalgal phase shift. As of 2008, the most prolific benthic substrate on reefs around Navassa Island was macroalgae. Macroalgal cover of 40% was common on most reefs and some reefs exhibited a cover as high as 70%. Coral decline, as high as 28% was observed at deeper reefs and this was possibly due to the prevalence of disease observed in 2004 and bleaching of corals in 2005. Coral cover on shallower

reefs (<30m) remained steady, with coral cover ranging from 10% to 25% (Miller et al. 2008).

More recently on mainland Haiti, Reef Check has carried out quantitative surveys at a number of coral reefs (totaling 400), which spanned around 95% of the entire coastline. Total mean coral cover observed in their surveys was 15%, while macroalgal cover was doubled at 30%. They observed the healthiest reefs (i.e. higher coral cover and fish abundance) to be located at Petite-Trou-de-Nippes and Anse-d'Azur, both close to Jeremie on the far west coast of Haiti. Coral cover at both reefs reached as high as 90%. Coral composition was dominated by critically threatened coral species, such as *Acropora* and *Orbicella* species. Fish populations were low at all sites surveyed by Reef Check, ranging from 0.5-5individuals/m^2. Grunts (Haemulidae) were the most observed family of fish, followed by snappers (Lutjanidae).

Hay (1984) assessed the herbivory of sea urchins and fish on overfished reefs, which included Caracol Bay and less fished reefs. In Caracol Bay, he observed sea urchin densities, particularly the black long-spined sea urchin, *Diadema antillarum*, to be as high as 20 individuals/m^2.

In 2013, Reef Check carried out 12 quantitative surveys in 3BNP, 83% of the sites were located within the bay of Fort Liberté. In their surveys, they identified 25 species of hard corals, with 88% of the coral species identified in Fort Liberté, and 60% of coral species identified in Caracol. The most frequent corals observed in 3BNP were *Porites astreoides*, *Siderastrea siderea* and *P. porites*. Critically threatened and/or endangered corals such as *Acropora palmata*, *A. cervicornis*, *Orbicella annularis* and *O. faveolata* were only observed at sites along the channel and directly outside the bay of Fort Liberté. In Caracol, acroporids were not observed and *O. faveolata* and *O. annularis* were observed along the northeast channel. Other sessile-benthic organisms counted included nine species of echinoderms, three species of cnidarians and one species of octocorals. Species of sponges were not identified.

Fishing communities outline all of these bays, however the largest fishing community is located in Caracol Bay. In 2009, ReeFIX estimated that the total ecosystem services for the mangroves and coral reefs in Caracol Bay were at US $109,733,000; however, a continuation of that study in 2013 found the value to actually be closer to US $3,246,000,000. The marine ecosystems of 3BNP have high ecological and economic importance and therefore are high priority for resource conservation and management. Even though 3BNP is considered an area of high diversity, there has not been an official species inventory conducted within park boundaries. There is data lacking on the presence of many important sessile-benthic organisms, such as sponges and octocorals. Moreover, there have only been coral reef surveys conducted within 3BNP, other marine ecosystems such as seagrass and mangroves have not been surveyed for benthic organisms.

The Three Bays National Park represents the largest intact area of mangrove and coastal wetlands in the country of Haiti (Aube and Caron 2001). A law was passed in 2013 to provide protection to all of Haiti's mangroves. However, despite the efforts to

protect these critical habitats, the mangroves of 3BNP are under increasing pressure from a host of threats including cutting and harvesting for fuel wood, clearing for agriculture and salt mining, development and industry, and associated point and non-point source pollution. Providing irreplaceable habitat to countless ecologically and economically important organisms, 3BNP is critical to the people of Haiti and their livelihoods.

The major published taxonomic work on freshwater fish species in the region is *Atlas of North American Freshwater Fishes, 1983 Supplement* by Lee et al. (1983) which focuses on the Greater Antilles. It provides details on collection records from Hispaniola and nearby islands. The comprehensive more recent *Check List of the Freshwater Fishes of South and Central America* edited by Reis et al. (2003) provides updated taxonomic information for the region. The online www.fishbase.org is perhaps the best resource for searches of the global literature on fish. *The Freshwater and Terrestrial Decapod Crustaceans of the West Indies with Special Reference to Dominica* (Chace and Hobbs 1969) is the major modern published work providing a synthesis of the early literature from the region. It represents the taxonomic, and to some extent ecological, basis for most subsequent aquatic decapod studies. Particularly relevant publications include the updated checklist of freshwater decapod records for Puerto Rico by Pérez-Reyes et al. (2013) which includes an extensive reference list, and several studies on freshwater crustaceans on other islands and areas in the broader Caribbean region (e.g. Hart 1961; Rodriguez and Williams 1995; Smith and Wier 1999; Debrot 2003; Pérez-Gelabert 2008; Torati et al. 2011; Pérez-Reyes 2015). Finally, Pérez (2008) provides a comprehensive checklist and bibliography for all arthropod taxa reported from Haiti and the Dominican Republic, most of which are terrestrial but aquatic taxa are included.

The major relevant literature on mollusks is more limited than that for the crustaceans. However, two recent books provide excellent coverage of the region, and include keys and illustrations sufficient for identifying most of the taxa encountered in the present study, and perhaps likely to occur in 3BNP, as well as ecological information on most species: *Guide to the Freshwater Molluscs of the Lesser Antilles* (Pointier 2008) and *Guide to the Freshwater Molluscs of Cuba* (Pointier et al. 2005). These volumes also contain useful reference lists.

Assessing the Biodiversity of 3BNP

The preliminary inventory and assessment of the biodiversity within 3BNP emphasized inventoring the most common taxa representing the more visible and charasmatic flora and fauna thought to occur in the area. The target taxa included: (I) Terrestrial plants; (II) Mangroves and Wetlands; (III) Terestrial Vertebrates (Mammals, Reptiles, Amphibians) and Birds; (VI) Freshwater Fish and Invertebrates; (V) Marine Benthic Invertebrates; (VI) Marine Fish. Lead scientists for each of the target taxa were contracted by TNC to provide assessments for Caracol Bay, Fort Liberte, and the wider 3BNP including Lagon Aux Boeufs. Each team conducted up to two trips to 3BNP over a six month period (June-November, 2015) to make on-the-ground observations and

species inventories. Attempts were made to have individual surveys overlap to the extent possible to reduce costs and simplify logistical challenges of conducting field work in Haiti. Individual sampling plans for the area were developed based on desktop reviews of previous work and examination of satellite imagery.

To help guide sampling and reporting strategies for each team, the 3BNP area was divided into eight (8) regional subdivision zones based on geomorphology as defined by Kramer et al. (2016) (Figure 8). Zones 1 and 2 include the commune of Limonade (Bord de Mer de Limonade), comprising the eastern banks of the Grande Rivière du Nord, its watershed, and Limonade Bay; Zones 3 and 4 include the Commune of Caracol and Terrier Rouge, and Caracol Bay; Zones 5 and 6 include Fort- Liberté and Ferrier, and Fort Liberté Bay; Zone 7 includes Lagon aux Boeufs, a brackish lake of 450ha in the Commune of Ferrier (this brackish lake is hydrologically linked to Rivière du Massacre, corresponding with the Haiti- Dominican Republic border); finally, Zone 8 covers the offshore section of the Park and is not included in this report because we know that the vast majority of (more than 90%) of marine biodiversity lies within the productive shelf areas (<30 m water depth), and the cost to conduct deep water or open water scientific work which typically requires a specially equipped research vessel, is very expensive and beyond the scope of the current study.

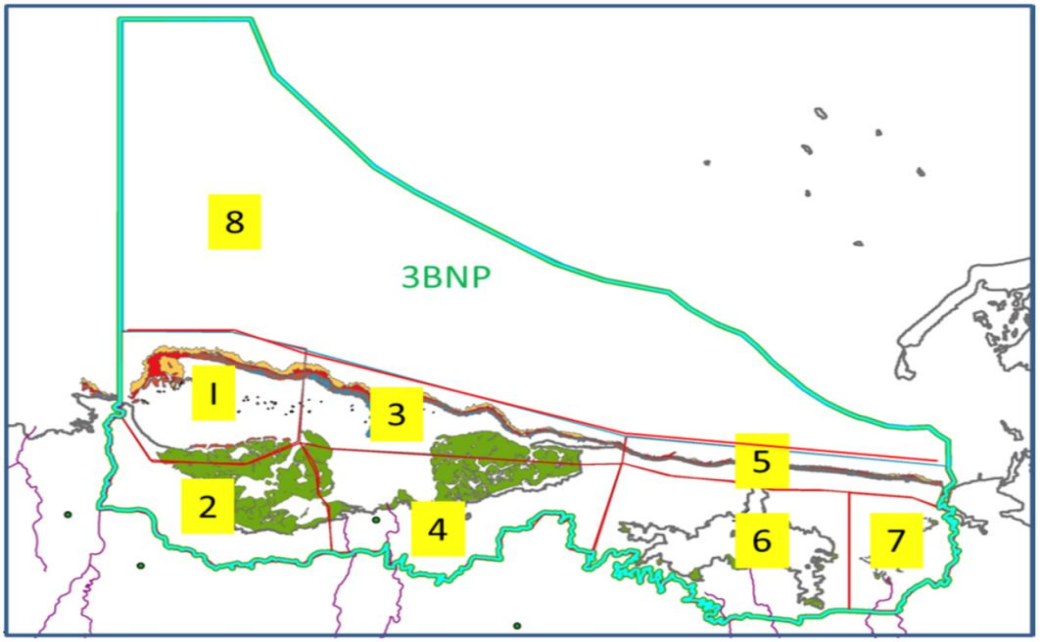

Figure 9: Map showing 8 subregions for 3BNP based on geomorphological and climatic differences of the área. Subregions were used to help guide and stratify biodivesity surveys.

Mapping of terrestrial and marine habitats: Patterns of species diversity are strongly correlated to the types, extent, and condition of terrestrial, freshwater, and marine habitats. Therefore, habitat maps are a critical component for designing species diversity sampling plans, charaterizing threats, and providing an overall baseline for

3BNP that can be used to inform management and zoning. Maps of portions of the North Coast of Haiti do exist and were syntheized as part of The Haiti North-east Coast Atlas published in 1997 (Ménanteau L. & Vanney J.-R., 1997). Land uses were classified into six classes and mapped using Landsat imagery. Within the Park, the two most dominat land classeses were Dry Shrublands and Agriculture/Agroforestry. The shrublands classes did not distinguish between intact and undisturbed areas and distubed areas dominated by *Acacia farensiana*. The agricultural classes did not capture the more recent expansion of larger-scale agricutural plantations.

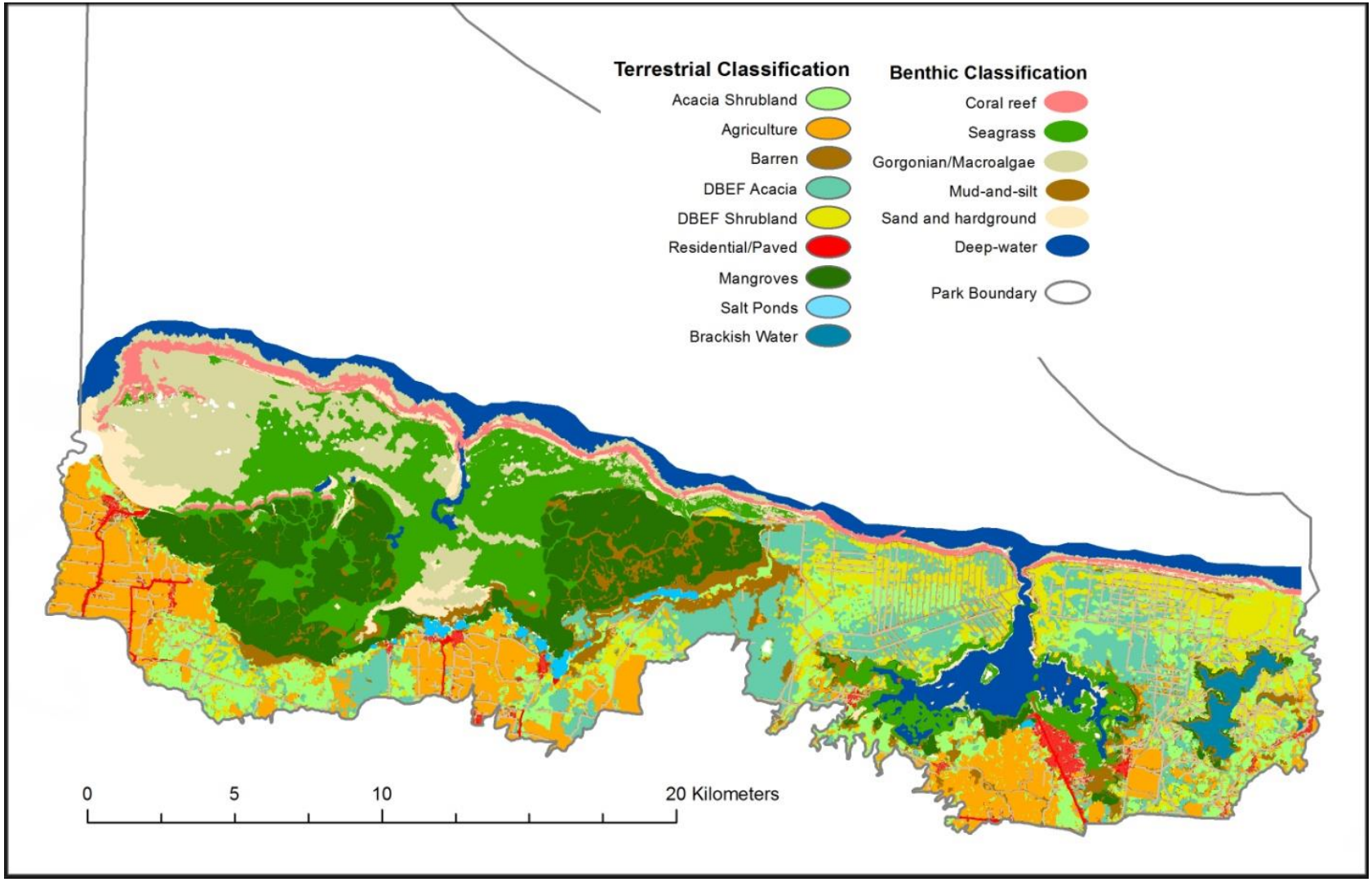

Figure 10. Map of terrestrial land cover and simplified shallow water benthic habitat classes of the Three Bays National Park.

As part of the baseline ecological assessment, we developed a more recent and refined map of the vegetation types using Landsat 8 imagery acquired in October 2014. The imagery was classified using ENVI 5.2 into primary land cover types including forest, scrub/shrub, savanna, barren, and human uses. An atmospheric correction and supervised classification was performed using a maximum likelihood classifying algorithm. Land cover types, such as urban and agriculture, areas were manually digitized and integrated into the classification product. A total of 53 groundtruthing points were collected across the major habitat classes: Agriculture, *Acacia farensiana* Shrubland, Dry Broadleaf Evergreen Formation (DBEF) with *Acacia*, DBEF with Shrubland, Salt Pond, and Barren. The total area of each of these land cover types by watershed can be seen in Table 3. Table 4 reports the land cover total area and percentages. When comparing the field points to the land cover map, only 8 out of the 53 points were misclassified resulting in 85% accuracy.

Table 3. Land cover and distribution within each watershed that drains into the Three Bays National Park, including the area within the Park itself.

Grande Rivière du Nord watershed (627km^2)		**Rivière Trou du Nord watershed (428km^2)**	
Class	***Hectares***	***Class***	***Hectares***
Agriculture	1,954	Agriculture	1,954
Barren	1,186	Barren	1,186
Dwellings	34,095 (points)	Dwellings	34,095 (points)
Forest	25,572	Forest	25,572
Mining	11	Mining	11
Road	720 (km)	Road	720 (km)
Salt Ponds	0	Salt Ponds	0
Savanna	9,573	Savanna	9,573
Scrub/Shrub	18,696	Scrub/Shrub	18,696
Rivière Marion watershed (218km^2)		**Rivière Jassa watershed (434km^2)**	
Class	***Hectares***	***Class***	***Hectares***
Agriculture	1,101	Agriculture	1,101
Barren	427	Barren	427
Dwellings	9,429 (points)	Dwellings	9,429 (points)
Forest	7,728	Forest	7,728
Mining	4	Mining	4
Road	487 (km)	Road	487 (km)
Salt Ponds	10	Salt Ponds	10
Savanna	5,322	Savanna	5,322
Scrub/Shrub	5,319	Scrub/Shrub	5,319

Similarly, there have been previous attempts to develop marine benthic habitat maps and bathymetric maps for portions of 3BNP. The Haiti North-east Coast Atlas did classify and map several shallow marine habitats including reefs and mangroves using SPOT imagery (Ménanteau L. & Vanney J.-R., 1997). However, the classes were very broad

and did not distinguish between different reef types, hardbottoms, and other types of benthic cover (gorgonians, seagrasses, sand). ReefCheck (2013) also developed hand-drawn benthic habitat maps that identified rare corals (e.g., *Acropora palmata*) around Fort Liberte and Caracol based on towed surveys conducted in 2013. However, these maps were not georeferenced and did not cover the entire 3BNP.

The Nature Conservancy acquired high resolution World View Satellite imagery of the area from 2014 and conducted groundtruthing via small boats using drop camera, fathometer, and a drone. TNC then contracted Dr. Sam Purkis of Nova Southeastern University to develop detailed benthic habitat and bathymetry maps for the entire shallow water (<30 m) areas of 3BNP based on a spectral analysis and groundtruthing information. Inspection of the 220 drop-camera, supplementary GoPro videos and WorldView-2 imagery suggested that 16 habitat classes captured most of the benthic habitat diversity of the Park (Purkis, 2015). Coral reefs make about 10% of the benthic habitats of the Park while seagrass beds found predominantly in Caracol Bay cover over 25% of the area (Table 4).Accuracy of the benthic habitat classes was estimated at better than 80%.

Table 4. Marine benthic classes and habitats developed as part of the mapping from high resolution World View satellite imagery acquired in 2014 (Perkis, 2015)

Simplified Class	Benthic habitat	Area (hectares)	Hab %	Class %
Coral reef	Lagoonal patch reef	62	0.5	9.0
	Algal Rim	75	0.6	
	Shallow coral buid-up	446	3.5	
	Orbicella fore reef	551	4.4	
Gorgonians/Macroalgae	Hardground with Gorgonians	652	5.2	9.1
	Hardground with Macroalgae	501	4.0	
Sea Grass	Dense seagrass	3,036	24.1	28.0
	Sparse seagrass	259	2.1	
Sand	Sand with sparse macroalgae	2,510	19.9	26.2
	Sand	794	6.3	
Mud and Silt	Mud + silt	1678	13.3	13.3
Deep water	Unclassified/Deep water	2,046	16.2	16.2
	Total	12,610		

Field Assessments: Field Assessments were used to gather data about the major focal taxa of 3BNP. All assessments attempted to document the biodiversity within representative habitats and note the interactions between the species present. These assessents were able to collect sufficient data for a general assessment of the flora and fauna The field assessments includied 300 person survey days and were conducted

June through November 2015. Details of the individual materials and methods for each of the major taxa teams is provided in Appendix 1.

I. Terrestrial Vegetation

Three Bays National Park (3BNP) terrestrially comprises both natural areas and human altered environments including settlements, farms, roads, fish ponds, etc.. The Park encompasses 16,677ha of coastal terrestrial habitat supporting a variety of animals and plants (Table 1). Since the arrival of Columbus over 500 years ago, the native terrestrial habitats have undergone significant conversion and use, ranging from small and medium scale agriculture to ranching. Little is known about which native plant species remain or which areas of the park still retain intact native habitats. Understanding the diversity, structure, and function of these terrestrial habitats and the threats that they face provides essential information to conserving and managing the 3BNP area for nature and people.

Description of Terrestrial Habitats

The terrestrial vegetation associated with the three main land use classes (Human Altered, *Acacia farnesiana* Shrubland, and Dry Broadleaf Evergreen Formation) are described below.

Human Altered (HA): HA includes active agriculture, fallow fields, roads, and buildings and was ~7300ha (~44% of the terrestrial portion of the park) in area. HA occurred throughout the entire 3BNP area on both soil and rock depending on the usage of the land. The largest area of HA is agricultural with a variety of crops being grown. The HA class areas have low plant diversity that is primarily filled by weedy, widely distributed native and non-native species including a number of invasives. While some areas are monoculture, the vast majority are a mix of a variety of crops including annuals (rice, corn), perennials (sugar cane, beans), and fruit trees (primarily Mango) (Figure 11). In some cases, the Mangifera indica (Mango) trees look similar to old-growth native forests from high resolution satellite imagery because of their very large sizes.

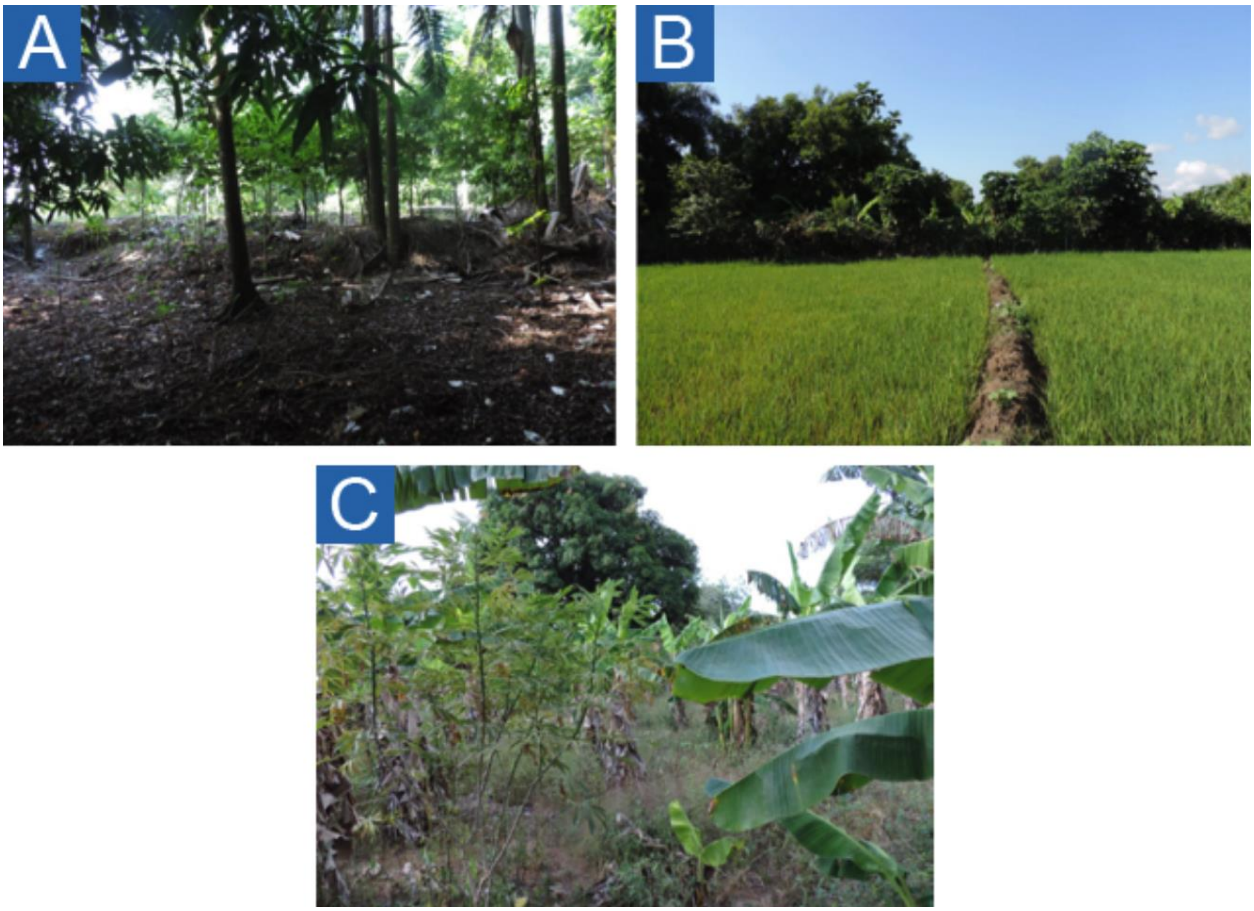

Figure 11. Landscape photograghs of **(a)** agroforestry area, **(b)** rice fields surrounded by mango trees, and **(c)** mixed agriculture area in 3BNP.

All riverine habitat was grouped within the HA habitat type. Very little intact native vegetation was present within any of the riverine areas surveyed. Agriculture and roads occur directly adjacent to the rivers surveyed (Figure 12). In some cases a few areas with native aquatic plants were present and noted. However, these areas were not mappable with the Landsat imagery due their small and highly fragmented footprint.

Acacia farnesiana Shrubland (AFS): *Acacia farnesiana* Shrubland is the dominant vegetation type particularly in the drier eastern sides of 3BNP that had been cultivated in previous years. Within the park boundaries there are ~3400ha (~20% of the park) in area of AFS. In areas that have been left fallow and for grazing, AFS occurs essentially as a monoculture often growing in iron rich clay alluvial deposits. The vegetation is 2-3m in height and forms a canopy over time (Figure 13). Very few species are able to co-exist within an AFS area. It is unsuitable as feedstock for grazers as it has an extensive system of 2-4cm thorns along the stems.

Figure 12. A riverine area with adjacent agricultural area in 3BNP.

Figure 13. *Acacia farnesiana* Shrubland in 3BNP.

Dry Broadleaf Evergreen Formation (DBEF): DBEF habitat occurs as two distinct types- DBEF-shrubland (DBEF-S) which contains predominantly undisturbed native vegetation and DBEF-Acacia (DBEF-A) which is partially invaded with *A. farnesiana*. The total spatial area of DBEF (both shrubland and Acacia) is ~5700ha (~33% of the park). DBEF is 1-4m in height occurring in areas with mixed clay and limestone substrate. DBEF- S is a high diversity vegetation type with many native species (Figure 14a and 14b). DBEF-S occurs as a band approximately 2km wide that is fairly common along the two peninsulas north of Fort Liberté that form Fort Liberté Bay. Along the edges of the DBEF-S is shoreline with slight variations in the plant community type that varies debending on the substrate which transitions between mixed siliciclastic and calcarous sand and limesone coral rock. In areas with a sand substrate, all areas surveyed appeared to have been disturbed at some point in the past and had *A. farnesiana* (Figure 14c). In areas with a rock substrate there was less *A. farnesiana* as well as *Coccoloba uvifera.*

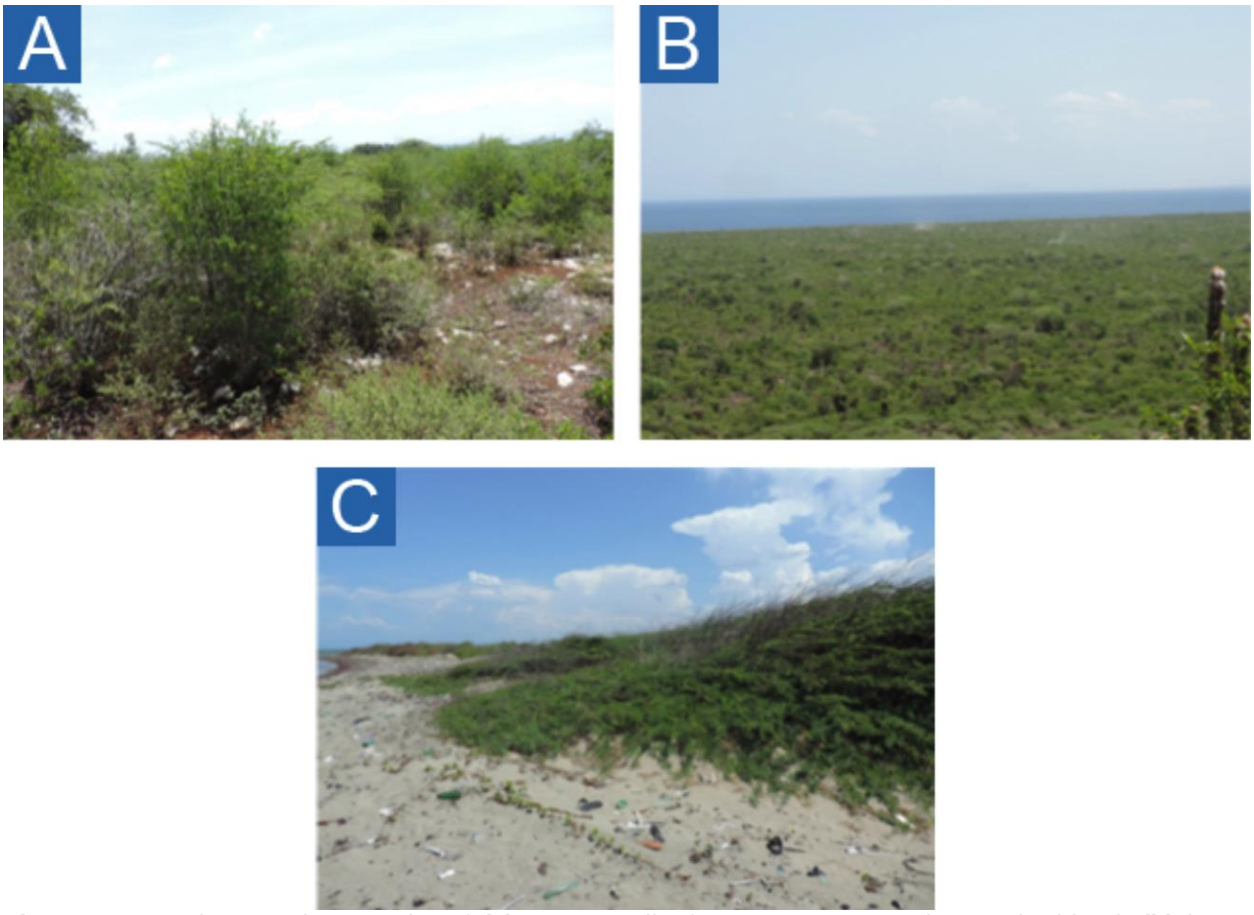

Figure 14. Landscape photographs of **(a)** Dry Broadleaf Evergreen Formation – Shrubland, **(b)** intact DBEF-S with charcoal production, and **(c)** shoreline with *Acacia farnesiana* in 3BNP.

Species diversity: Our surveys identified one hundred and seventy-nine (179) vascular plant species throughout the park (Appendix 2). This number excludes agricultural species and there are numerous species that were not identifiable in the field as they were in vegetative conditions when they were observed. The Fort Liberté Peninsula regions had the highest level of diversity with one hundred and ten (110) species identified (Appendix 2). Portions of the Fort Liberté Peninsula class (including the Dauphin Plantation area) contain relatively intact DBEF-S habitat with mostly native species (Appendix 2) and "normal" vegetation structure. All five of the Redlisted plant species were observed in this area.

Redlisted Species: Of the fifty-three (53) potential IUCN Redlisted species for Haiti, 12 endangered or threatened species were designated as likely to occur within the park boundaries (Appendix 3). Of those 12, populations of four species were observed during the survey period (Table 5). Additionally two populations of *Mammilarria ekmanii* that the desk survey did not indicate would be within the area were observed in the Dauphin Plantation region.

Table 5. List of IUCN Redlisted species observed within 3BNP based on the rapid botanical assessment.

Genus	Species	Red List status
Consolea	*picardæ*	DD
Guaiacum	*sanctum*	EN
Mammillaria	*ekmanii*	DD
Opuntia	*taylorii*	DD
Selenicereus	*pteranthus*	DD

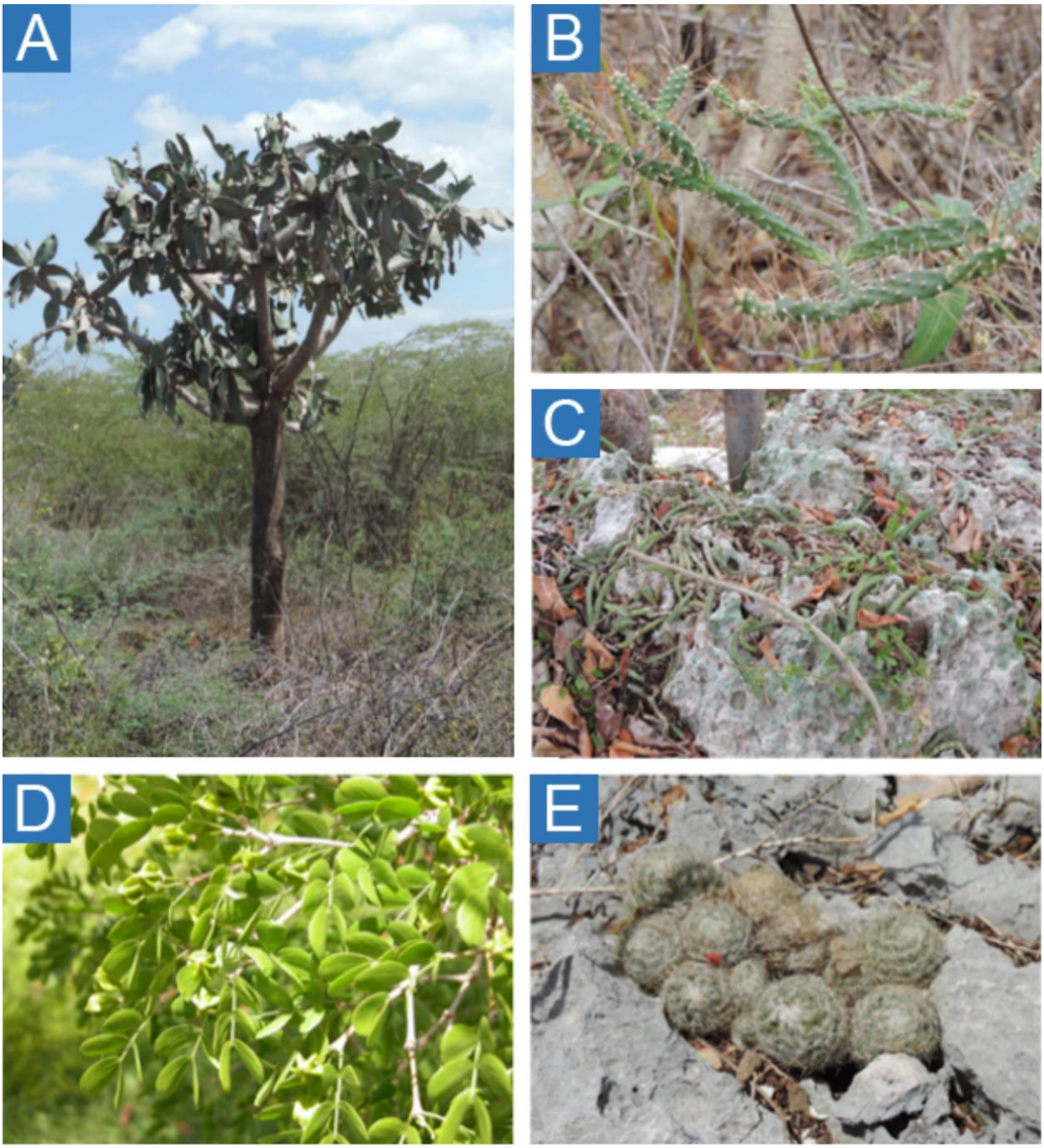

Figure 15. Photographs of **(a)** *Consolea picardae*, **(b)** *Opuntia taylorii*, **(c)** *Selenicereus pteranthus*, **(d)** *Guaiacum sanctum*, and **(e)** *Mammilaria ekmanii* observed in 3BNP.

Comparisons to Previous Studies

Threats to 3BNP terrestrial plants: The main threat to terrestrial plant diversity within 3BNP is expanded agriculture and charcoal production. In the remaining natural areas north of Fort Liberté, Haitians are actively cutting trees and producing charcoal. Fortunately, the trees they cut are not always killed and the remaining stumps may grow back over time. The two main issues with these activities are reduced fruit and seed

production from the regrown portions, and the increasing encroachment of *Acacia farnesiana* which can outcompete native species due to its fast growth and deeper roots.

Four of the five redlisted species documented within 3BNP had wide spread populations and are not currently under direct threat of extirpation. A fifth species, *Mammilaria ekmanii* (Figure 15e), was only observed as having two small populations on a single ridge tip near the Dauphin Plantation. It is highly likely, given the rapid nature of the current survey, that additional populations of this species may occur in other locations of 3BNP. Of the five Redlisted species, only one (*Guaiacum sanctum*) is harvested for charcoal.

A. farnesiana continues to spread into the Fort Liberté Penisulas, displacing native species. Although *A. farnesiana* is collected for charcoal production, it regrows faster than the native species by outcompeting it for light, nutrients, and water. Over time, the continual removal of native species for charcoal will increase the spread of the *A. farnesiana* and it will essentially supplant all native species. Charcoal production occurs throughout the area (Figure 16), but the selective removal of trees has not eradicated the native species and the rate of species regrowth continues. Cattle, goats, and sheep free-range graze throughout the area. It is not possible to know how much plant diversity has been lost over the centuries due to persistent grazing.

Figure 16. Charcoal production in Dry Broadleaf Formation – Shrubland in 3BNP.

Conclusion

The terrestrial areas of 3BNP have been heavily influenced by human activity over many centuries. Field surveys and mapping have documented that very little of the original habitat remains. Native trees and plants have been largely displaced, but a few pockets of relatively intact plant communities remain – primarily Dry Broadleaf Evergreen Shrubland. Two priority zones for protection and management of intact native habitats include: Morne Deux Mamelles Fort Liberté Peninsula, and east from the bay to the Haitian/Dominican border. In addition, the riparian corridors for the four major drainages should be an area for restoration of native trees and setbacks to reduce grazing and erosion into the watersheds should be established. Areas of high terrestrial plant diversity or potential for recovery contine to be threatened by charcoal production, large and small scale agricultural expansion, and the spread of *A. farnesiana.* The management of 3BNP should include zoning and policies coupled with enforcement designed to reduce these threats and maintain and improve the quality of remaining native vegetation.

II. Mangroves and Coastal Wetlands

Three Bays National Park (3BNP) represents one of the largest mangroves and coastal wetlands in the country of Haiti (Aube and Caron 2001), comprising some 4,274ha of mangroves.

Despite efforts to protect these critical habitats, the mangroves within the Park are under increasing pressure from a host of threats including cutting and harvesting for fuel wood, clearing for agriculture and salt mining, development and industry, and associated point and non-point source pollution. Providing irreplaceable habitat to countless ecologically and economically important organisms, 3BNP is critical to the people of Haiti and their livelihoods.

The mangroves and coastal wetlands plant communities were divided into four distinct areas Caracol Bay and Bord de Mer, Fort Liberté, and Lagon aux Boeufs as described below.

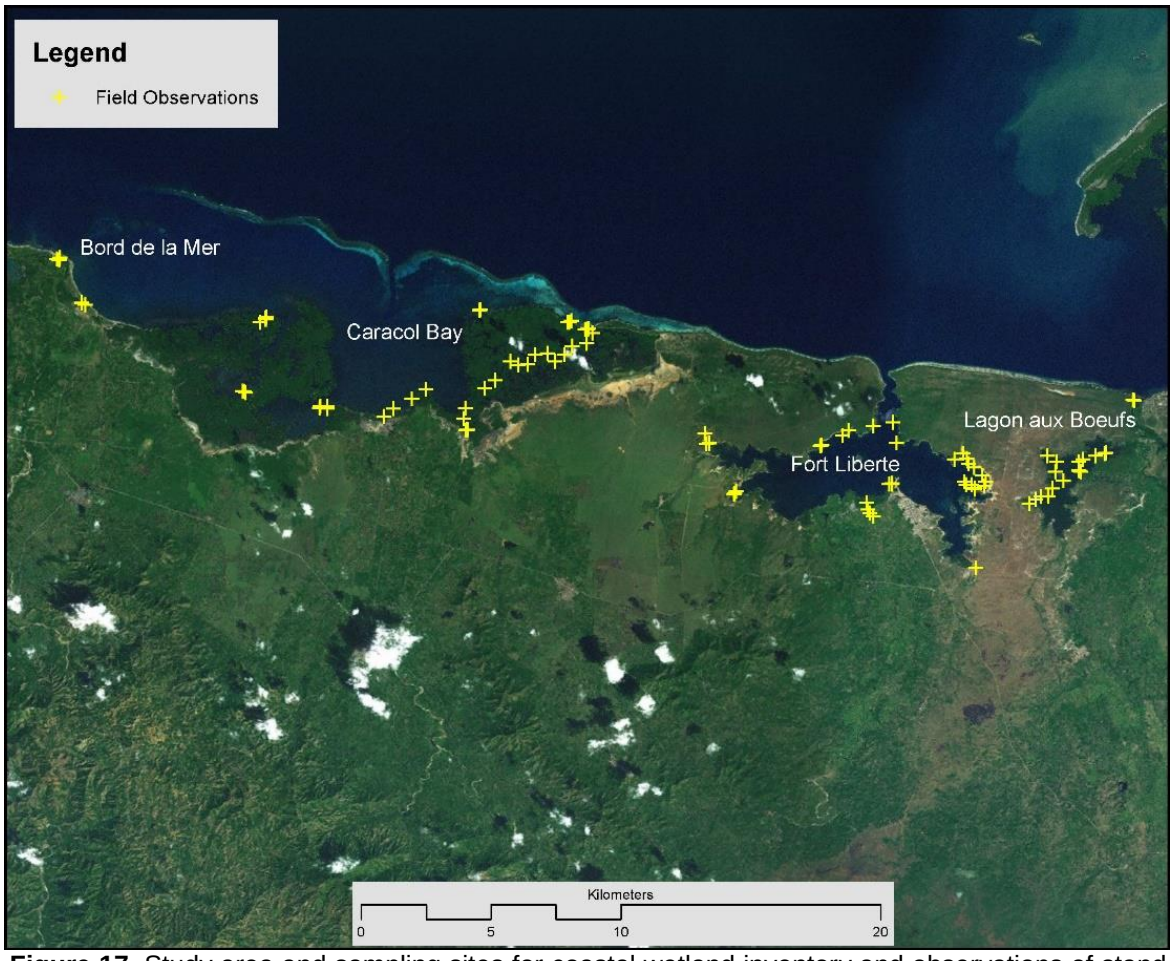

Figure 17. Study area and sampling sites for coastal wetland inventory and observations of stand characteristics within 3BNP from June to November 2015.

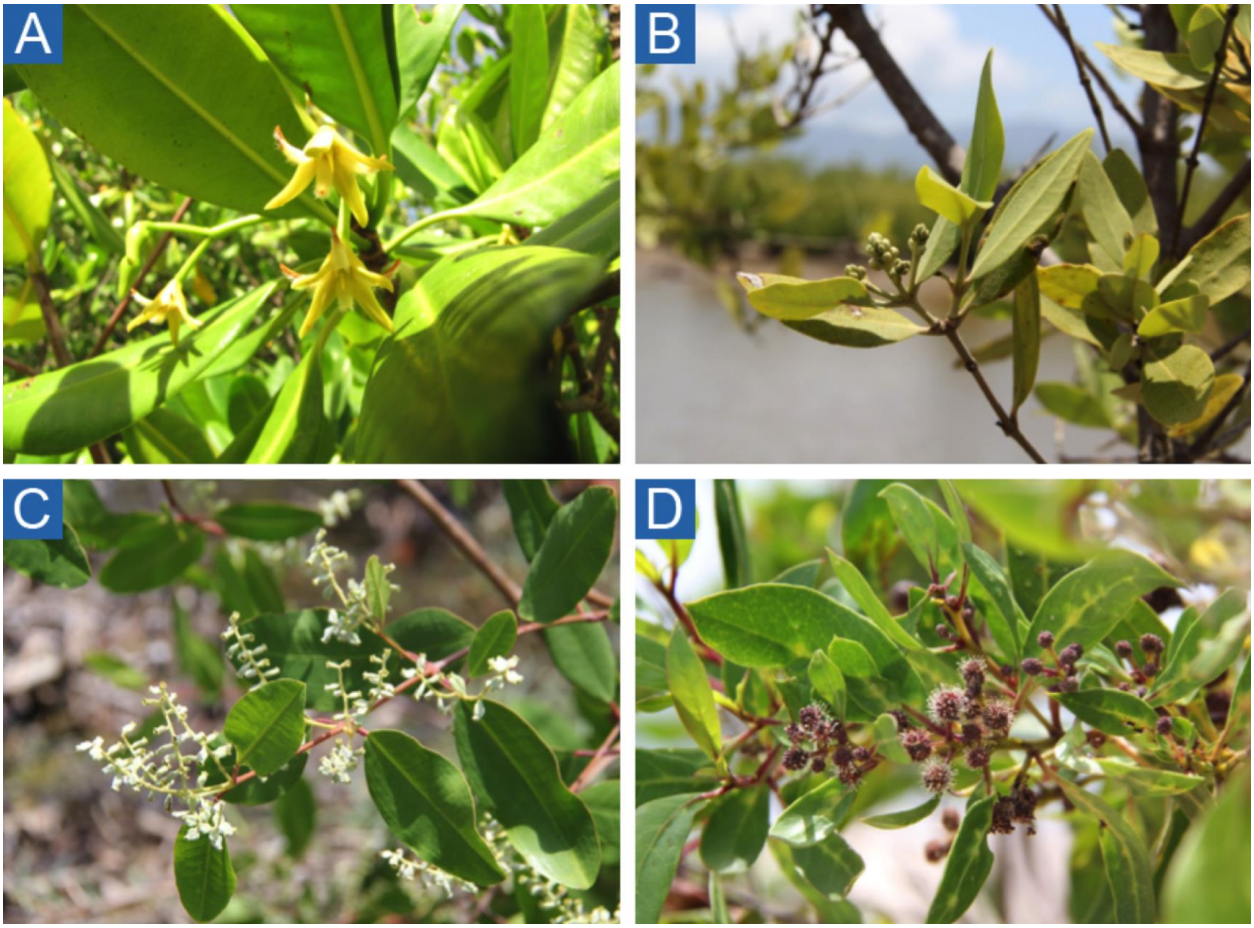

Figure 18. Dominant mangrove and mangrove associates including **(a)** *Rhizophora mangle*, **(b)** *Avicennia germinans*, **(c)** *Laguncularia racemosa*, and **(d)** *Conocarpus erectus.*

Description of Mangrove and Wetlands Habitats

*Caracol Bay***:** The mangrove of Caracol Bay is the largest and most complex of the mangrove systems within 3BNP. Land cover mapping estimates provided by the land cover mapping undertaken by The Nature Conservancy (TNC) indicates that Caracol has 4,030ha of mangrove. The Caracol mangrove system is built upon historic fluvial outwash deltas. Recent deltas around the mouths of the True du Nord River and Grand River du Nord remain highly dynamic today. The mangroves within Caracol Bay may be grouped in two broad categories: 1) the landward basin mangrove that originate behind a fairly defined beach berm and extend shoreward into the mainland where they experience periodic flooding, and 2) the seaward fringe and hammock mangrove that create expansive mangrove 'islands' on the outwash plain and are influenced by regular tidal action.

The basin mangrove is dominated by typical mangrove species common throughout the region (Figure 18) including black (*Avicennia germinans*) and red (*Rhizophora mangle*) mangrove with white (*Laguncularia racemosa*), buttonwood (*Conocarpus erectus*), and saltwort (*Batis maritima*) occurring at the drier, higher elevation locations throughout

(Appendix 6). At the upper edge of these systems, the invasive sweet acacia (*Vachellia farnesiana*) was noted. The basin system provides habitat for abundant fiddler crabs (*Uca* sp.) that burrow in the basin sediments and to a lesser degree, mangrove crabs (*Aratus pisonii*) that patrol the upper branches (Figure 21a). In contrast, the fringe and hammock mangrove are dominated by red mangrove, although black and white were also documented. Patches of dwarf red mangrove were noted in both habitats. All red mangroves in flooded, fringing habitats provided habitat for abundant mangrove and pearl oysters (*Crassostrea rhizophorae* and *Pinctada* sp., respectively), as well as many sponges and tunicates on the seaward-reaching rhizophores of flooded areas (Figure 21b). Accordingly, both stand height and density is quite variable throughout the site, dependent upon water/flood depth, position within the tidal gradient, and other influences (including evidence of present and historic mangrove cutting and harvest).

The mangrove of Caracol is of moderate height overall when compared to each of the sampling areas. With evidence of present-day cutting and a documented history of such impacts (Aube and Caron 2001), it is not surprising that forest recovery may be slow. Mean canopy height is 3.3m ±0.4m and did not differ from other sites with the exception of Lagon aux Boeufs (Figure 23). Canopy heights measured in this mean include the scrub and dwarf red mangroves within the inundated fringe islands off the shore of Caracol, leveraging the average down overall. Yet percent cover was relatively dense (62.1% ±6.8%) and not significantly different than Fort Liberté or Lagon aux Boeufs (Figure 23).

Pore water conditions were fairly regular throughout Caracol (Figure 24), mediated by regular tidal flushing (42.7ppt ±1.9ppt). Hypersaline conditions in salt flats pushed the overall average above that of open water (~36ppt). Redox potential and sulfide concentrations reflected flooded conditions at -281mV ±20mV and 1.97mM ±0.21mM, respectively. Finally, soil pH was comparable to all sites (6.9 ±0.1). Representing fairly typical edaphic for mangroves, these values would not be expected to preclude successful restoration actions (Appendix 6).

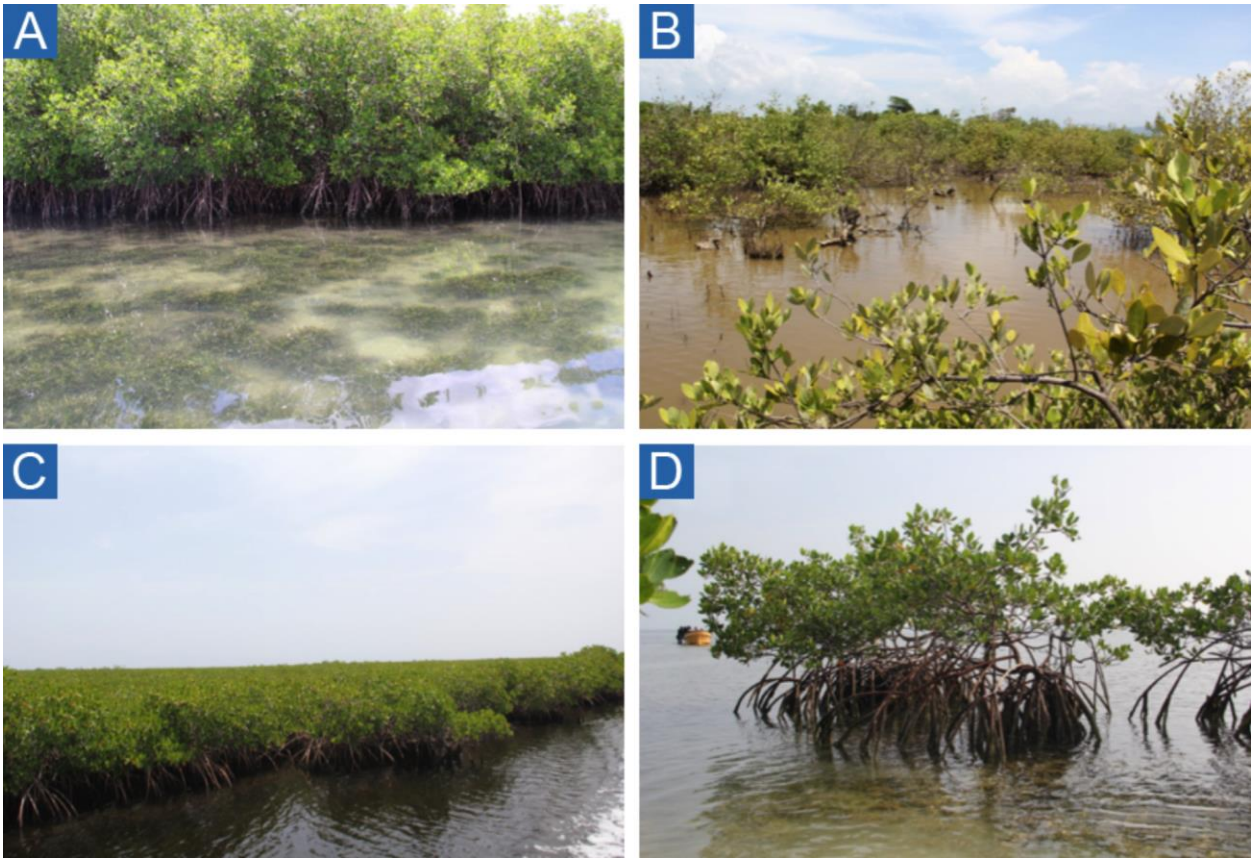

Figure 19. Examples of common mangrove habitat classifications present in 3BNP, including **(a)** fringe, **(b)** basin, **(c)** scrub/dwarf, and **(d)** hammock.

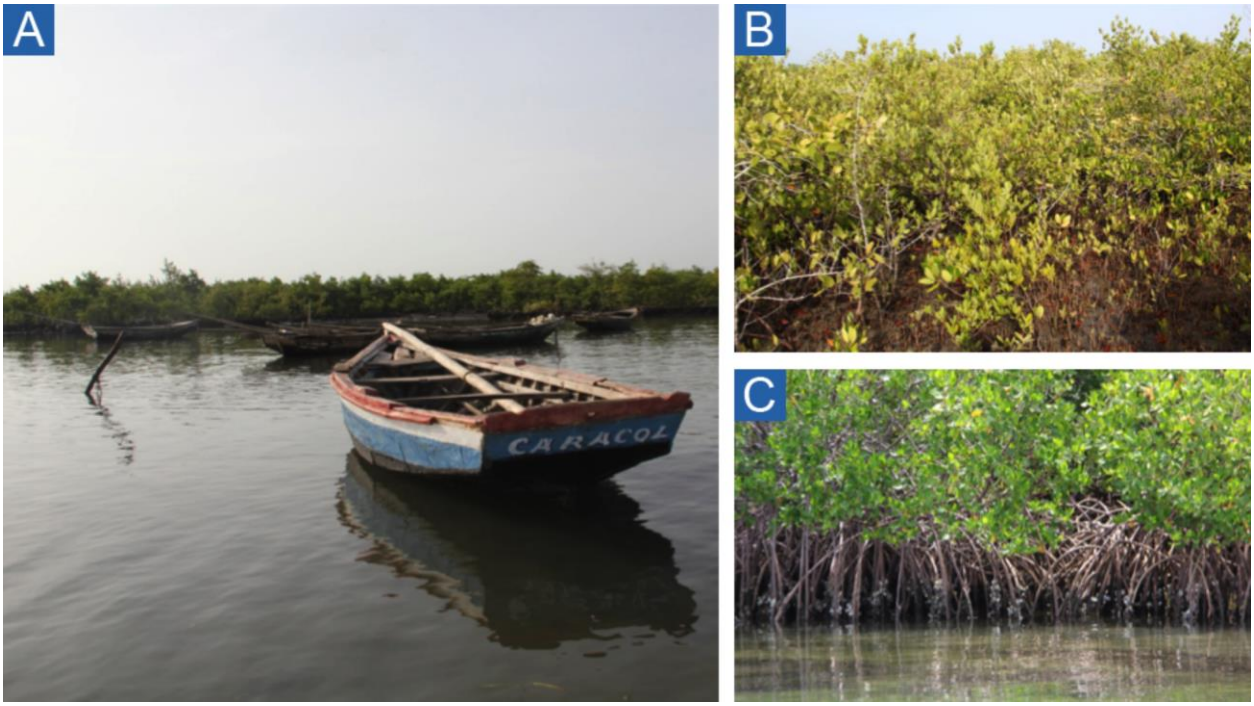

Figure 20. Fishing village in Caracol Bay **(a)** containing both basin and fringe mangrove habitats. Black mangroves dominate the basin habitat landward of the beach berm and show signs of significant human impact, **(b)** while the red mangrove fringe habitat of the outwash plain is comparatively less impacted, **(c)** despite some evidence of cutting and resource extraction.

Figure 21. Photgraphs of **(a)** mangrove crabs (*Aratus pisonii*) patrol the upper branches of black mangroves and **(b)** mangrove oysters (*Crassostrea rhisophorae*) clustered on prop roots of red mangrove (*Rhizophora mangle*).

Bord de Mer de Limonade: The Bord de Mer region of 3BNP stretches from the community of Bord de Mer northwest to the outlet of the Grande Rivière du Nord, forming the western boundary of 3BNP. A fairly uniform basin mangrove system extends behind the barrier beach. Several minor embayments and tidally influenced drainages occur along this system, cutting through the beachfront during seasonal periods of high flow, and tidally restricted after coastal storms reconfigure their outlets with sand. Uniformly short, scrub red mangrove dominates this habitat that spans approximately 12ha, although white and black mangroves also occur with frequency throughout the system (Figure 22a). While virtually all drainages and rivers observed

were populated by mangrove and mangrove associates, a unique salt tolerant herbaceous plant community was noted along a muddy bank of Grande Rivière du Nord (Figure 22b). This small, emergent system was the most botanically diverse coastal wetland encountered in 3BNP. The adjacent floodplain has long since been converted to agriculture (e.g. banana and sugarcane), except for small, discontinuous brackish tidal patches of vegetated banks along the fluvial delta remain. One such area contained over 30 herbaceous species tolerant of low to moderate salinity (Appendix 6). While quite possibly ephemeral, this habitat represents a critical diversity hot spot for native species that should be acknowledged and protected. Species observed include widgeon grass (*Ruppia maritima*), cattail (*Typha domingensis*), yellow burhead (*Limnocharis flavis*), and several species of spikerush (*Eleocharis* spp.) among others (Figure 25).

The mangrove of Bord de Mer is dominated by a fairly protected inland basin system, connected to the sea by three tidally influenced drainages (including Grande Rivière du Nord). Predominantly comprised of shrubs, that stature of its canopy is quite short at 1.6m ±1.1m, significantly shorter than Fort Liberté and Lagon aux Boeufs. It is also the least dense with percent cover estimated at 17.5% ±4% for the areas sampled. Evidence of cutting throughout contributes to these low stand height and density averages (Figure 23).

Pore water conditions were highly variable at Bord de Mer. Mangrove dominated sites were within typical salinity ranges (~40ppt), but when averaged with tidal riverine habitats (2.3ppt), suggest the site is brackish overall (18.8ppt ±7.5ppt). Tidal riverine habitats also likely influenced the mean values for pore water redox potential (-136mV ±16.0mV) and sulfides (1.10mM ±0.54mM), representing the least anaerobic conditions of all sampling sites in 3BNP, while pH did not vary significantly from the other sites, at 6.9 ±0.5 (Appendix 5).

In some areas, tidal inlets and drainages led to more expansive and diverse mangrove habitats, including some brackish tidal habitats as well, flanked by agricultural fields (Figure 27a). In these backwaters, the red mangrove fringe increases in stature with trees in excess of 10m, where not cut for agricultural purposes. In addition to black and white mangrove, this study documented an additional species of black mangrove, or ‘mangle negro’, (*Avicennia schaueriana*) (Figure 27b). This observation represents a significant range expansion for this less common species whose population center is far south (Ellison et al. 2010, Polidoro et al. 2010, Moore et al. *2014*). While preliminary review of available literature suggests otherwise, they may potentially be a hybrid of *A. germinans* (Nadia et al. 2013, Mori et al. 2015).

Fort Liberté: Unlike Caracol, Fort Liberté is a large, open, and relatively well-flushed marine system with discontinuous narrow bands of fringing mangrove. IT also has, to a lesser degree, isolated patches of hypersaline mudflat with dwarf stands of black mangrove. Cumulatively, TNC's land cover maps estimate 168ha of mangrove present today. The majority of the mangroves of Fort Liberté are contained within a narrow band pressed tightly against the banks of the embayment (Figure 26a). Little basin habitat exists, due to steep slopes and dry cliffs surrounding the majority of the bay, of which few had been fortified into colonial-era forts and prisons (Figure 26b).

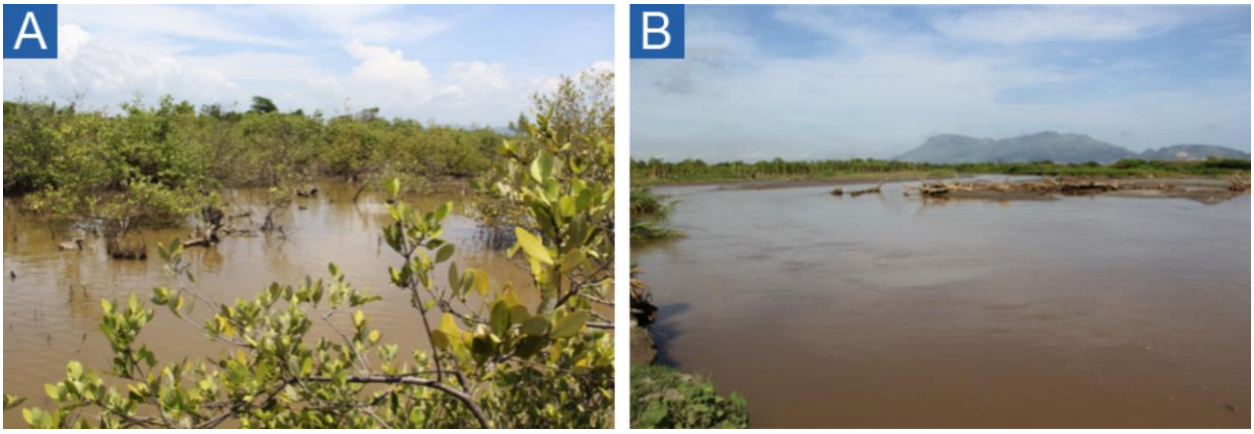

Figure 22. Landscape photographs of **(a)** shrub-dominated basin mangrove protected behind the beach berm of Grande Rivière du Nord and **(b)** brackish tidal habitat at the mouth of Grande Riviére du Nord.

In most areas, steep rocky banks prevent landward migration of the mangrove. Comprised predominantly of red mangrove, the narrow fringe habitats are relatively dense and tall (>8-10m). The rhizophores at the water's edge of the stands provide habitat for an abundance of mangrove oysters and pearl oysters, while the upper branches of *Rhizphora* and *Avicennia* species provided ample habitat for mangrove crabs that were more common here than any other site. These fringes are associated adjacent seagrass beds that are abundant in the Bay and comprised of numerous seagrass species including turtlegrass (*Thalassia testudinum*), manatee-grass (*Syringodium filiformis*), and shoalgrass (*Halodule wrightii*).

The mangroves of Forte Liberté are spread out along the periphery of the embayment, in contrast to the dense concentrations contained with Caracol, for example. Since there is a great deal of separation between forested areas, there are different influences likely affecting forest stature and habitat quality. Accordingly, mean forest height was 4.2m ±0.4m, placing this embayment squarely between the exceptionally tall trees of Lagon aux Boeufs and the scrub shrub habitats of Bord de Mer and parts of Caracol. Where present, canopy cover was the most dense of all sites at 63.6% ±7.3% (Figure 23).

Similar to Caracol, pore water conditions were fairly regular throughout Fort Liberté, mediated by regular tidal flushing (40.9ppt ±3.9ppt). Hypersaline conditions in salt flats of Phaeton strongly influenced the overall average, driving it above that of open water (~36ppt). Redox potential and sulfide concentrations reflected flooded conditions at -272mV ±42.8mV and 2.45mM ±0.43mM, respectively. Finally, soil pH was comparable

to all sites (7.1 ±0.1). While salinity and sulfide levels at isolated locations represent stressful edaphic for seedling establishment, these values would not be expected to preclude successful restoration actions (Appendix 5).

Lagon aux Bœufs: Perhaps the most unique mangrove habitat observed in this study is contained in Lagon aux Boeufs. This brackish embayment has limited tidal influence/exchange and is dominated by a narrow, but exceptionally tall fringe of red mangroves, bordered by a narrow discontinuous band of black mangrove creeping up the rapidly sloping banks that encircle the system (Figure 30c). Mangrove fern (*Acrosticum aureum*) can be seen at this site in abundance among patches of white mangrove, particularly at the landward edge of the mangrove (Figure 30a). Meanwhile, widgeon grass (*Ruppia maritima*) is found in the shallows within the embayment itself, providing habitat for tilapia (*Oreochromis mossambicus*) and crayfish (*Macrobrachium sp.*), among other species of commercial value. More common submerged aquatic vegetation includes prolific spiny water nymph (*Najas marina*) and periodic blooms of the nuisance green algae known as muskgrass (*Chara* sp.) (Figure 29). A complete list of wetland taxa observed is included in Appendix 6. Agro-pastoral activities on adjacent lands have impacted landscape and eliminated virtually all vegetated buffer adjacent to the mangrove (Figure 30d).

Lagon aux Boeufs contains some of the tallest mangroves in the country of Haiti. With some trees measuring over 15m, the system dwarfs all others sampled in this study, yet cutting and clearing brought down the mean height overall to 8.7m ±0.6m and to some degree this also affected forest cover and density with an intermediate value of 55% ±10.4%, showing relatively high variability overall (Figure 23). Lagon aux Boeufs had the most consistently low salinity of all sites with a mean of 6.6ppt ±0.9ppt. Low salinity was in contrast to elevated sulfide levels 2.66mM ±0.78mM, which were the highest of the sites sampled overall, and the lowest redox potential (2.89mV ±34.2mV). Interestingly, pH values were higher than all other sites (7.4 ±0.1), and possibly influenced by freshwater additions from the adjacent river. Restoration efforts would likely be facilitated by the lower salinity, despite slightly elevated sulfide conditions (Appendix 5).

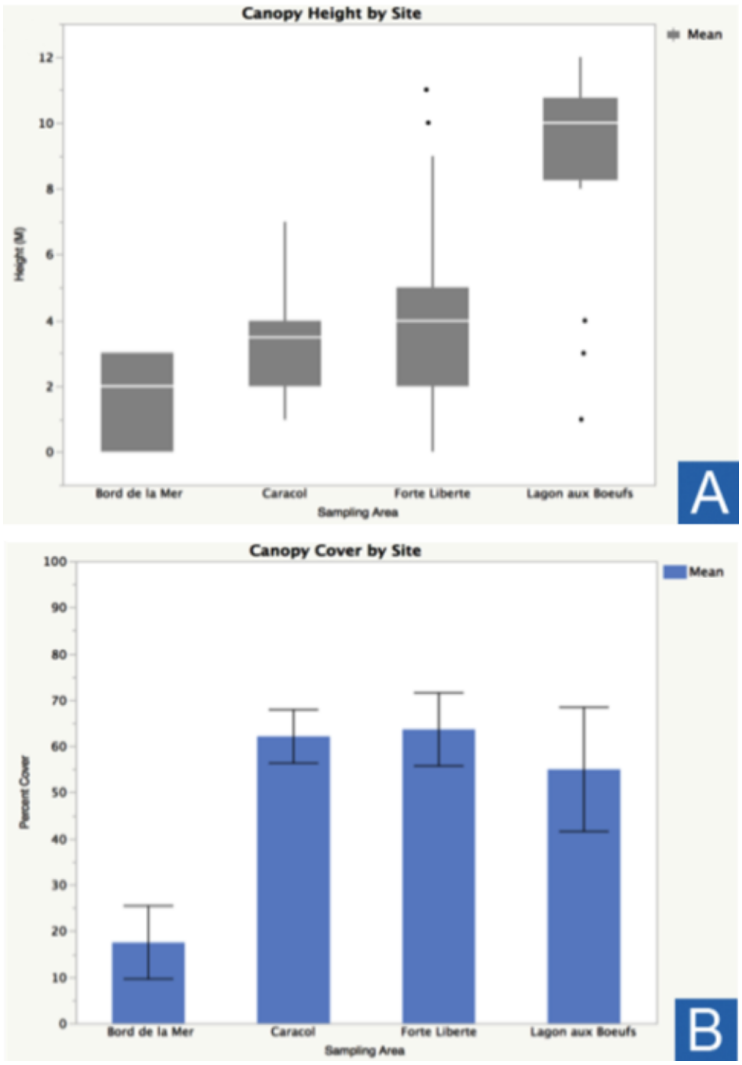

Figure 23. Comparison of mean canopy height **(a)** and percent cover **(b)** by sampling area.

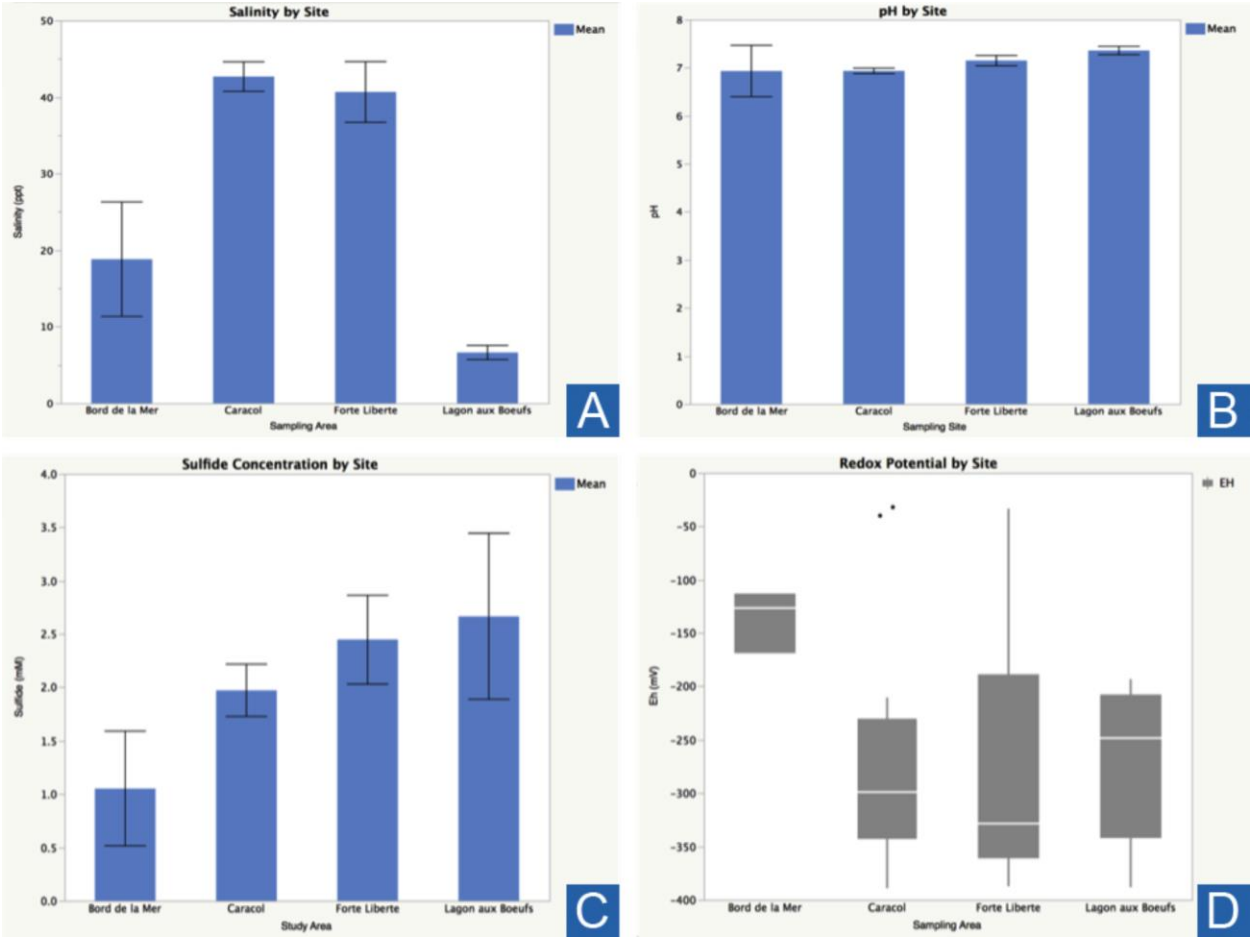

Figure 24. Comparison of pore water conditions by site, including **(a)** salinity, **(b)** pH, **(c)** sulfide, and **(d)** redox potential.

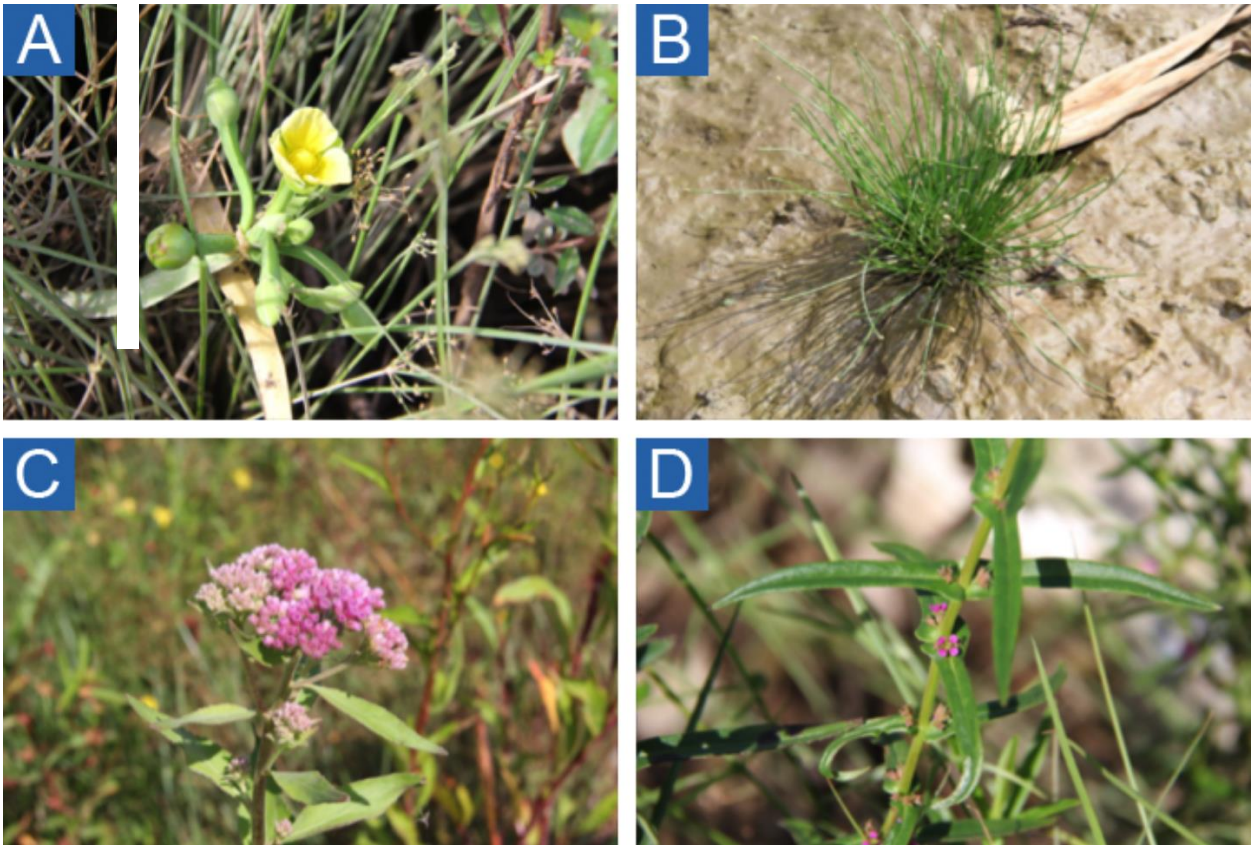

Figure 25. Examples of taxa from tidal fresh and brackish habitats of Grande Rivière du Nord including **(a)** yellow burhead (*Limnocharis flavis*), **(b)** spikegrass (*Eleocharis spp.*), **(c)** camphorweed (*Pluchea caroliniensis*), and **(d)** purple loosestrife (*Lythrum salicaria*).

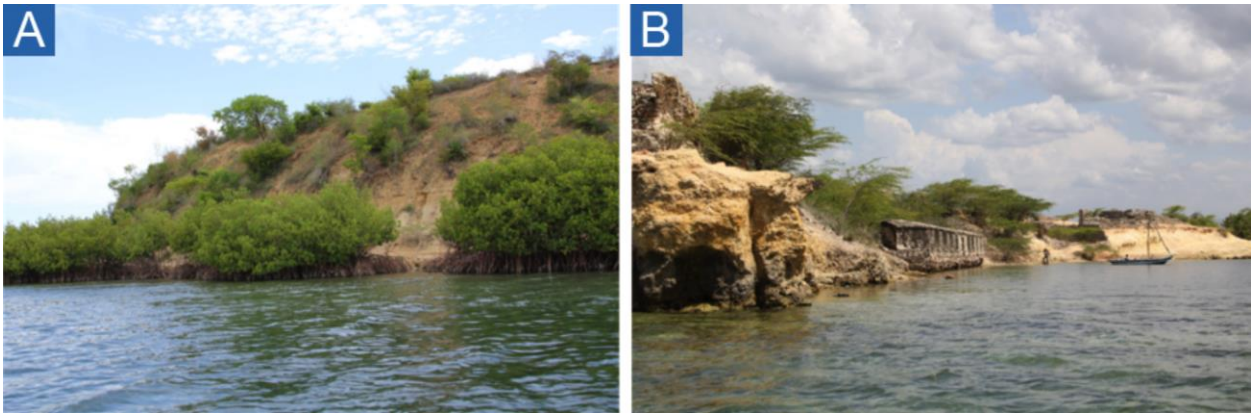

Figure 26. Landscape photographs of **(a)** steep dry banks surrounding the majority of Fort Liberté, limiting mangrove to fringe habitats (primarily dominated by red mangrove) and **(b)** colonial ruins, a common feature of the eroded cliff shores of Fort Liberté.

Figure 27. (a) sugarcane, banana, and rice plantations flank the eroded banks of tidal inlets and creeks near Fort Liberté Bay and **(b)** example of the characteristic rounded leaf tips of mangle negro (*Avicennia schaueriana*) from Fort Liberté, likely representing a range expansion for this more southern species.

Figure 28. Traditional fishers in the brackish waters of Lagon aux Beoufs.

Figure 29. Dense nuisance alga *Chara* sp. clogs the bottom of the brackish waters of Lagon aux Boeufs.

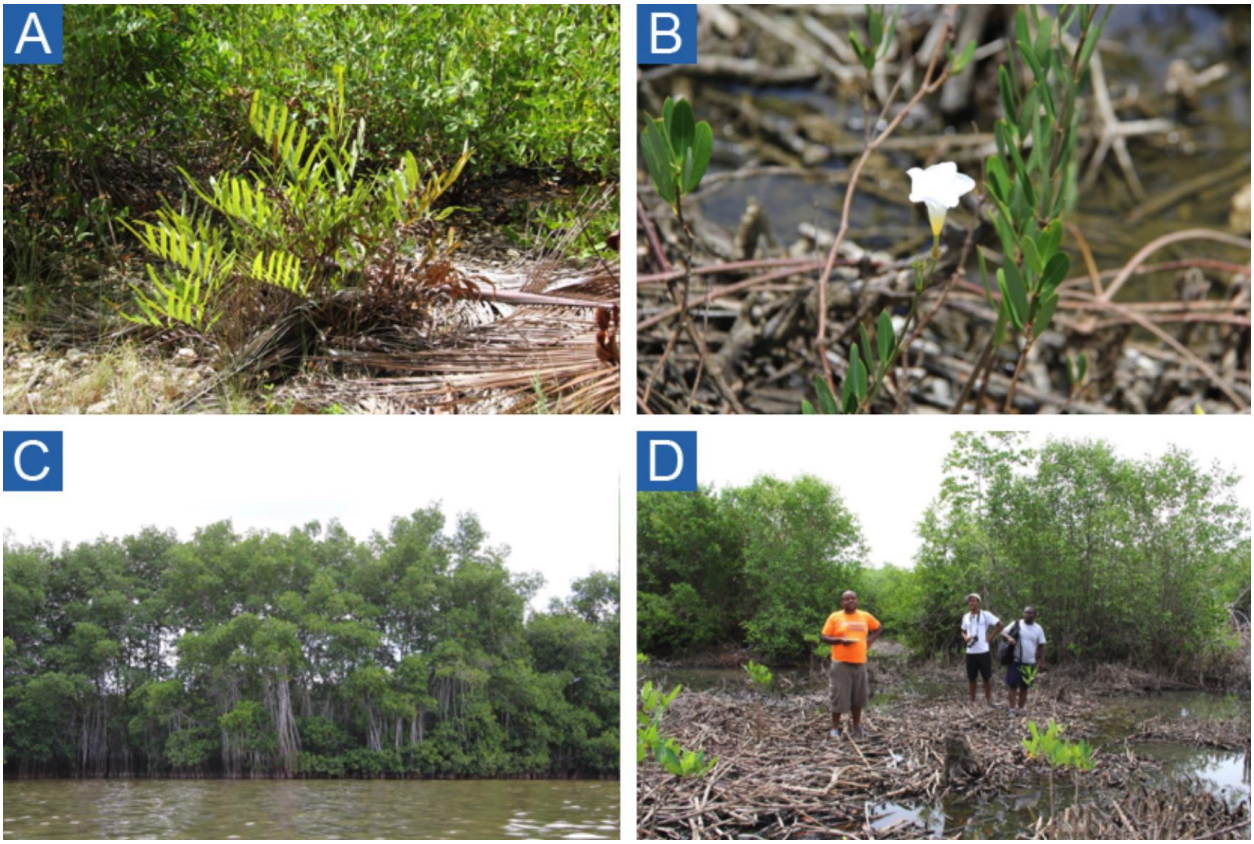

Figure 30. Examples of forest cover in Lagon aux Boeufs including **(a)** mangrove fern (*Acrostichum aureum*), **(b)** mangrove vine (Rhabdadenia biflora), **(c)** fringing red mangrove, and **(d)** significant area of forest cutting and loss.

Threats to Mangroves and Coastal Wetlands

Overall, the mangroves and coastal wetlands of 3BNP remain an ecologically significant habitat containing all the mangroves and mangrove associates that occur within the region, a possible range expansion for less common mangrove species, and a diversity of brackish-tidal species as well. Despite this overall quality, there are clear and present threats readily identified in each of the embayments studied, similar to virtually all coastal wetlands in the world. The threats to these globally threatened systems in 3BNP may be grouped into the following five broad categories:

1. Cut and Harvest: Unregulated cut and harvest of mature mangrove for charcoal and fuel wood;
2. Land Conversion: Clearing of mangrove stands for salt mining, agriculture, and/or development;
3. Deforestation: Clearing of adjacent lands for agro-pastoral endeavors and associated unrestricted livestock trampling, browsing, and nutrient additions;
4. Impact to Buffer Zones: Loss of wetland buffer zone vegetation, including coastal/littoral forest, riparian buffers, etc., that provide infiltration and a ‘first line of defense’; and

5. Pollution: Point and non-point source pollutants, nuisance algae, eutrophication

These threats play out very differently in each of the three embayments assessed in this study. Accordingly, the expectation is that there will be differential effects based on the type of mangrove system one considers (e.g. fringe, basin, hammock, riverine, etc.) and its position in the tidal regime.

Evidence of mangrove cutting is prevalent throughout the Caracol basin system (Figure 33). Cutting includes mangrove *and* wetland buffer vegetation. The latter exacerbates erosion and movement of terrestrial sediments, leaving barren, often hypersaline mud flats behind. The open habitats that often result from cutting within the mangrove (i.e. mud flats and salt barrens) may provide habitat and forage opportunities for wading shorebirds, but provides little benefit for buffering coastal storms or accelerated sea level rise. Furthermore, cutting at the upland edge may also encourage spread of invasive species, including *Acacia farnesiana* that was noted in patchy distributions just up gradient of the mangrove edge.

Figure 31. Photographs of **(a)** fishers working the nearshore waters of Caracol Bay, **(b)** crabbers near the mouth of Fort Liberté, **(c)** eel netters at Bord de Mer, and **(d)** the artisanal boats at Lagon aux Beoufs.

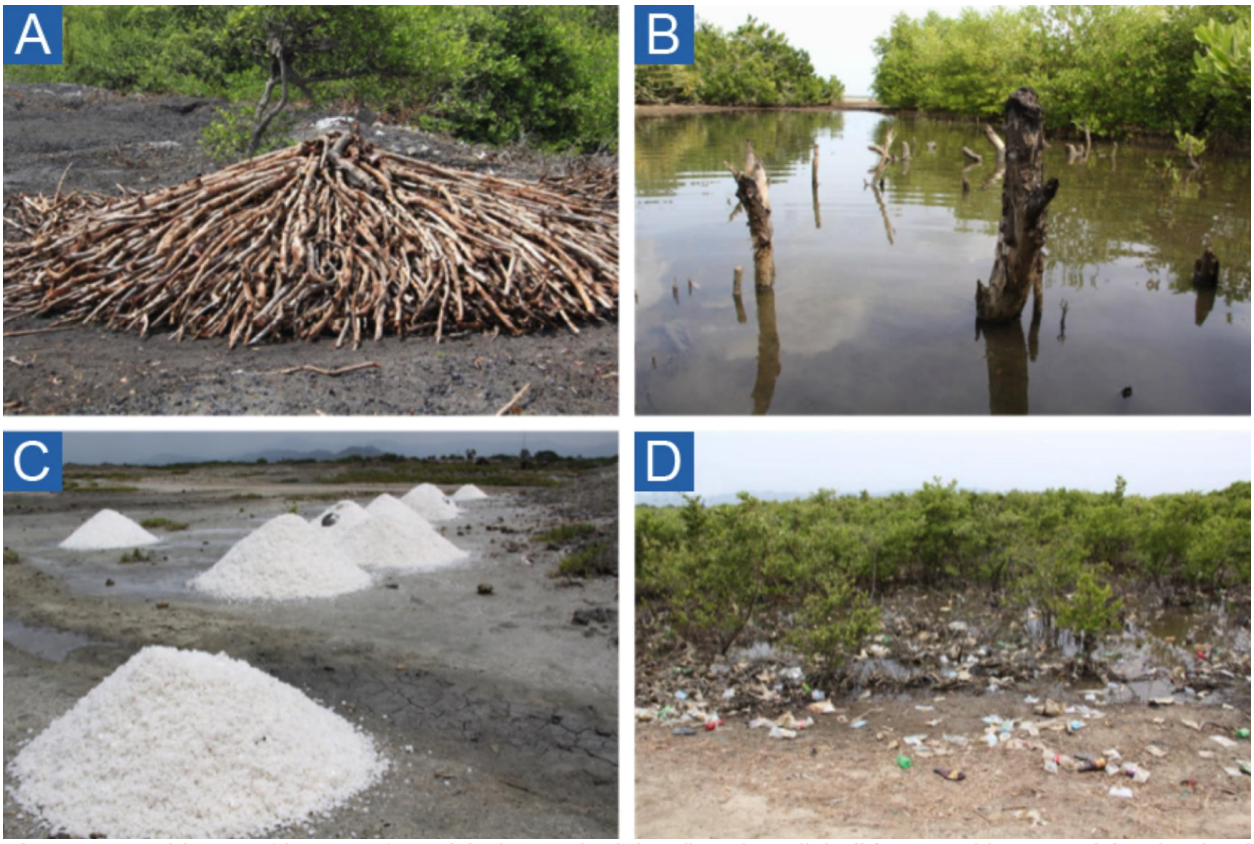

Figure 32. Evidence of impacts from **(a)** charcoal mining (burning pile), **(b)** cut and harvest, **(c)** salt mined from reclaimed mangrove areas, and **(d)** trash accumulation.

Figure 33. Grazing cattle and barren lands resulting from cutting, agriculture, and development.

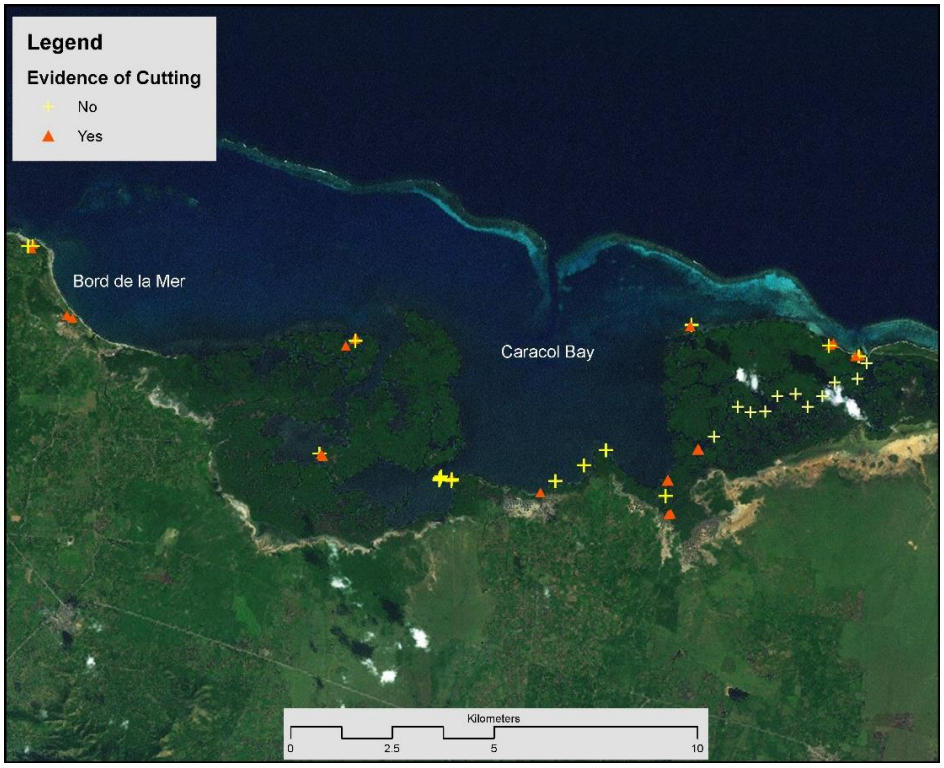

Figure 34. Observation plots where evidence of cutting was noted in Regions 1-4 (Caracol Bay).

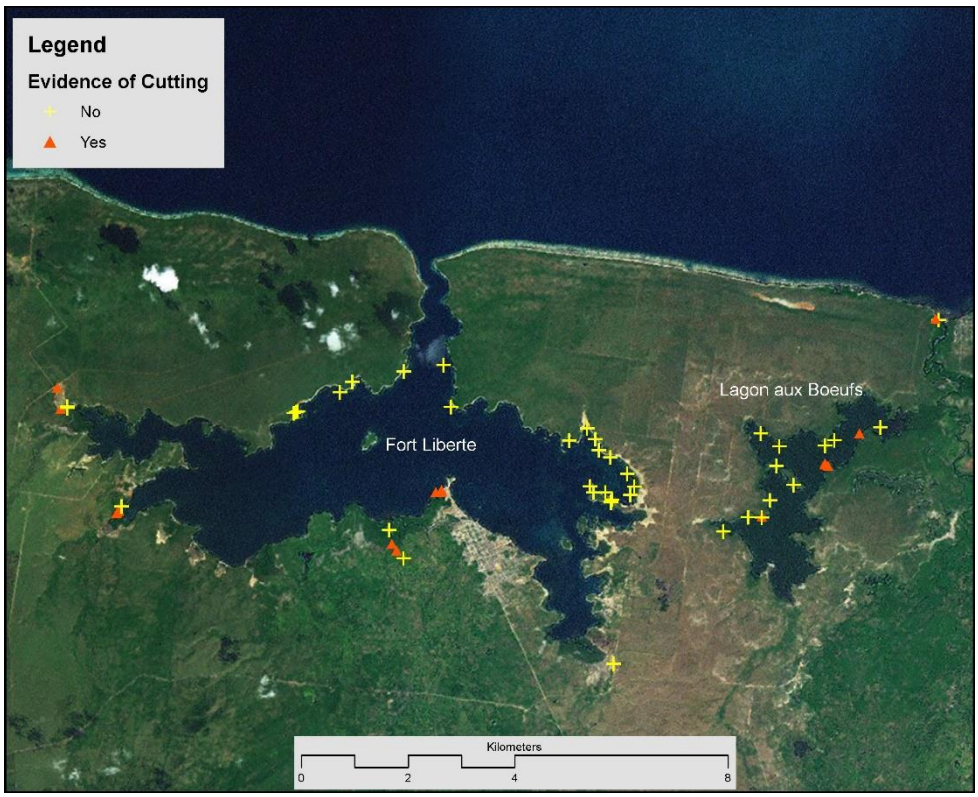

Figure 35. Observation plots where evidence of cutting was noted in Regions 5-6 (Fort Liberté) and Region 7 (Lagon aux Beoufs).

Conclusion

The mangrove should be considered one of the principal ecological features of 3BNP with a high natural aesthetic value. Unlike much of the terrestrial habitats, mangroves habitats have largely retained their species and occupy much of the same area they did several hundred years ago. Moreover, they have proven to be resilient to large scale fishing and declining water quality in many areas. Specific areas of importance highlighted in this chapter include the extensive basin mangroves from Caracol Bay and the structurally complex fringing mangrove system that border Lagon aux Boeufs. Surveys have also found that much of the freshwater wetland plant communities have been converted by agriculture. Small pockets of wetland plants remain near the mouth of the Grande Rivière du Nord and around the ephemperal seasonal flats known as Grande Saline. These areas should be a priority for protection. The future of the mangrove and remaining wetland communities will depend on the success of 3BNP in enforcing existing olicies that prohibit cutting of mangrove for charcoal production and implementing zoning and other measures to reduce infilling and encroachment into the transitional zone driven by expanding human activity.

III. Birds and Terrestrial Vertebrates

Three Bays National Park (3BNP) is home to many species of birds and terrestrial vertebrates. In order to have meaningful management and conservation of these Park residents, assessing their diversity and distribution is a necessity. This chapter involves assessment of terrestrial vertebrate community structure and composition, specifically an inventory of resident and migratory birds, terrestrial mammals, and herpetofauna (reptiles and amphibians). Faunal survey methods were tailored to the targeted taxon to determine species distribution, occurrence, and relative abundance.

Figure 36. Principal areas (outlined red areas) for terrestrial faunal surveys were conducted in 3BNP.

This chapter elucidates the assessment of the birds, reptiles, mammals, and amphibians within the boundaries of 3BNP. The results of this study were gathered during two field expeditions, from June 17 to July 5 and from November 17-27, 2015 allowing for detection of seasonal changes in species abundance and particularly the presence of migratory birds.

Birds: A total of 6411 birds of 95 species were recorded overall, including 24 non-breeding visitors or migrants (Appendix 7). Among the most notable records observed was a pair of Hispaniolan Parrots (*Amazona ventralis*), a flock of 14 flamingoes (*Phoenicopterus ruber*) in Lagon Aux Boeufs, 10 Roseate Spoonbills (*Platalea ajaja*) and 4 White Ibises (*Eudocimus albus*). Several areas covered with coastal mangroves

were also surveyed, but without success in locating a single Reddish Egret (*Egretta rufescens*).

Amphibians and Reptiles: Total recorded species included 4 amphibian species and 11 reptile species (Appendix 9). Low amphibian diversity is likely the result of heavy contamination and eutrophication of all the lagoons visited. This may be caused by, among other things, cattle observed having unrestricted access to rivers and lagoons inside the park boundaries. There were more species of reptiles in lowland areas with large trees and agricultural fields surrounded by hedgerows and live fences. This is the case near the settlements of Garde Saline and Montolon (Figure 37). These areas do not appear to be as heavily exploited for charcoal production as more remote localities with few permanent settlements. For example, there were numerous charcoal ovens found around the hills known as Mornes Deux Mamelles, 3.7km north of Phaeton. These hills are the highest point of the 3BNP, and one of the few areas where remnants of the dry forest were found that probably covered most of the coastal lowlands (Figure 37).

Terrestrial Mammals: Two species of terrestrial mammals endemic to Hispaniola are thought to exist at 3BNP - the Solenodon (*Solenodon paradoxus*) and the Hutia (*Plagiodontia aedium*). During the two periods of fieldwork that included noctural surveys, no direct evidence (visual sighting, tracks, scat) of either of these two species was found. In fact, only two interviewees out of 97 (both from the commune of Garde Saline) even mentioned the presence of a “tailless tree rat” which is a local name for the Hutia. Searches of the specific area mentioned by interviewees again found no evidence of its presence. Only one interviewee (a student from the local university of Limonade) recognized the Solenodon; however, he observed this mammal more than a decade ago and far from the area of 3BNP, in the locality of Hinche (Central Plateau).

The principal larger mammals that now occur in 3BNP are two introduced predators- the Small Indian Mongoose (*Herpestes auropunctatus*) and the Feral Cat (*Felis catus*). Both of these predators are well established and widespread in 3BNP. There was direct evidence that local farmers occasionally capture feral cats as a source of animal protein or to sell locally. However, whether the mongoose is targeted for the same purpose is unknown. The relative abundance of other introduced mammals, such as rats (*Rattus rattus* and *R. norvegicus*) and house mice (*Mus musculus*) were not assessed but are known to be quite abundant. No feral dogs (*Canis familiaris*) were encountered during the bird and reptile surveys, but local farmers often have dogs and use them occasionally for hunting.

Description of Terrestrial Vertebrate Habitats

All the sites visited within 3BNP boundaries, regardless of habitat type (e.g. mangroves, mudflats, or inland habitats), are heavily influenced by human extractive activities. This rapid assessment is based on some 80 hours of cummulative active observation and should be regarded as preliminary until more systematic studies are carried out. This

section describes the the principal terrestrial habitat types used by terrestrial vertebrates and birds.

Figure 37. Large fruit trees in the gardens around Garde Saline (left) and landscape of Mornes Deux Mamelles (right) in 3BNP.

Saline mudflats: Saline mudflat areas were classified as “barren” by TNC land use classification scheme and generally are found along the transitional areas between mangroves and scrublands (Figure 9, Table 4). A total of 641 hectares of barren mudflats occur within 3BNP, over half of which are in the lower reaches of the True du Nord watershed around the central and eastern edge of Caracol Bay (Table 4). These areas have little or no vegetation but are surrounded by mangroves or shrubs – mainly bayahonda (*Prosopis juliflora*). The soil is usually composed of clay and can either be saturated with water or dry depending on the time of year (Figure 38a). Mudflats are especially important for shorebirds, sometimes harboring hundreds of individuals (Appendix 8). The number and diversity of birds utilizing these areas depends strongly on the availabiliy of food (copepods, brine shrimp, polychaete worms) which fluctuate based on local consitions- salinity, water levels, nutrients. The climate in 2015 appears to have been drier than average, and resulted in the conversion of large sections of some interior lagoons to mudflats in Saline Morena (Figure 38b) and Saline du Sel (Figure 38c).

Figure 38. landscape photographs of **(a)** a mudflat, **(b)** Saline Morena, and **(c)** Saline du Sel in 3BNP.

Mangroves: Mangroves are an important habitat for birds and reptiles, and are also crucial for maintaining the local fishing communities.

Figure 39. Photograpghs of coastal mangroves in **(a)** the mouth of Caracol Bay, **(b)** Lagon aux Beoufs, and **(c)** mangrove clear cutting to produce charcoal in 3BNP.

Interior Lagoons: Interior lagoons are enclosed or semi-enclosed shallow water bodies usually surrounded by a mangrove fringe. The largest interior lagoon is Lagon aux Boeufs located on the eastern edge of 3BNP. Other areas that act as lagoons or ponds are usually located in lowland areas which flood seasonally. Sometimes they are formed by abandoned river meanders (e.g. oxbows). Lagoons are often surrounded by agricultural fields that can be heavily used by free range cattle, goats, and horses. As a result, interior lagoons can be heavily polluted and eutrophied, as in the case of the Lagoon de Phaeton (Figure 40). These polluted conditions may explain the near total absence of native amphibians in many of these lagoons. The principal amphibians that occupy these lagoons were found to the Cane toad (*Rhinella marina)* and the American bullfrog (*Rana catesbeiana)*, both of which are introduced and possibly invasive.


Figure 40. Landscape photograph of Lagon de Phaeton in 3BNP.

Salt Ponds: Salt ponds are structures near the coast designed to extract salt through natural evaporation of sea water (Figure 41). A total of 140 hectares of salt pond occur within 3BNP based on TNC's land use classification (Figure 9, Table 4). Most salt ponds are locate around the villages of Caracol and Jacquezyl. Species found in low-salinity ponds are similar than those in natural habitats nearby. As with mudflats, the water depth and salinity of salt ponds stongly influences the amount and type of prey present. In high-salinity salt ponds, no fish are able to survive, but abundant brine shrimp and brine flies support numerous waterbirds. Salt ponds no longer needed for salt production offer a significant opportunity for habitat restoration. Maintaining some salt ponds as managed pond habitat can benefit resident and migratory shorebirds and waterfowl by providing a range of resting, foraging, and breeding areas. They also offer an opportunity to increase public access to observe waterbirds to increase tourism, in conjunction with restoration, enhancement, or conversion of ponds to aquatic or wetland habitat.

Figure 41. Landscape photograph of a salt pond near Jacquezyl in 3BNP.

Estimating the area of mangroves that have been converted to salts ponds is difficult. A comparison in Google Earth using aerial imagery taken between 2003 and 2015 shows an increment in the number of salt ponds around the village of Caracol from 104 to 140 (Figure 42). East of Jacquezyl, although there are new areas occupied by salt ponds, they do not appear to be located in areas previously covered by mangroves.

Scrub Savannas: Scrub savannas include Acacia Shrubland (AS) and Dry Broadleaf Evergreen Formation (DBEF-S; DBEF-A) (Figure 43).

Figure 42. Aerial photographs of salt ponds near Caracol in 2003 and 2015 in 3BNP.


Figure 43. Scrub savannas covered in bayahonda (*Prosopos juliflora*) in 3BNP.

Riparian: The east and west boundaries of 3BNP are defined by the Riviére du Massacre and Grande Riviére du Nord, respectively. These two rivers, plus several small ones (e.g. Riviére Trou du Nord and Riviére Lamatry) maintain corridors of riparian vegetation that are highly fragmented and degraded (Figure 44). The presence of water and alluvial soils allow the development of large trees, although few native trees remain (most of them have been replaced by mangos and coconuts). Despite its degraded human altered state, riparian zones are important for numerous species of birds (e.g. *Todus subulatus*, *Petrochelidon fulva*, and *Coccyzus longirostris*), reptiles (e.g. *Anolis chlorocyanus* and *Anolis cybotes*) and amphibians (*Osteopilus dominicensis* and *Bufo guentheri*). Because of the abundance of food resources and tree cavities for

shelter, these riverine corridores are also the most likely plalces to find the two endemic terrestrial mammals of the island, the Solenodon (*Solenodon paradoxus)* and the Hutia (*Plagiodontia aedium)* although neither mammal was documented within 3BNP during this study. Furthermore, this habitat is would likely also be the most likely place to find bats (althugh none were recorded during our surveys).

Figure 44. Riparian vegetation between Carrefour Panois and Samson in 3BNP.

Pasture and Grasslands: Pasture and Grasslannds include both the Agricultural and Grassland land classes mapped by TNC and cover approximately 4,109 hectares of 3BNP (Table 4, Figures 7, 45). Pastures tend to support the lowest number of species, but when they are bordered by live fences of mangos and other useful plants, can act as biological corridors for a several common species of birds and reptiles. Agricultural plots in general are relatively small, reflecting the prevalent type of land tenure inside the park.

Agroforestry: Agroforestry is a subclass of the agricultural lands that include old growth trees that exceeded 40cm in diameter and 15m in height (e.g. those shown in Figure 36). Seasonal crops and pastures are randomly mixed with these trees. Depending of the density and diversity of the tree cover, these areas can harbor a considerable number of terrestrial vertebrate species.

Terrestrial vertebrate and bird species diversity: Table 6 shows a list of species that were reported at various times for the area but were not detected during our surveys. The sampling effort and technique used may not have been adequate to detect uncommon, rare, or strictly nocturnal species, as suggested by the species accumulation curve (Figure 46). The survey teams may have missed a number of passage migrants that spend a few days in the area between September and October

(Table 8). Despite these limitations, it is likely thatt some habitat-sensitive species previously reported for the area –particularly those associated with extensive and well preserve mangroves and forests, or clean streams – may now be locally extirpated.

Figure 45. Pastures and annual crops near Lagon aux Boeufs in 3BNP.

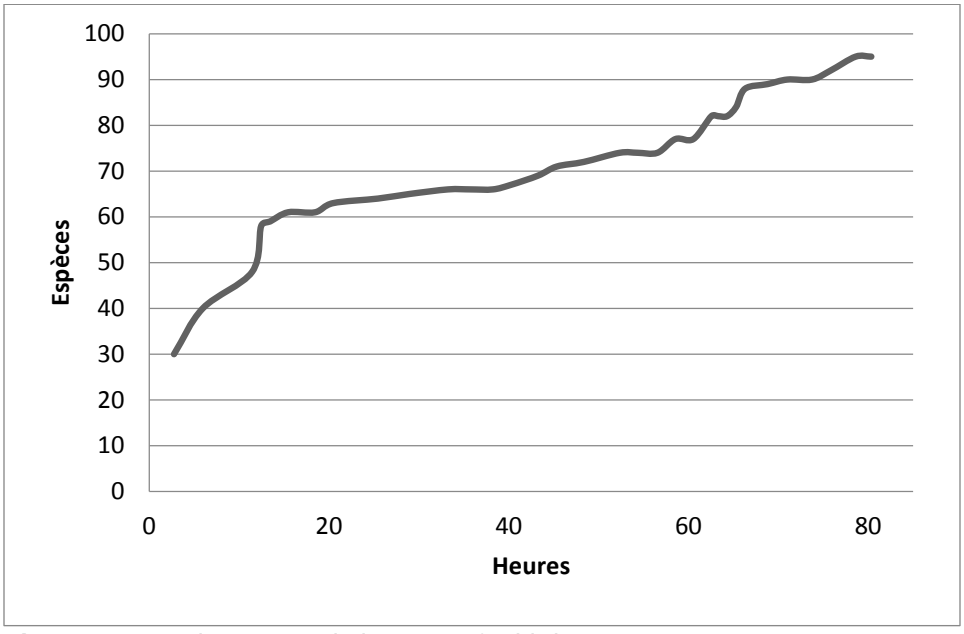

Figure 46. Species accumulation curve for birds at 3BNP.

Table 6. Expected resident bird species, based on information provided in Latta et al. (2006) that were not detected during surveys of 3BNP. N – nocturnal; E – endemic.

Scientific name	English Name	Remarks
Dendrocygna arborea	West Indian Whistling-Duck	
Nomonyx dominicus	Masked Duck	
Oxyura jamaicensis	Ruddy Duck	
Ixobrychus exilis	Least Bittern	
Egretta rufescens	Reddish Egret	
Mycteria americana	Wood Stork	
Buteo jamaicensis	Red-tailed Hawk	
Porzana flaviventer	Yellow-breasted Crake	
Porphyrula martinica	Purple Gallinule	
Fulica americana	American Coot	
Aramus guarauna	Limpkin	
Burhinus bistriatus	Double-stripe Thick-knee	
Jacana spinosa	Northern Jacana	
Geotrygon chrysia	Key West Quail-Dove	
Geotrygon montana	Ruddy Quail-Dove	
Aratinga chloroptera	Hispaniolan Parakeet	E
Coccyzus americanus	Yellow-billed Cuckoo	
Tyto glaucops	Ashy-faced Owl	N; E
Athene cunicularia	Burrowing Owl	N
Asio flammeus	Short-eared Owl	N
Siphonorhis brewsteri	Least Pauraque	N; E
Caprimulgus eckmani	Hispaniolan Nightjar	N; E
Tachornis phoenicobia	Antillean Palm-Swift	
Nesoctites micromegas	Antillean Piculet	E
Contopus hipaniolensis	Hispaniolan Pewee	E
Vireo nanus	Flat-billed Vireo	E
Progne dominicensis	Caribbean Martin	
Turdus plumbeus	Red-legged Thrush	
Microligea palustris	Green-tailed Ground-Tanager	E
Icterus dominicensis	Hispaniolan Oriole	E

The amphibian community within 3BNP is now dominated by introduced species, probably a reflection of overall contamination of most of the lagoons and rivers visited. Reptiles are considered more a mix of native and introduced species. Species that require large trees and forested landscapes have been hit hard by high level of deforestation and overall habitat degradation of 3BNP. Expected species amphibians and reptiles, based on historical records and range projections deserve the most attention (Tables 6 and 7). Although not documented in this survey, some species, in particular rare species or species with secretive habits, may still exist in the Park. However, their absence in all surveys would suggest that there is a reasonable expectation that they are locally endangered or extinct. For example, there were no documented sources of water which were either not heavily contaminated or almost completely stripped of native riparian vegetation (especially large trees).

Table 7. Expected species of amphibians in 3BNP based on information provided in Caribherp (Hedges 2015). O – observed; E – endemic; I – introduced.

Expected	English Name	Remarks
Peltophryne guentheri – Cochran, 1941	Southern Crested Toad	O, E
Rhinella marina – Linnaeus, 1758	Marine Toad	O, I
Eleutherodactylus abbotti – Cochran, 1923	Tuck- Wheep Landfrog	E
Eleutherodactylus inoptatus – Barbour, 1914	Hispaniolan Giant Landfrog	E
Eleutherodactylus limbensis – Lynn, 1958	Haitian Streamside Landfrog	E
Hypsiboas heilprini – Noble, 1923	Hispaniolan Green Treefrog	E
Osteopilus dominicensis – Tschudi, 1838	Hispaniolan Laughing Treefrog	O, E
Osteopilus pulchrilineatus – Cope, 1869	Hispaniolan Yellow Treefrog	E
Osteopilus vastus – Cope, 1871	Hispaniolan Giant Treefrog	E
Lithobates catesbeianus – Shaw, 1802	Bullfrog	O, I

Table 8. Expected species of reptiles in 3BNP based on information provided in Caribherp (Hedges 2015). O – observed; E – endemic; I – introduced.

Expected	English Name	Remarks
Crocodylus acutus – Cuvier, 1807	American Crocodile	
Amphisbaena manni – Barbour, 1914	Hispaniolan Dwarf Amphisbaena	E
Celestus costatus – Cope, 1861 (1862)	Hispaniolan Smooth Galliwasp	E
Celestus stenurus – Cope, 1862 (1863)	Hispaniolan Keeled Galliwasp	E
Celestus warreni – Schwartz, 1970	Hispaniolan Giant Galliwasp	E
Anolis chlorocyanus – Duméril et Bibron, 1837	Northern Green Anole	O, E
Anolis cybotes – Cope, 1862	Hispaniolan Stout Anole	O, E
Anolis distichus – Cope, 1861	Hispaniolan Gracile Anole	O, E
Anolis olssoni – Schmidt, 1919	Desert Grass Anole	E
Anolis ricordii – Duméril et Bibron, 1837	Haitian Giant Anole	E
Anolis semilineatus – Cope, 1864	Hispaniolan Grass Anole	E
Anolis whitemani – Williams, 1963	Pallid Stout Anole	E
Hemidactylus haitianus – Meerwarth, 1901	West African House Gecko	I

Expected	English Name	Remarks
Hemidactylus mabouia – Moreau de Jonnès, 1818	Tropical House Gecko	O, I
Cyclura cornuta – Bonnaterre, 178	Rhinoceros Iguana	E
Leiocephalus personatus – Cope, 1862	Hispaniolan Masked Curlytail	O, E
Leiocephalus schreibersii – Gravenhorst, 1837	Hispaniolan Khaki Curlytail	O, E
Spondylurus lineolatus – Noble et Hassler, 1933	Hispaniolan Ten-lined Skink	E
Aristelliger expectatus – Cochran, 1933	Hispaniolan Desert Gecko	E
Aristelliger lar – Cope, 1861 (1862)	Hispaniolan Giant Gecko	E
Sphaerodactylus difficilis – Barbour, 1914	Hispaniolan Eyespot Sphaero	E
Sphaerodactylus lazelli – Shreve, 1968	Cap-Haitien Sphaero	E
Ameiva chrysolaema – Cope, 1868	Hispaniolan Giant Ameiva	O, E
Ameiva lineolata – Duméril et Bibron, 1839	Pygmy Blue-tailed Ameiva	E
Chilabothrus fordii – Günther, 1861	Hispaniolan Desert Boa	O, E
Chilabothrus gracilis – Fischer, 1888	Hispaniolan Gracile Boa	E
Chilabothrus striatus – Fischer, 1856	Hispaniolan Boa	O, E
Hypsirhynchus ferox – Günther, 1858	Hispaniolan Hog-nosed Racer	E
Hypsirhynchus parvifrons – Cope, 1862	Hispaniolan Lesser Racer	E
Ialtris dorsalis – Günther, 1858	Hispaniolan W-headed Racer	E
Uromacer catesbyi – Schlegel, 1837	Blunt-headed Treesnake	O, E
Uromacer oxyrhynchus – Duméril, Bibron et Duméril, 1854	Greater Sharp-nosed Treesnake	O, E
Tropidophis haetianus – Cope, 1879	Hispaniolan Trope	E
Typhlops pusillus – Barbour, 1914	Hispaniolan Common Blindsnake	E
Trachemys stejnegeri – Schmidt, 1928	Antillean Slider	E

Threats to Terrestrial Vertebrates and Birds

The principal threats to the birds and terrestrial vertebrates within 3BNP include introduced invasive species, hunting, habitat loss, and pollution and eutrophication of water bodies (Kramer et al., 2016). Introduced species such as the Small Indian Mongoose (*Herpestes auropunctatus*), the Feral Cat (*Felis catus*), rats (*Rattus* spp.), the Cane Toad (*Rhinella marina*) and the Bullfrog (*Lithobates catesbeianus*) all of which are well established pose a significant threat particularly to native reptiles and ground ground birds, The Small Indian Mongoose has been blamed for the demise of many reptile species in every Caribbean island where it has been introduced, in particular

skinks and geckos (Hedges & Conn 2012). On a similar note, mongooses and rats are well known predators of eggs and nestlings of many bird species (Townsend et al. 2009). Cats are well adapted to prey both on small reptiles and a wide array of bird species (Nogales et al. 2013).

Subsistance hunting also poses a significant threat particularly to birds. Several instances of subsistence hunting were documented during our field work. In the locality of Ferrier, a woman carrying a dead Blue-winged Teal (*Anas discors*) was documented (Figure 47), and in a small creek near Caracol, the survey team liberated a Pied-billed Grebe (*Podilymbus podiceps*) that was entangled in fishing net (Figure 47). A local hunter was observed carrying two live Helmeted Guineafowl (*Numida meleagris*) and a dead feral cat (*Felis catus*). However, whether these encounters represent isolated cases or a widespread local practice with a significant impact on local bird populations was not clear. During the bird surveys at Lagon aux Boeufs, the survey team encountered a group of well-equipped hunters. According to the local fishermen that serve as guides for these hunters, they target all species of ducks and pigeons.

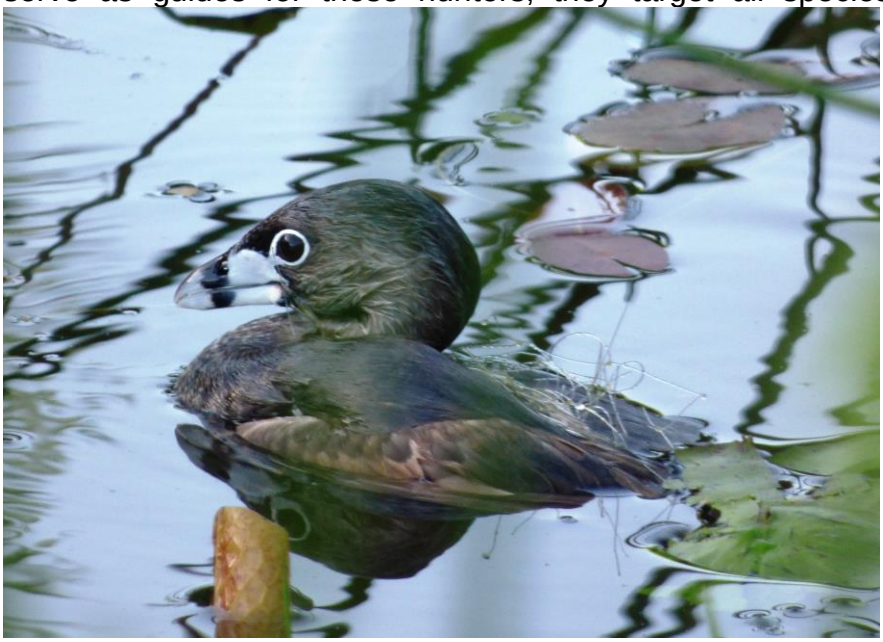

Figure 47. Picture of a recently killed Anas discors for sale in Ferrier (left) and a Pied-billed Grebe entangled in a fish net (right) in 3BNP.

Conclusion

The terrestrial fauna of 3BNP has been heavily impacted by the loss of natural habitat, the introduction of non-native species, degrading water quality, and over-harvesting. The most intact remaining natural fauna documented were birds. Important bird areas remain Lagon aux Boeufs, other lagoons and flats (e.g., salines), and the shallow tidal seagrass flats of Caracol Bay. Amphibian and reptiles communities occur mainly within the riparian corridors, but are now dominated by non-native species. Native mammals were not documented within the Park boundaries and are thought to have been displaced by human activities and the introduction of mongoose, cats, and dogs. The legal denomination of 3BNP has yet to produce any tangible change in land uses or the regulation of hunting or fishing. Awareness of the Park remains low and the lack of a functioning example to demonstrate the concept of protection for nature makes it difficult to convey. Priority should be given to establish a well-funded, long-term program to raise awareness of the importance of 3BNP. A first step will be to identify the target audience for such intervention and to design a monitoring framework that measures changes on stakeholders' attitudes on specific issues, such as management of water sources (lagoons, streams, and wetlands in general), grazing of free-range livestock, and land-use planning. Only then should efforts be placed on developing reintroduction and management plans for individual terrestrial species.

IV. Freshwater Fauna

The Three Bays National Park (3BNP) contains several types of natural fresh and brackish water ecosystems: rivers, seasonal streams, a large brackish lagoon, and associated wetlands. Two major rivers ─ the Grande Rivière du Nord and Rivière Trou du Nord ─ discharge to marine waters, and therefore are estuarine at their mouths. Each ecosystem also consists of different micro-habitat types such as pools, riffles, vegetated bottoms, etc. (Figure 48). Such complex systems are typical of the islands in the Caribbean, and some have been well-studied with respect to at least some components of their faunas.

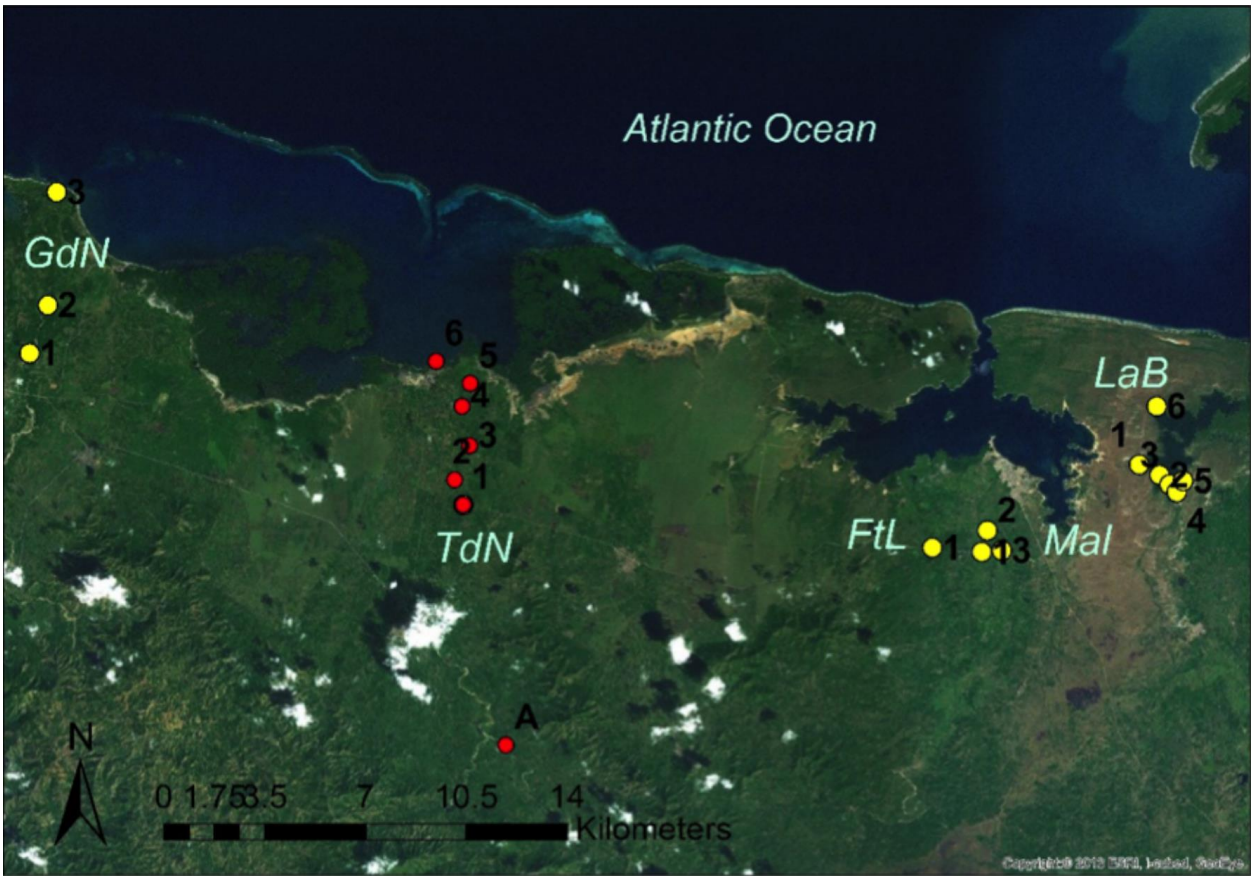

Figure 48. Fresh, brackish, and estuarine fish and invertebrate sampling sites visited in June 2015 in Rivière Trou du Nord (six TdN sites) and August 2015 in the Grande Rivière du Nord (three GdN sites), a small stream near Ft. Liberté (FtL site), a small stream near Malfety (three Mal sites), and in the brackish Lagon aux Boeufs (six LaB sites). See Appendix 9 for site coordinates and other information.

This chapter describes the results of a study of the fauna in major types of fresh and brackish water habitats within 3BNP and an assessment of the fauna in the context of existing literature on Haiti and the region. Even though several studies over the past 20 years have underlined the heritage value of this area, no inventory of biodiversity exists. This study was undertaken with the intention of better defining park resources, facilitating strategic planning, and mitigating the impacts of a new industrial park on the natural resources.

Details on the sampling methodology and materials can be found in Appendix 1.

Description of Freshwater Habitats

A diversity of freshwater habitats occur within 3BNP including permanent rivers (Grande Rivière du Nord and Rivière Trou du Nord; labeled GdN and TdN in figures and tables), small seasonal streams near the towns of Fort Liberté (FtL) and Malfety (Mal), and associated wetlands. Reduced-salinity habitats were sampled at several sites in the Lagon aux Boeufs (LaB), a permanently brackish lagoon, and in estuarine waters at the mouths of the two river systems (TdN 6 in Figure 49 and GdN 3 in Figure 50). For a

habitat-based analysis, the sites were grouped following the IUCN Habitat Classification Scheme, version 3.1.

- *Permanent river* (*IUCN Wetlands Type 5.1*). A total of nine (9) sites were sampled in the two major rivers, Trou du Nord and Grande du Nord (TdN and GdN sites in Figure 48).
- *Seasonal/intermittent stream* (*IUCN Wetlands Type 5.2*). A total of three (3) sites were sampled in small, seasonal streams (Mal and FtL sites in Figure 48).
- *Permanent saline, brackish lake* (*IUCN Wetlands Type 5.14*) (LaB sites in Figure 48)
- *Estuary* (*IUCN Marine Neritic Type 9.10*) (TdN6 and GdN3 in Figure 48)

Figure 49. Photographs of sites sampled in the Riviére Trou du Nord in June 2015.

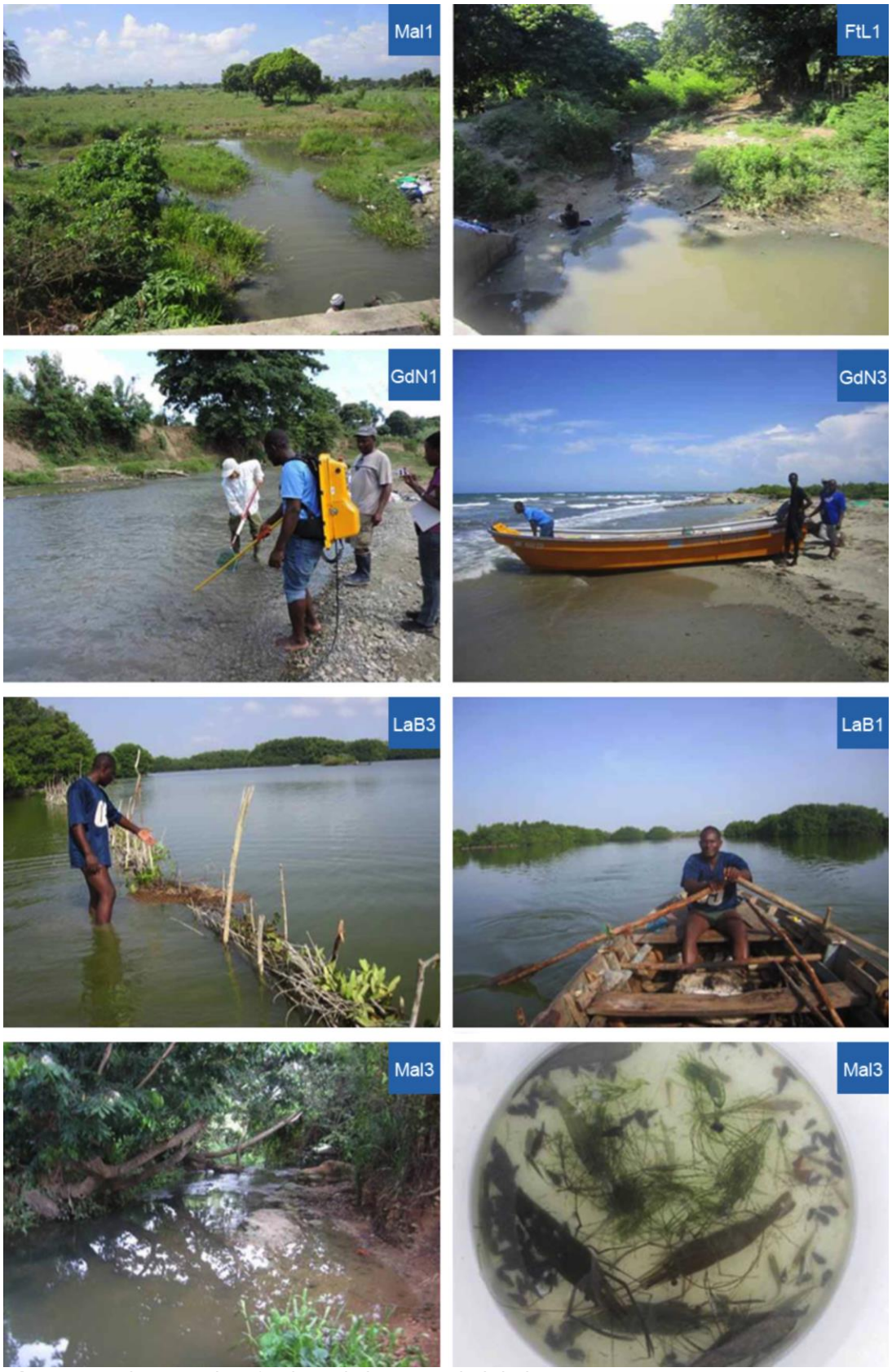

Figure 50. Photographs of selected sites sampled during August 2015.

Freshwater species diversity: A total of fifty-nine (59) animal taxa were collected or observed: twenty-two (22) fish and thirty-seven (37) invertebrates (Appendix 11). The fish taxa consisted of twenty (20) native species, one (1) invasive species, and one (1) endemic species. The major fish taxa represented were poeciliids (livebearers; 4 species) and eleotrids (sleepers; 3 species). Among the invertebrates, there were (34) native species, three (3) invasives, and no endemic species. The major invertebrate taxa represented were decapod crustaceans (11 shrimp species and 7 crab species) and mollusks (mainly gastropods; 9 species). Additionally, five (5) insect species and one (1) polychaete annelid species were collected.

The sampling effort (number of sites sampled) varied widely among the four habitats: nine (9) in permanent rivers, three (3) in seasonal streams, and two (2) in estuarine waters. Five (5) sites were sampled in the permanently brackish Lagon aux Boeufs (LaB), but the samples were consolidated in the field, as discussed above. Thus, the five LaB sites shown in Figure 48 were reduced to one site in the final analysis. Although quantitative analysis of faunal abundance and diversity in 3BNP was limited by the qualitative sampling methods employed during our survey, there were several clear trends among the four major habitat types in species composition and relative abundances (Appendix 12).

The highest diversity was found associated with either the estuarine river mouths or from the freshwater portions of permanent riverine habitat. A total of twelve (12) fish species and seventeen (17) invertebrate species were collected from Estuarine habitat and ten (10) fish species and eighteen (18) invertebrate species were collected from the freshwater portions of the two rivers (permanent river habitat) (Appendix 12). In comparison, seasonal streams and brackish lagoons contained significantly lower diversity. Only six (6) fish species and nine (9) invertebrate species were collected from Seasonal Stream habitat, and seven (7) fish species and eight (8) invertebrate species from the permanent brackish habitat.

Eight species of fish collected from the rivers warrant discussion (Figure 51). The most commonly encountered fish at the permanent river sites were the smallscaled spinycheek sleeper (*Eleotris perniger*) collected at 6 of the 7 river sites, and the poeciliid Hispaniolan gambusia (*Gambusia hispaniolae*) collected at 5 sites (Appendix 11). The sleeper family (Eleotridae) was also represented in the rivers by two additional species: *Eleotris amblyopsis* and *Dormitator maculatus*. Two additional poeciliids were found in the rivers: *Limia tridens* and *Limia pauciradiata*. All six species are native to the region; *L. tridens* has been reported only from Haiti and the Dominican Republic, and *L. pauciradiata* is endemic to Haiti. The invasive Mozambique tilapia (*Oreochromis mossambicus*) was also found at two of the river sites, one seasonal stream site, and in the brackish Lagon aux Boeufs (Appendix 11), indicating that it is probably well established and widely distributed in 3BNP. Another commonly occurring fish was the highly migratory as well as socially and economically important American eel (*Anguilla rostrata*), collected at three river sites.

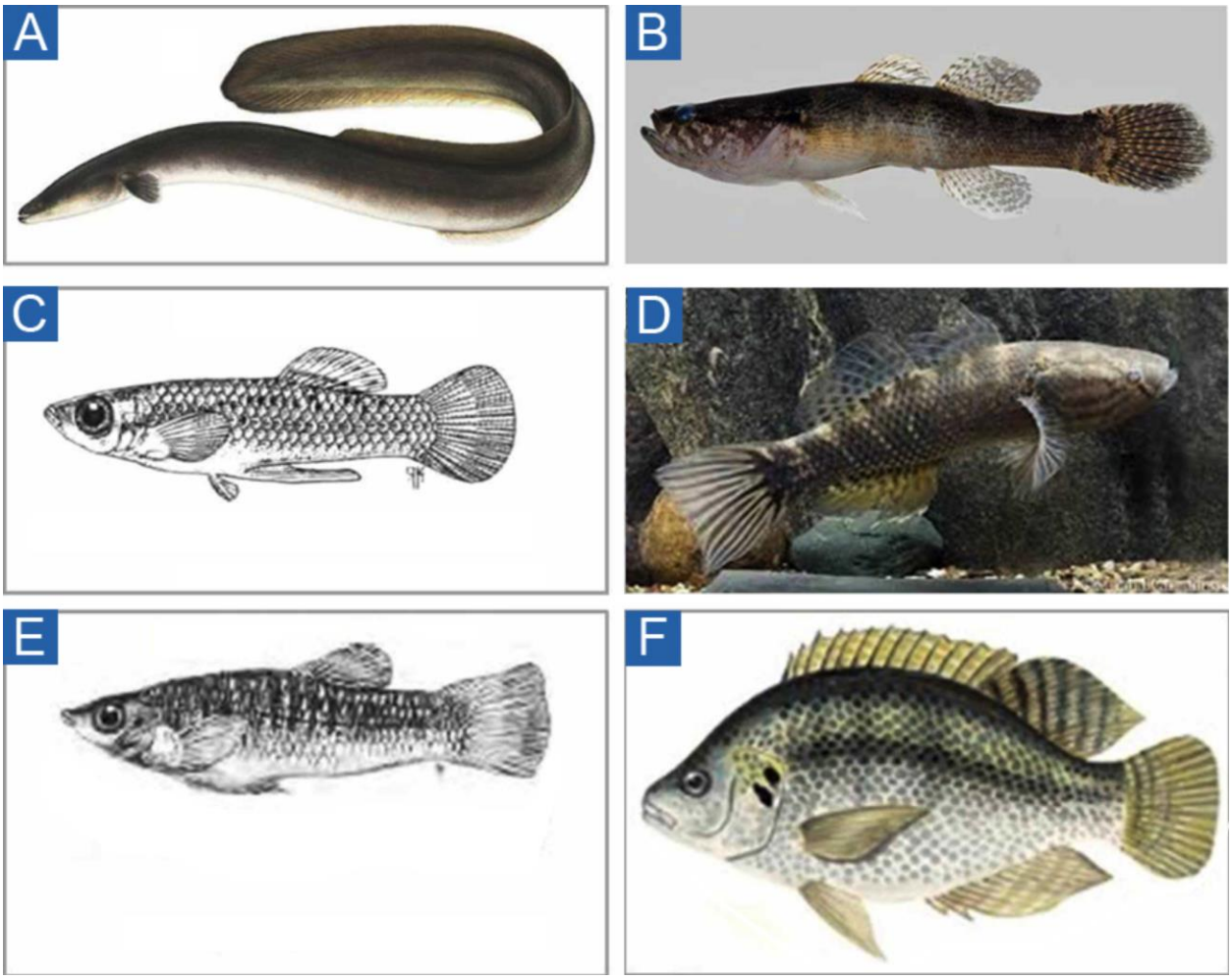

Figure 51. Ecologically and/or socioeconomically important species of fish: **(a)** American eel, *Anguilla rostrata* (from: http://www.dierenafbeeldingen.com), **(b)** smallscaled spinycheek sleeper, *Eleotris perniger* (from: http://biogeodb.stri.si.edu/caribbean/en/pages/random/9528), **(c)** Hipaniolan gambusia, *Gambusia hispaniola* (from: Lee et al. 1983), **(d)** fat sleeper, *Dormitator maculates* (from: www.segrestfarms.com), **(e)** few-rayed limia, *Limia pauciradiata* (from: Lee et al. 1983). **(f)** Mozambique tilapia, *Oreochromis mossambicus* (from: www.waiwiki.org.)

Figure 51-B. Few-rayed limia, *Limia pauciradiata* from Trou du Nord River

Three species of invertebrates collected from the rivers are particularly noteworthy (Figure 51). The most commonly encountered invertebrates at the permanent river sites were the river prawn (*Macrobrachium crenulatum*) found at all seven (7) sites, the yellow rhino shrimp (*Xiphocaris elongata*) found at 6 sites, and a small snail *Tarebia* (now *Thiara*) *granifera* found at five (5) sites (Appendix 12). Both shrimp species were abundant at some sites, and are thus likely a major component of the food web. River prawns (three species of *Macrobrachium* were collected in the overall study) were also observed among the catch of several local fishermen in the Riviére Trou du Nord. The widely distributed and commercially important blue land crab (*Cardisoma guanhumi*) was found at site TdN 5, where its burrows were common along the edges of the river and associated wetlands.

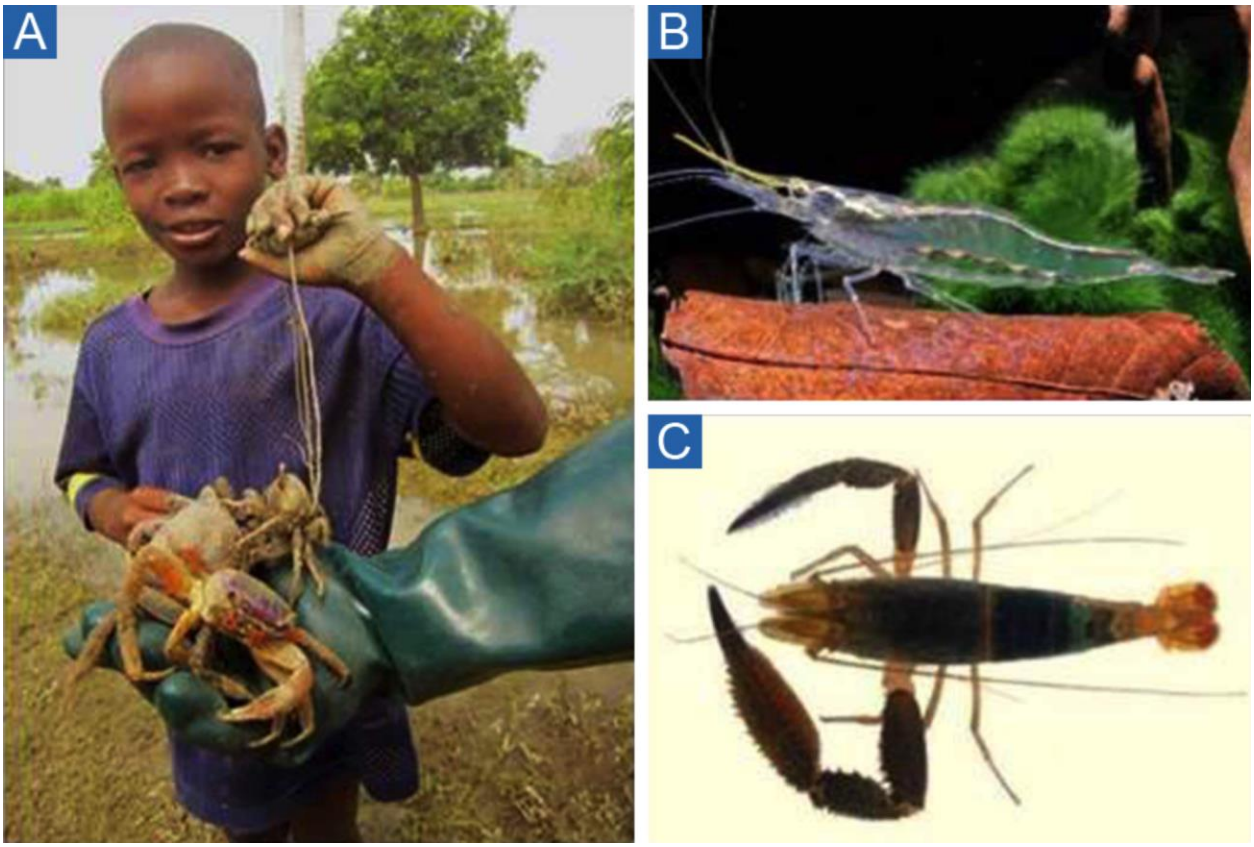

Figure 52. Ecologically and/or socioeconomically important invertebrates: **(a)** land crab (*Gecarcinus* sp.), **(b)** rhino shrimp (*Xiphocaris elongata*) (from: www.zoologischemededelingen.nl/85/nr02/a01), and **(c)** river prawn (*Macrobrachium crenulatum)* (from: García-Guerrero et al. 2013).

The seasonal stream habitat was represented by collections from two small streams near the eastern border of 3BNP near the towns of Malfety (Mal) and Fort Liberté (FtL) (Figure 48). The extent of the range of water levels in these streams is substantial, as mentioned in the Introduction, and during the August sampling, FtL sites were little more than isolated shallow pools with very little water flow between them. The two most common fish were the same as in the permanent rivers: *Eleotris perniger* and *Gambusia hispaniolae*, further evidence of the widespread occurrence and ecological importance of these species. Three invertebrates were dominant in the seasonal streams: two small snails *Tarebia* (now *Thiara*) *granifera* and *Melanoides tuberculata*, and the apple snail, *Pomacea* sp. (Figure 53). Apple snails were only found in the seasonal streams, but *T. granifera* was found at one site in both permanent rivers (Appendix 11), and it was abundant at most sites where it was collected.

The permanent brackish lagoonal habitat (all sites in Lagon aux Boeufs; LaB) could not be assessed by taxonomic ranking because the specimens from all sites were combined, as discussed in the Methods section. Nonetheless, fish and invertebrate species typical of low-salinity waters were collected, and some relevant comments can be made on species composition of the fish and invertebrate communities as well as general environmental conditions (Figure 54). The catches of several local fishermen were inspected and most of the species listed in Appendix 11 and 12 were purchased

from their catches. The invasive Mozambique tilapia (*Oreochromis mossambicus*) appeared to be the most commonly captured species, and most were small specimens less than ~15cm total length. Snook (*Centropomus* sp.), sleepers (*D. maculates* and *E. perniger*), mullet (*Mugil* sp.), river prawns (probably mostly *Macrobrachium acanthurus*), and penaeid shrimp (*Penaeus* sp.) were also among their catches. The lagoon is heavily fished using gillnets, beach seines, and traps. Fish kills reportedly occur on occasion, probably a result of its eutrophic condition; the waters were a deep green color and very turbid in all areas surveyed during August 2015 (Figure 54). However, the water reportedly becomes clear at times and there is a strong seasonality to water levels, as well as the fish that are caught. All five sites visited had soft sediments, ranging from soft mud to firm sand/shell hash mixtures. The lagoon is surrounded by mangroves and there were no obvious sources of excess nutrients, other than feral goats and cattle, which were observed in several areas (Figure 54).

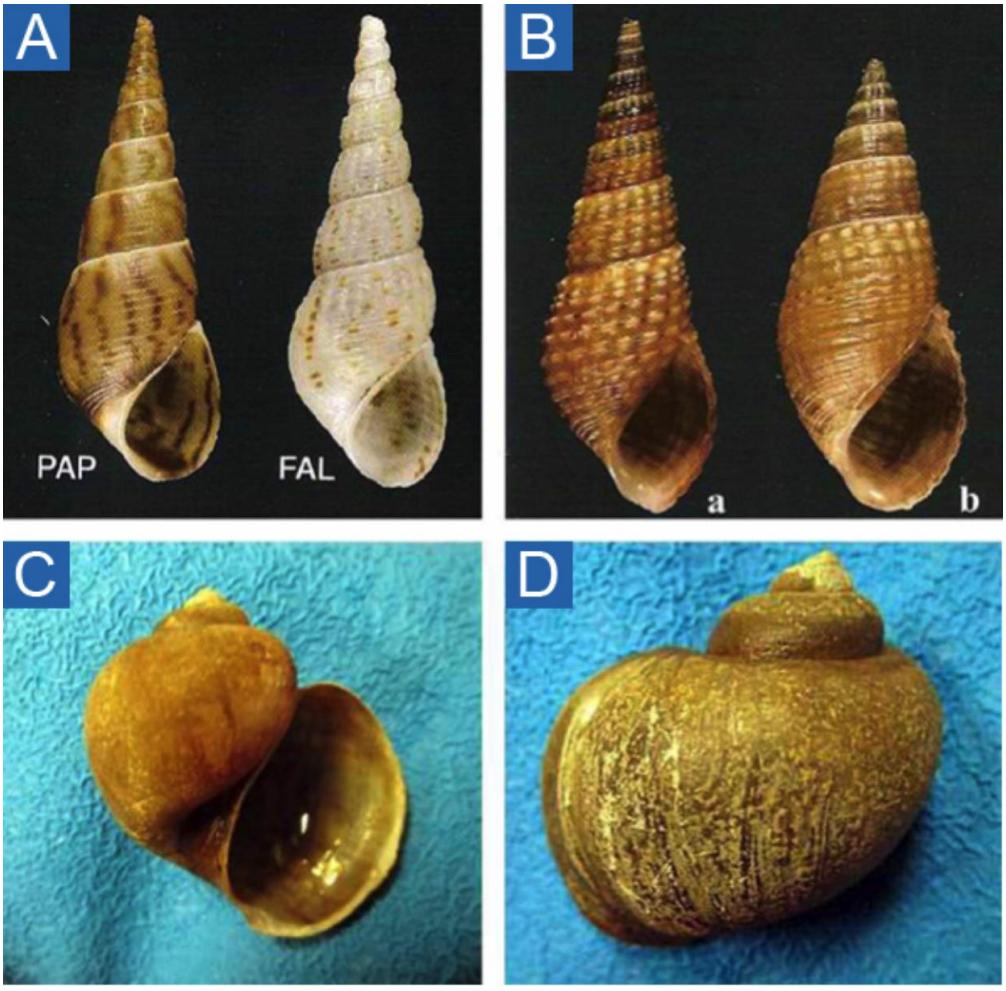

Figure 53. Invertebrates with public health significance: **(a)** fawn melania (*Melanoides tuberculate*), **(b)** quilted melania (*Tarebia granifera*) ((a) and (b) from: Pointier 2008), and **(c)** and **(d)** apple snail (*Pomacea* sp.).

Estuarine waters were only extensively sampled at the mouth of Riviére Trou du Nord. High winds/waves and deeper waters (>2m) at the more open mouth of the Grande Rivière du Nord limited our ability to sample the area estensively with our gear. We did collect fish from fisherman that used a beach seine just off the mouth of the TDN river; these fish included the following species: parrotfish (*Sparisoma* sp.), balao (*Hemiramphus balao*), snook (*Centropomus* sp.), unidentified mojarra (Gerreidae), mullet (*Mugil* sp.), sea bream (*Archosargus rhomboidalis*), unidentified jack (Carangidae), unidentified flounder (Bothidae), and an unidentified goby (Gobiidae). All were small individuals, mostly less than ~20cm length, indicating the catch largely consisted of juveniles.

Figure 54. Lagon aux Boeufs: **(a)** and **(b)** catches from fishermen, **(c)** small skiffs used by fishermen in the lagoon, **(d)** fishermen deploying net, **(e)** feral goats along shoreline, **(f)** net set adjacent to mangrove-lined shore. Note highly turbid green waters in (e) and (f) indicating eutrophic state of the lagoon.

The most common invertebrate species at the estuarine sites were taxa typical of that habitat. Penaeid shrimp (*Penaeus* sp.) and the swimming crab (*Callinectes* sp.) were collected in the seagrasses. The infaunal cross-rayed venus bivalve, (*Chione cancellata*) was common in the soft sediments. Mangrove oysters (*Crossostrea rhizophorae*) and pearl oysters (*Pinctada* sp.) were common among the mangrove prop

roots (Figure 55). The mangrove crab (*Aratus pisonii*) and fiddler crabs (*Uca* sp.) were abundant in the soft sediments among the mangroves, and the ghost crab (*Ocypode* sp.) was observed along the sandy beaches.

Interestingly, we found little ovelap between species collected at both of the estuarine sites. Other than the differences in sampling effort noted above, this is also probably due to the general environmental differences between the two river mouths. The mouth of the GRDN is more open with a sand beach and steep river banks covered with terrestrial grasses. The higher freshwater flows and sediment depostion coupled with greater wave exposure produces shifting sandbars that limit mangrove or seagrass colonization. In contrast, the TDN river mouth has lower overall freshwater flows and is divided into several smaller openings that are lined by mangroves and surrounded by extensive shallow seagrass flats (Figure 55).

The freshwater systems of 3BNP are all characterized by the highly dynamic nature of water flow in rivers and streams. The effects of a recent flood when the Riviére Trou du Nord had overflowed its banks (near TdN 4; see Figure 48) and changed coursewere observed, resulting in a closed rivermouth filled in by sediments and debris, and a “new” mouth consisting of several small discharge channels (Figure 55). River channels in many areas may be expected to migrate to some extent during high water flow conditions. However, the extensive deforestation of the uplands in the region likely exacerbates the effects of natural fluctuations in river flows.

Comparative General Ecology: The general patterns of animal species richness among the four habitat types reflected expected trends: greatest in the permanent (freshwater) river and estuarine habitats and much reduced in the seasonal stream and permanent brackish habitats (Appendix 12). The classic overall biodiversity pattern for surface waters spanning a complete fresh/brackish/estuarine salinity gradient is a general increase in taxonomic richness proceeding downstream in freshwater streams and rivers, then rapid loss of taxa in low-salinity (<5ppt) waters, followed by increasing species richness in estuarine areas to maximal species richness in fully marine waters (Remane and Schlieper 1971). Although the overall pattern varies widely among the different types of surface waters and major taxonomic groups (Ward 1998, Williams et al. 2004, Allen and Castillo 2007, Moss 2010), the classic pattern is in large measure a response to changes in salinity and the number of species adapted to each salinity regime. Thus, when considered collectively by major habitat types (Appendix 12) the overall distribution of animal species in the surface waters of 3BNP followed expected patterns.

Although this study was limited in scope, particularly geographically, some comparisons of the species richness of the fish and invertebrates in 3BNP can be qualitatively made to nearby islands such as Cuba and Puerto Rico that have been studiedmore in depth. For example, in their brief review of the literature, Lara et al. (2010) state that 57 species of freshwater fish have been reported from Cuba. Neal et al. (2009) list 82 species of freshwater fish that occur in Puerto Rico. Twenty-two (22) fish species were collected in all four habitats in 3BNP during this survey, including estuarine waters which likely included species not considered in other “freshwater” studies. Even so, the

sampling indicates that the surface waters of 3BNP contains a substantial percentage of the total fish species likely to occur in this region of Haiti.

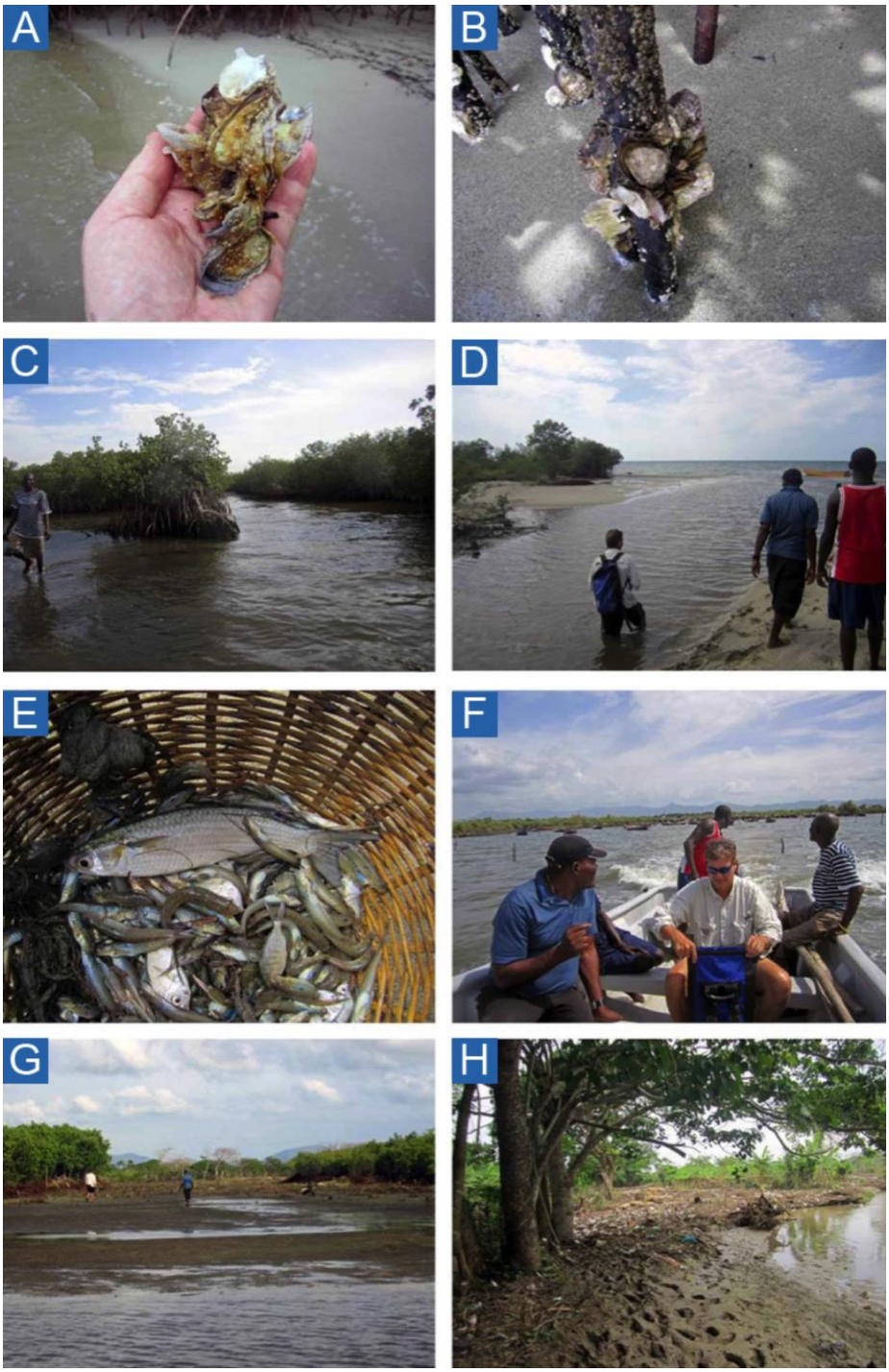

Figure 55. Estuarine habitats at mouth of Rivière Trou du Nord: **(a)** clump of mangrove oysters (*Crassostrea rhizophorae*), **(b)** mangrove oysters and pearl oysters (*Pinctada* sp.) attached to mangrove prop root, **(c)** and **(d)** two of several newly formed small discharge channels, **(e)** catch of local fisherman, **(f)** motoring to site TdN 6 (Caracol fishing village in the background), **(g)** historical mouth of the Rivière Trou du Nord closed by

debris and sediments during recent flood, **(h)** site TdN 4 where Rivière Trou du Nord had recently changed course; original debris-filled channel on left, new channel on right.

Pointier et al. (2005) and Perera and Valderrama (2011) describe forty-two (42) species of freshwater mollusks in Cuba, thirty-three (33) gastropods and nine (9) bivalves. This is compared to eight (8) gastropods and one (1) bivalve collected in the fresh and brackish waters of 3BNP (Appendix 11). Perez-Reyes (2015) reported eighteen (18) species of freshwater decapods crustaceans (crabs and shrimp) from Cuba; eleven (11) species were found in 3BNP. Hart (1961) reported twelve (12) species of freshwater shrimp from Jamaica, compared to the collection of ten (10) species in 3BNP. Thus, based on our preliminary sampling of the surface waters of 3BNP, we may conclude that freshwater invertebrate fauna is comparably diverse as adjacent greater antillian islands. This is a surprising result considering the high level of human uses that the rivers and streams of 3BNP currrently receive.

Species of Special Concern: Several fish and invertebrate species warrant further discussion due to their ecological, socioeconomic, and/or public health significance (Figures 51 and 52). Ecological importance can be inferred from relative abundance with the more abundant taxa likely important with respect to food web dynamics, energy flow, and other processes. The most commonly encountered fish species collected from all four habitat types was the eleotrid smallscaled spinycheek sleeper (*Eleotris perniger*), a moderate size fish with a maximum length of ~25cm (Figure 51b). It is native to and distributed widely throughout the Caribbean, ranging from marine to freshwater and occurring at high densities in some areas (Pezold et al. 2015, also see Pezold and Cage 2001 for an extensive review of the taxonomic status of the six species in the genus in the western Atlantic). It is an omnivore, and larger specimens are harvested as a food item in some areas, including 3BNP as it was observed in the catch of local fishers in the Riviére Trou du Nord. *Eleotris perniger* is IUCN Red-Listed as “least concern” but is potentially threatened by habitat loss associated with coastal development, including loss of mangroves and dams that block migration.

The poeciliid Hispaniolan gambusia (*Gambusia hispaniolae*) was also collected from most of the river and seasonal stream sites. *G. hispaniolae* is only known from central and southern Haiti and the Dominican Republic (Lee et al. 1983), and it apparently has not been assessed for the IUCN Red List. Thus, while not endemic to Haiti, it has a very restricted range. *G. hispaniolae* is a small fish (maximum length ~5cm), likely a significant prey item for larger fish, and probably an omnivore as are most species in the genus. Otherwise, little is known of its ecology.

Two additional poeciliids that should be noted and were found only in the rivers: trident limia (*Limia tridens*) and few-rayed limia (*Limia pauciradiata*; Figure 51e). Both species are native to the region, and *L. pauciradiata* is endemic to Haiti and previously only reported in the published literature from the Grande Rivière du Nord (Rivas 1980, Lee et al. 1983, Chambers 1987). However, it was collected only from the Riviére Trou du Nord, same as Weiner et al. (2013). It also should be noted that *L. pauciradiata* was *not* collected from any of the three sites sampled in the Grand Rivière du Nord during the

present study. The genus *Limia* consists of at least 20 described species and most occur only or mainly in Haiti and/or the Dominican Republic (Rivas 1980, Lee et al. 1983, Lucinda 2003). There is some dispute regarding the taxonomic status of the genus, and most *Limia* species have not been well studied since their original descriptions (Cohen et al. 2015). Thus, these two species warrant additional studies to determine the extent of their distributions in 3BNP as well as how various potential threats might affect their distribution and abundance.

Two final important fish species are the American eel (*Anguilla rostrata*; Fig. 52a) and the Mozambique tilapia (*Oreochromis mossambicus*; Figure 51f), both important socioeconomically and ecologically. The highly migratory American eel was found at 4 river sites including fresh and estuarine waters. Thus, it is likely widespread in the surface waters of 3BNP, and it represents a potentially important fishery species. Due in part to its migratory movements that take it from the upper reaches of small freshwater streams to the mid Atlantic, it faces many challenges in addition to human harvest (http://fishbase.org/summary/Anguilla-rostrata.html). Wiener et al. (2013) stated that local fishermen report that its numbers have been in decline in 3BNP. Mozambique tilapia also is widespread in 3BNP based on discussions with local fishers and personal observations of several catches. This species was collected in rivers, streams, and the brackish Lagon aux Boeufs (Appendix 12). It is a highly invasive species now established in many areas, in large measure due to its widespread use in aquaculture. It can reportedly harm native fish populations through competition for food and nesting space, as well as by directly consuming small fish (http://fishbase.org/summary/Oreochromis-mossambicus.html).

There are also several ecologically and socioeconomically significant invertebrate species, which may have public health importance. The most commonly encountered invertebrates at the permanent river sites were the river prawn (*Macrobrachium crenulatum*; Figure 52c), the yellow rhino shrimp (*Xiphocaris elongate*; Figure 52b), and the small snail *Tarebia granifera*. Both shrimp species were abundant at some sites, and are thus likely a major component of the food web. River prawns (three species of *Macrobrachium* were collected in the overall study) were also observed among the catch of local fishermen in the Riviére Trou du Nord and the brackish Lagon aux Boeufs. Several *Macrobrachium* species are the basis of important aquaculture industries globally, and there is an extensive literature on this aspect of several of the species in the genus (New et al. 2010). In 3BNP, it was observed in the catches of local fishermen. Ecologically, river prawns have been studied on other islands in the region (Hart 1961, Crowl and Covich 1994, Smith and Wier 1999, Torati et al. 2011, Perez-Reyes 2015). Chace and Hobbs (1969) summarizes much of what was known from the early studies and provide useful personal observations on the ecology of many of the species described. Recent books (e.g. New et al. 2010) summarize the basic biology and ecological information on some species. Briefly, *Macrobrachium* spp. occur in habitats ranging from small mountain streams to large estuarine river mouths in the Caribbean and are very abundant in many areas. Many species are more active at night than during the day and some display complex behaviors. Most species are omnivorous, as well as effective predators on any smaller animals they can capture.

Taxonomic dominants in the seasonal streams included the small snails *Melanoides tuberculata* (Figure 53a) and *Tarebia granifera* (Figure 53b) which also occurred in other habitat types, and apple snails *Pomacea* sp. (Figures 53c and 53d) which were largely restricted to the seasonal streams. *T. granifera* and *M. tuberculata* are invasive species now occurring throughout the Caribbean in a wide range of freshwater habitats (Pointier et al. 2005, Pointier 2008). Major concerns are its ability to displace native species and its role as an intermediate host of trematodes that parasitize mammals (Pointier et al. 2005, McKoy et al. 2011). Thus, these species warrant further study because of their potential public health significance. The genus *Pomacea* includes three species that potentially occur in Haiti, and their morphological features are quite variable (Pointier et al. 2005). They occur in a wide range of freshwater habitats and some can survive extended periods of desiccation by burying into the sediments, explaining their most common occurrence in the seasonal streams.

Comparisons to Previous Studies

Comparisons of these findings to the total species richness reported for all of Haiti can be made for freshwater fish. A search of FishBase indicates that 40 freshwater fish have been reported in the published literature, including eleven (11) endemic species and four (4) invasives. Directly comparing the FishBase list to this study's findings is difficult because of the inclusion of an apparently very select group of estuarine species in FishBase. Despite this, a total of twenty-two (22) fish species were collected (Appendices 11 and 12), compared to the 40 species in FishBase. A major difference between this study's list and FishBase is in the much greater number of species of *Limia*, a genus that is largely restricted to Haiti and the Dominican Republic, as discussed above. However, when considering the fact that these findings were made by a "rapid assessment," it reasonable to conclude that the freshwater fish fauna in 3BNP is relatively diverse, perhaps surprisingly so when considering the level of human uses of the Park's surface waters and the potential threats to biodiversity in general.

For 3BNP, the only comparable study found is the *Rapid ecological baseline assessment of the lower Trou du Nord River* by Weiner et al. (2013). The same six sites in the Riviére Trou du Nord which were sampled by Weiner were also sampled in this study (TdN 1-6) in June, and re-sampled TdN 1 in August. However, the current study used an electrofisher which likely more effectively sampled some taxa, such as fish, compared to the nets used by Weiner et al. Thus, this study was expected to yield additional species, and it did. Weiner et al. reported a total of five (5) fish species and eleven (11) invertebrates from the five freshwater sites (1-5), compared to seven (7) fish species and twelve (12) invertebrate species in the current survey. Overall, these data suggest that the species richness of the animal fauna of the freshwater portions of the Riviére Trou du Nord has been reasonably well characterized qualitatively. However, there were substantial differences between the two studies in the taxonomic composition of the fauna, particularly the freshwater invertebrates. For example, Weiner et al. report the commercial peneid shrimp *Penaeus* sp. from all of their sites, but this survey only collected it from TdN 6 at the mouth of the river. Additionally, they reported

an unidentified shrimp from all five sites, but did not list any *Macrobrachium* species. Thus, it seems likely that their unidentified shrimp were one or more species of *Macrobrachium*; This study found *M. crenulation* to be common at all five freshwater sites, and also found two species of shrimp (*Xiphocaris elongata* and *Potimirim mexicana*) not reported by Weiner et al. and others.

This survey and Weiner et al. (2013) only sampled one estuarine site. They listed a total of five (5) fish species and five (5) invertebrate species compared to the current survey's twelve (12) fish species and twelve (12) invertebrates. The current fish list mostly consists of species purchased from a local fisher (see above), thus likely explaining the additional fish species richness. However, most of the invertebrates were collected with dipnets. Together, the two studies probably provide a useful qualitative characterization of many of the estuarine animal species that occur in 3BNP.

Figure 56. Examples of human uses of the rivers and streams: **(a)** clothes washing in GdN, **(b)** fishermen catch in TdN, **(c)** washing buses in TdN, **(d)** fence trap set in cove in LaB, **(e)** clothes washing in the GdN, and **(f)** fishermen deploying small-mesh nets in TdN.

Threats to Freshwater Fauna

Threats to the freshwater fauna of 3BNP are primarily associated with invaisive species, overfishing, reductions or alterations in flows associated with dams or diversions, the Caracol industrial park (PIC), and potential expansion of aquaculture (Kramer et al., 2016). Other threats that influence these already impacted riparian systetms include land-based sources of pollution, sand and gold mining, and charcoal production.

Assessing the threat impacts to freshwater biodiversity patterns within 3BNP was not possible because essentially all areas sampled have already been heavily affected by human activities (Figure 55). The surface waters in 3BNP are regularly used collectively for laundering of clothes, washing of vehicles, sand mining, agricultural irrigation, and harvest of fish and invertebrates for food (Grizzle personal observations, Weiner et al. 2013, see Miller 2016 for fisheries assessment in 3BNP). The environmental effects of these activities on species richness may be substantial, though little data appears to exist (see further discussion below of Weiner et al. 2013).

Conclusion

The freshwater biodiversity of 3BNP is composed of a fairly rich array of native fish and invertebrates despite a history of widespread human activities in and around the water bodies causing them to be degraded. Areas of high freshwater importance based on this survey include the Trou du Nord river system, Lagon aux Boeufs, and estuarine mouths of all the major freshwater bodies. The sensitivity of remaining freshwater fauna to changes in water quantity and quality are well known. These processes should be highlighted and efforts made to control and improve them within the management plan. More detailed investigations of all the freshwater bodies and their fauna are also warranted and will help inform future management that will ideally make 3BNP a prime example of a functioning and healthy freshwater ecosystem.

V. Marine Benthic Invertebrates

Marine communities have been dramatically changing throughout the Caribbean over the past three decades. The magnitude of change is difficult to assess due to the lack of baseline and long-term data in the region. Haiti, part of the Greater Antilles region, is one of the countries which lacks baseline data of marine ecosystems. The few qualitative and quantitative assessments conducted in Haiti have focused only on coral reef habitats, so that information is lacking for seagrass and mangrove communities.

The marine ecosystems of 3BNP have high ecological and economic importance and, therefore, are a high priority for resource conservation and management. Even though 3BNP is considered an area of high diversity, there has not been an official species inventory conducted within the Park boundaries. There is data lacking on the presence of many important sessile-benthic organisms, such as sponges and octocorals. Moreover, there have only been coral reef surveys conducted within 3BNP, other marine ecosystems such as seagrass and mangroves have not been surveyed for benthic organisms.

In this chapter we provide an overview of the sessile- and motile-benthic invertebrates that occur within 3BNP. The marine areas assessed during our fieldwork included the principal benthic habitats of the Park (e.g. coral reefs, seagrass and mangroves) and distinct coral reef habitats (e.g. reef crest, patch reef and *Orbicella* reef). The assessments were conducted during two sampling periods, early June and late August 2015.

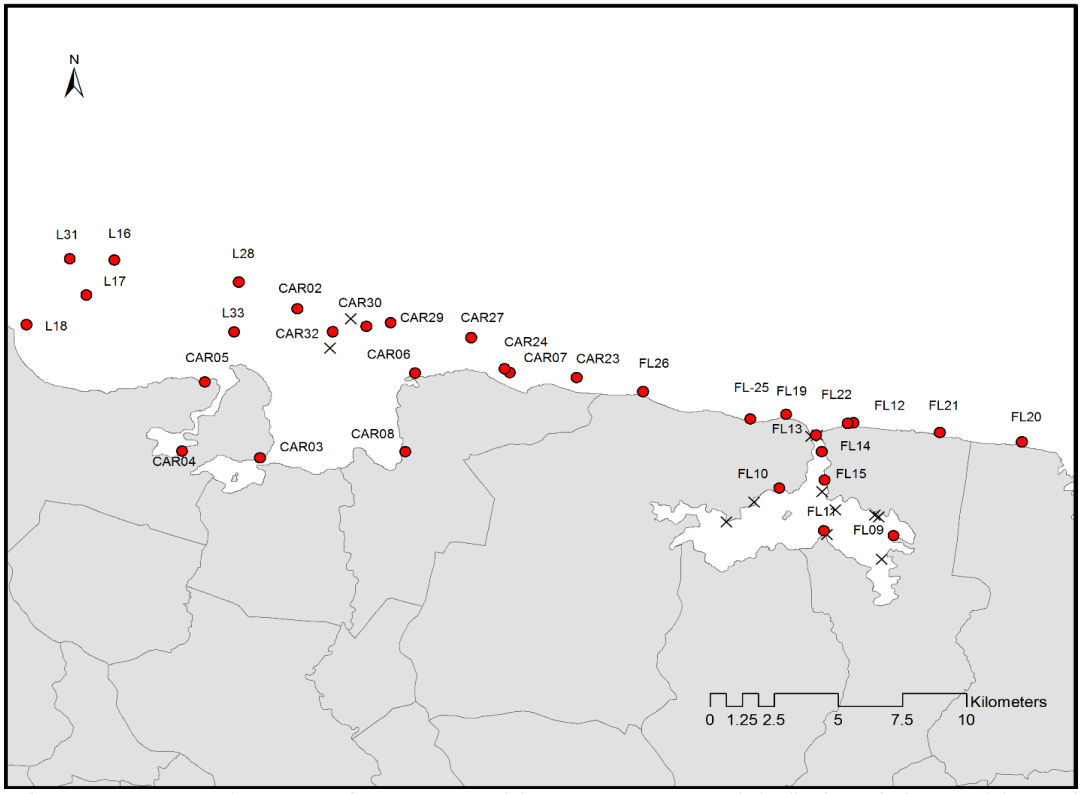

Figure 57. Map of 3BNP. Sites surveyed in June 2015 are labelled and denoted by red circles, while Reef Check sites are labelled as a black X.

Description of Marine Benthic Habitats

3BNP contains a total of 10,657 hectares of shallow water (<30m) areas that contain the vast majority of the marine species diversity (Figure 10, Table 4). The principal benthic habitats investigated during the two field sessions included coral reefs, seagrasses, and mangroves.

Coral reefs: Within coral habitat, we further distinguished a number of different coral reef zones and habitats including reef crest, backreef, reef wall, patch reef, and deep forereef. Deep fore reef contained a number of different morphological types: *Orbicella* dominated reef with the highest structural complexity, spur and groove reef with 2-4 meter high coral ridges separated by sand channels, and flat hardground with low topographiic relief that was dominated by gorgonians (termed gorgonian plain). Deep forereef sub-type varied spatialy along the platform shelf edge in response to differences in geomorphology and wave energy. *Orbicella* reefs were found predominatly close to Fort Liberté, while spur and groove habitats were typical in front of Caracol Bay. Forereef around Limonade were mostly hardgrounds which are influenced by freshwater discharges from the Grande Rivier du Nord and Cap Hatian rivers.

Seagrasses: Extensive seagrass beds were observed within Caracol Bay area and Fort Liberté Bay. Light availability and unstable sediment are possible factors limiting seagrass beds from developing on the far West of the park, close to Limonade. In

Caracol, density and blade length of seagrass did vary from inshore to offshore. Seagrass density (Braun Blanquet 5) and blade length (>70 cm) were greater inshore, especially at sites CAR03 and CAR08. This is indicative of higher nutrients and less water movement at these areas, compared to more exposed, offshore seagrass habitats (CAR05 and CAR06). At inshore sites, there was limited space for benthic invertebrate to colonize, given the density and blade length. Therefore, there was a higher abundance and diversity of benthic invertebrates at more exposed, offshore seagrass habitats in Caracol.

Mangroves: As stated previously, the mangrove of Caracol Bay is the largest and most complex of the mangrove systems within 3BNP. Land cover mapping estimates provided by the land cover mapping undertaken by The Nature Conservancy (TNC) indicates that Caracol has 4,030ha of mangrove. There are extensive mangrove channels within the Caracol region. Limited mangrove development was observed along the coastline in Fort Liberté bay. Given the density and root mass, surface area of mangrove roots for sessile benthic invertebrates to colonize was much greater in Caracol than in Fort Liberté. However, there was little colonization of encrusting organisms on the mangrove roots in Caracol, specifically mangrove oysters (Crassostrea gasar) Poor water quality (water turbidity, contamination, etc.) can be factors affecting the colonization of marine organisms in Caracol.

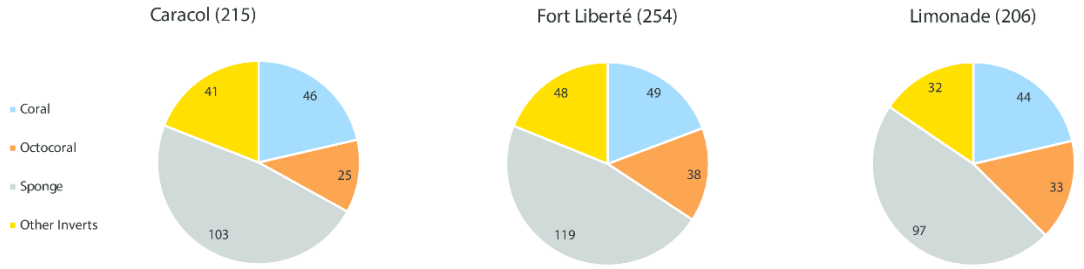

Figure 58. Pie diagrams of motile- and sessile-benthic invertebrate richness at Caracol, Fort Liberté, and Limonade in 3BNP. Total richness for each area is located in parentheses.

Marine benthic species diversity: A total of 307 sessile- and motile-benthic organisms were identified within the marine waters of 3BNP (Appendices 14-16). Sponge richness was the highest (149 species), followed by corals (51 species), octocorals (43 species), and echinoderms (21 species). Coral reef habitats, especially forereefs and reef crests, displayed the highest species richness. Seagrass habitats had the second highest overall species richness, followed by mangroves. When compared across the different spatial zones of the Park (Figure 9), the highest species richness of the benthic organisms was observed in Fort Liberté (Zone 5) with a total of 254 species, followed by Caracol (Zone 3) with 215 species, and Limonade (Zone 1) with 206 species (Figure 58). It is important to note that the total species richness found around Limonade was similar to Caracol despite only five coral reef sites were surveyed in Limonade compared to 12 sites in Caracol that covered included seagrass and mangroves haitats. The highest species richness we encountered was at ste FL-12 in Fort Liberté with 151

species identified, followed by another Fort Liberté site (FL-13) with 143 species. The lowest species richness was measured at CAR-04 (5 species) and CAR-08 with 11 species (Figure 59).

Coral Reef habitats: A total of 261 species of invertebrates were identified within coral reef habitats of 3BNP. Sponge richness was the highest with 147 species identified, followed by corals (51 species), and octocorals (43). Species richness of all benthic invertebrates varied between coral reef sites, ranging from 25 benthic species at a backreef in Caracol (CAR-23) to 123 species on a deep *Orbicella* fore reef, FL-12) in the Fort Liberté zone (Figure 59a). Overall, the coral reefs of Fort Liberté presented the highest species richness, with richness values reaching 101 and 96 benthic species at another deep forereef (FL-26) and reef wall (FL-14), respectively. Site FL-12 exhibited the highest coral richness (37 species, see Figure 57b) compared to other coral reef sites surveyed in the trip. In Limonade, species richness was also relatively high at a deep forereef (L-31) and deep patch reef (L-33), with 110 and 97 benthic species identified, respectively (Figure 59). The most frequent corals identified on coral reef habitats within 3BNP were *Porites astreoides*, *Agaricia agaricites*, *Pseudodiploria strigosa,* and *Montastraea cavernosa* (Figure 60).

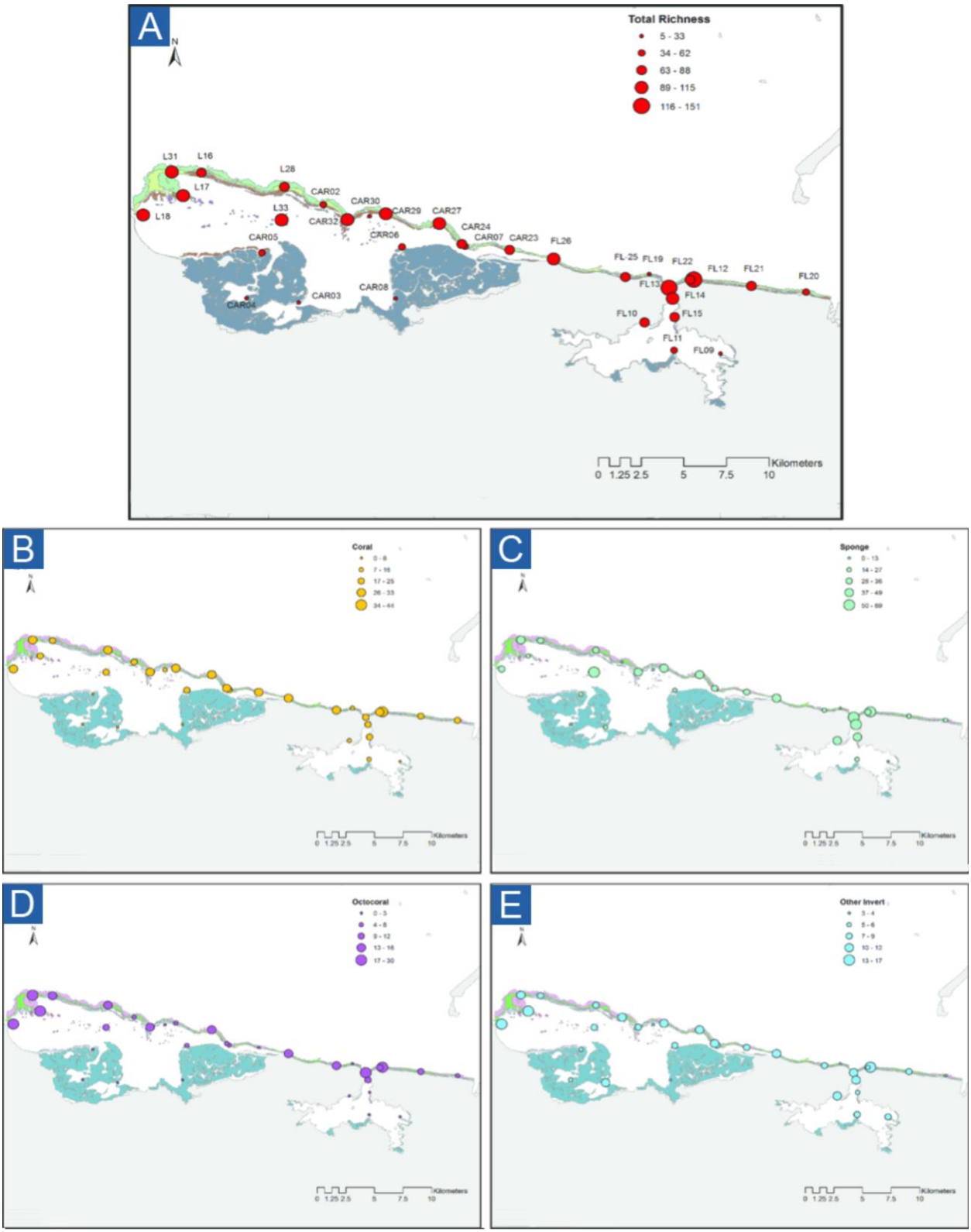

Figure 59. Richness of **(a)** all sessile- and motile-benthic organisms, **(b)** corals, **(c)** sponges, **(d)** octocorals, and **(e)** other invertebrates at each site (total 23) in 3BNP. The size of the bubbles is proportional to the total richness for that site.

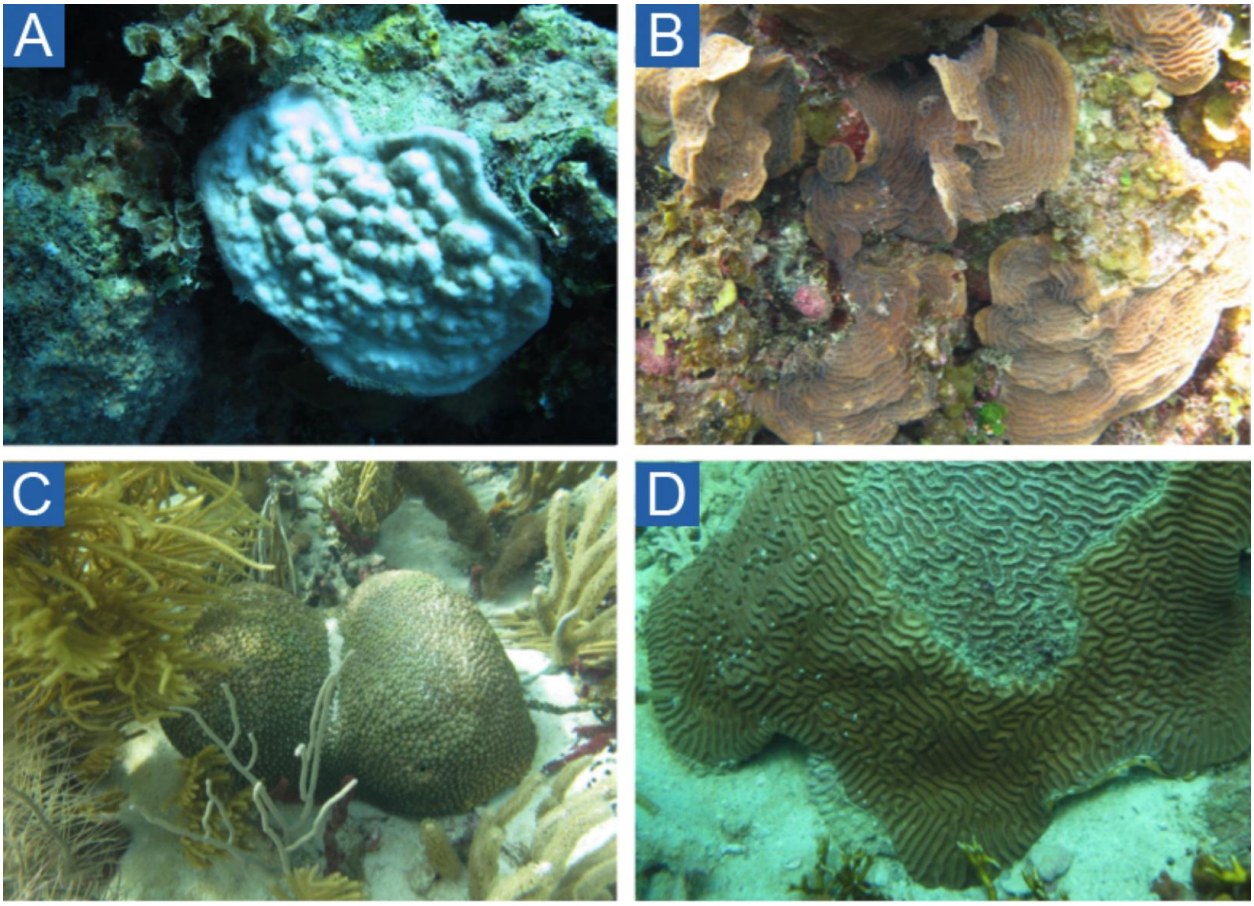

Figure 60. The most common hard corals in 3BNP. species shown are: **(a)** *Porites astreoides*, **(b)** *Agaricia agaricites*, **(c)** *Montastraea cavernosa*, and **(d)** *Pseudodiploria strigosa*.

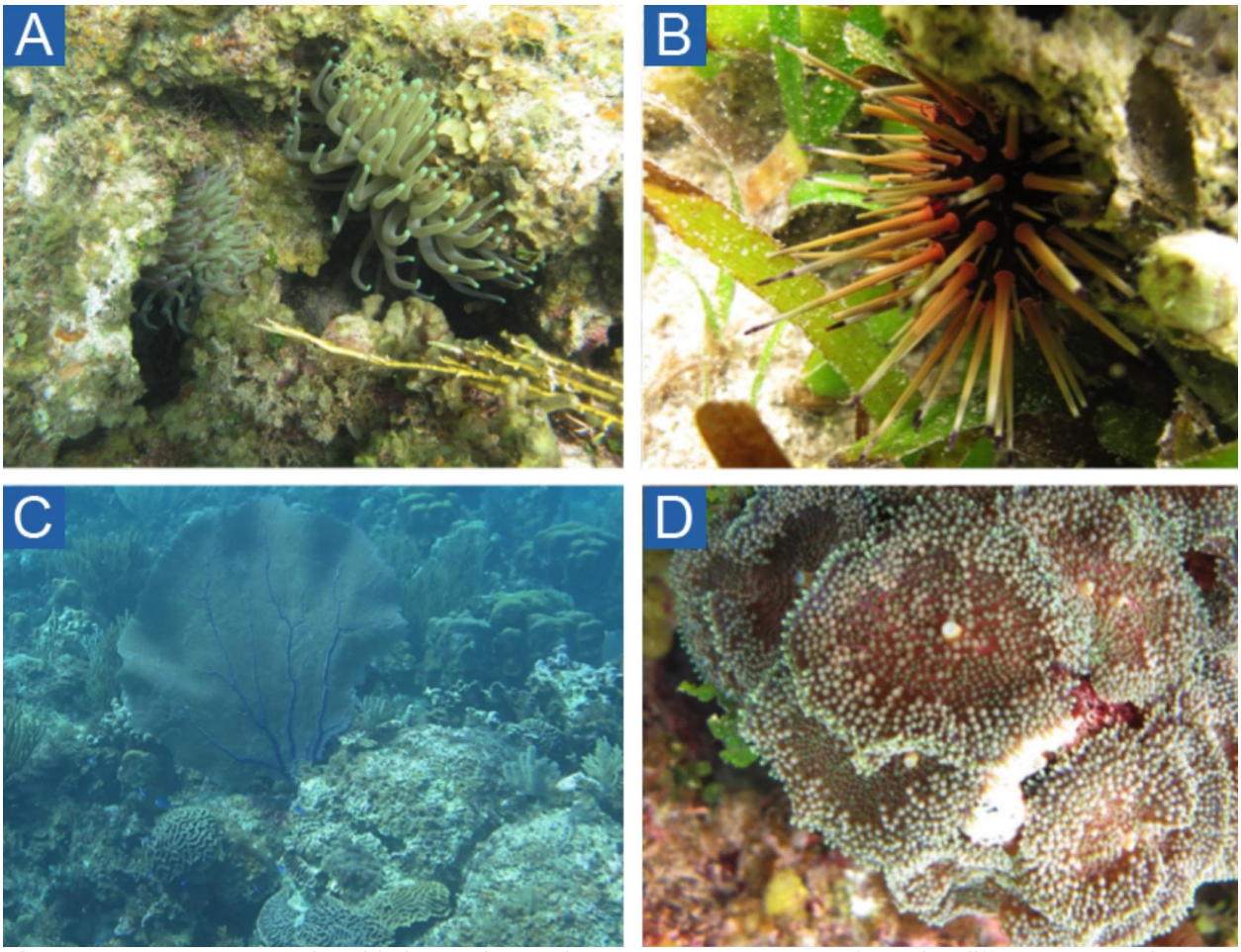

Figure 61. Most common benthic invertebrates in 3BNP. Most common from the different categories are: **(a)** *Condylactis gigantae* (anemone), **(b)** *Echinometra viridis* (echinoderm), **(c)** *Gorgonia ventalina* (octocoral), and **(d)** *Ricordea florida* (corallimorph).

For the other benthic organisms, the most frequent species observed were *Condylactis gigantae* (anemone), *Echinometra viridis* (sea urchin), *Gorgonia ventalina* (octocoral), *Ricordea florida* (corallimorph), *Halocordyle disticha* (hydroid), *Aplysina fistularis* (sponge), *Cliona tenuis* (sponge), *Spirastrella coccinea* (sponge), *Polycarpa spongiabilis* (tunicate) and *Palythoa caribaeorum* (zoanthid) (Figure 60 and 61, and Appendices 14-16).

Species of Special Concern: Hard corals listed under the Endangered Species Act (ESA, Figure 62) are species of special concern for the western Altantic region, and these include *Orbicella* spp., *Acropora* spp., *Dendrogyra cylindrus* and *Mycetophyllia ferox*. *Acropora palmata* was more frequently observed (11 sites) compared to the other acroporid species. *A. cervicornis* was recorded at nine sites and *A. prolifera* only at FL-17. *Orbicella annularis* was recorded at every coral reef site except Site 13 in Fort Liberté. *Orbicella faveolata* was observed at 23 coral reef sites and *O. franksi* was only observed at eight sites. *Dendrogyra cylindrus* was observed at 16 sites, while *M. ferox* was only observed at five coral reef sites.

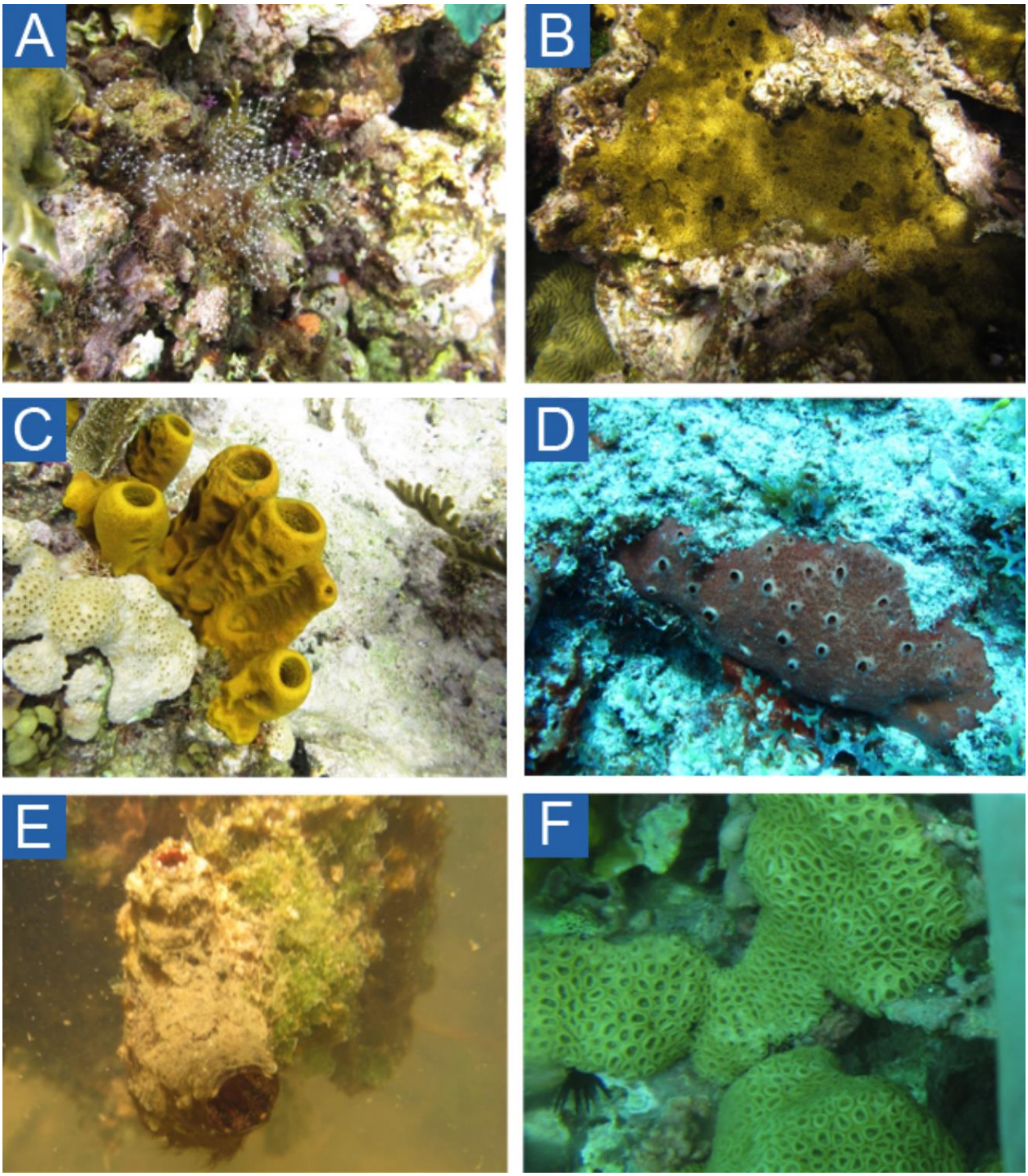

Figure 62. Most common benthic invertebrates in 3BNP. Most common from the different categories are: **(a)** *Halocordyle disticha* (hydroid), **(b)** *Cliona tenuis* (sponge), **(c)** *Aplysina fistularis* (sponge), **(d)** *Spirastrella coccinea* (sponge), **(e)** *Polycarpa spongiabilis* (tunicate), and **(f)** *Palythoa caribaeorum* (zoanthid).

Our benthic surveys also encountered a new species of coral (Figure 64). The preliminary analysis suggests that the species is *Cladopsammia manuelensis*, a cup coral normally found on deeper reefs (>50m) in the Straits of Florida, Gulf of Mexico,

Bahamas, Curacao, Brazil, Uruguay, Eastern Atlantic, Cape Verde, and Senegal. To our knowledge, this is the first report of its occurrence in Haiti (and the Central Caribbean region) for this coral. Moreover, it is the first time it has been reported on shallow reefs (5-15m). We found *C. manuelensis* to be fairly common to 3BNP across all 3 geographic zones (Appendix 14-16).

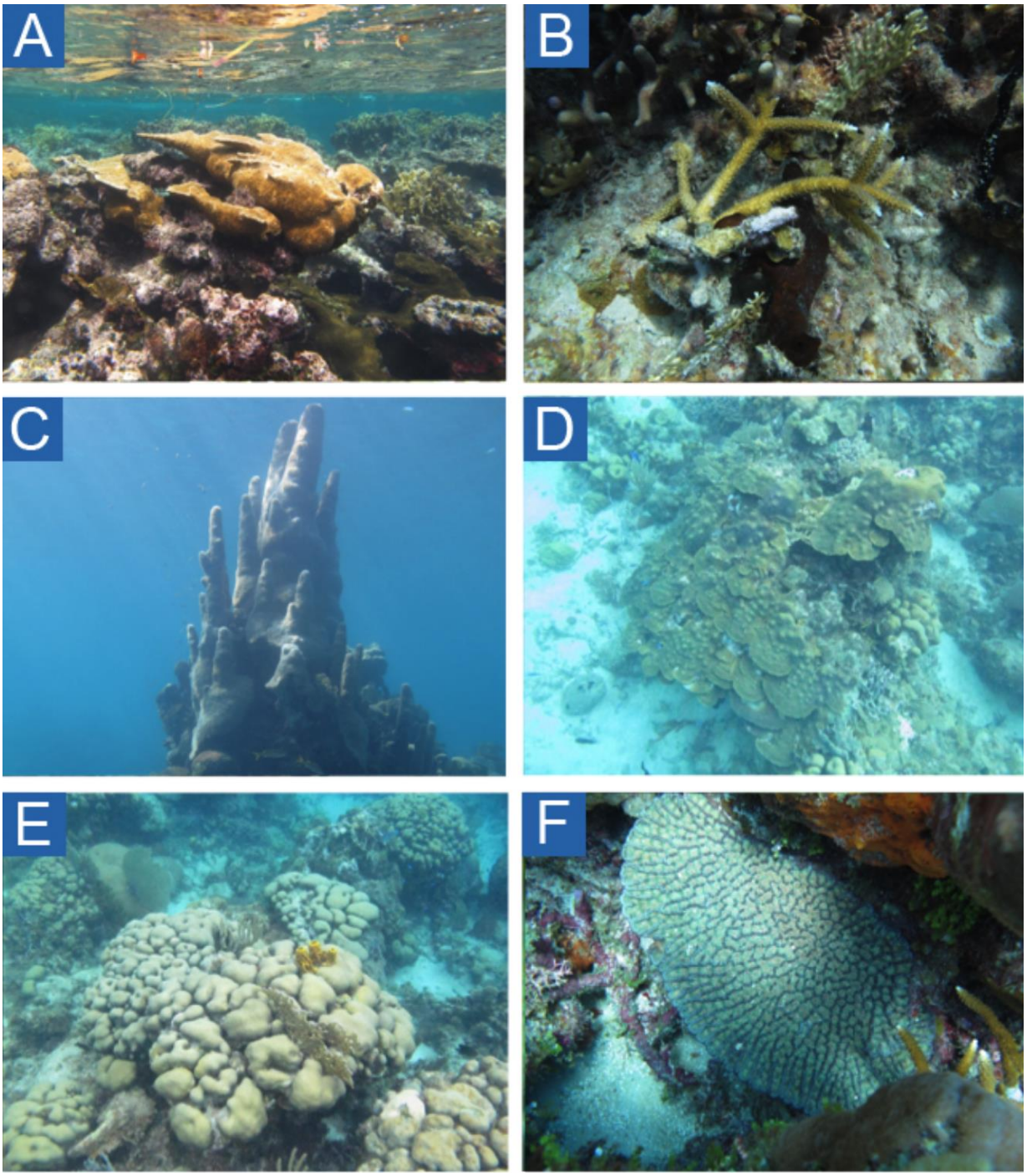

Figure 63. Hard corals listed under the Endangered Species Act observed in 3BNP. Corals shown are: **(a)** *Acropora palmata*, **(b)** *Acropora cervicornis*, **(c)** *Dendrogyra cylindrus*, **(d)** *Orbicella faveolata*, **(e)** *Orbicella annularis*, and **(f)** *Mycetophyllia ferox*.

Figure 64. A new cup coral (*Cladopsammia manuelensis*) for Haiti, observed in 3BNP.

Areas of importance: Overall, the coral reef areas located in Fort Liberté (Zone 5) exhibited the highest species diversity of sessile- and motile-benthic invertebrates (Figure 59). Out of all the coral reef habitats surveyed, *Orbicella* reefs exhibited the highest benthic diversity. These reefs were located on the outside of bay, to the east and west of the bay opening. A coral reef site of special concern was at site FL-12. The structural complexity at the reef crest was high, which dropped sharply to a well-developed *Orbicella* reef (Figure 65). The coral diversity was the highest at this reef and all the corals listed under ESA were located on either the reef crest or at deeper *Orbicella* reef.

In addition, live coral cover was high (>60%) on the *Orbicella* reef and corals located at this site were relatively healthy (low disease). The healthy condition of the *Orbicella* corals on these reefs suggests that they either avoided or were only lightly impacted by major coral bleaching events in 1998 and 2005 that have decimated their populations elsewhere in the Caribbean. Interestingly, we did detect evidence of fresh ground water inflow at site FL-12 which made the water slightly turbid and lowered seawater temperature. Large amounts of freshwater inflows will normally suppress coral growth but small amounts of groundwater flow may provide some protective benefits around summertime bleaching events. Wells around Fort Liberté suggest that a permanent

freshwater lens does exist in the area that is associated with the highly permeable limestone bedrock. The lens appears to be thickest on the east side of Fort Liberté Bay.

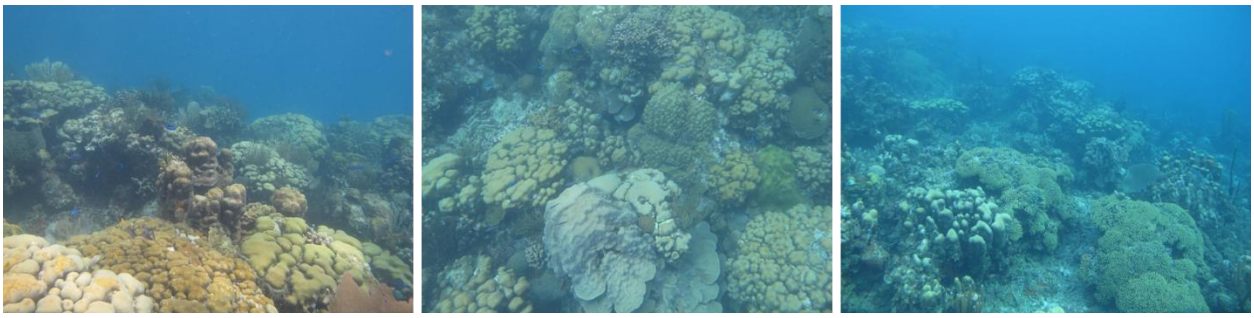

Figure 65. Panoramic photographs of an Orbicella reef at site FL-12 in Fort Liberté in 3BNP.

Seagrass Habitats: A total of 86 species of invertebrates identified within the seagrass habitats in 3BNP. Out of all the benthic categories, sponges had the highest richness (46 species), followed by tunicates (12), and echinoderms (11). No bryozoans, corallimorphs, or zoanthids were observed at any of the seagrass sites. The most common species were *Lyechitnus variegatus* (sea urchin), *Amphimedon viridis* (sponge), *Bartholomea annulata* (anemone), *Porites astreoides* (coral), and *Siderastrea radians* (coral). Three tunicate species were common in the seagrass habitat: *Polycarpa spongiabilis*, *Rhopalaea abdominalis*, and *Symplegma viride*. Seagrass habitats were only surveyed in Caracol Bay and Fort Liberté where it is widespread (Figure 9). Overall, species richness of invertebrates was higher at Fort Liberté (64 species) than Caracol (45). Sites CAR-14 and CAR-19, both sites close to the opening of the bay, had the highest species richness (Figure 58a), especially of corals (Figure 58b), and other invertebrates (Figure 58e), such as echinoderms and tunicates.

Species of Special Concern in Seagrass Habitats: Echinoderms, especially sea urchins and sea cucumbers are of special concern. Sea urchins are ecologically important, and both sea urchins and sea cucumbers are frequently fished in the Caribbean. At Site FL-11, there were many small echinoderm recruits, especially of the species *Diadema antillarum*. *D. antillarum* is one of the most important herbivores on Caribbean reefs (Figure 66). Populations of this sea urchin have been slowly recovering after a mass die-off that occurred in the early 80s. Therefore, Site FL-11 may be acting as a sink for these important sea urchins and should be further monitored and considered for greater levels of protection.

Seagrass Habitats of Importance: Seagrass habitats outside the mangrove channels, such as Site CAR-5 in Caracol, and within the bay of in Fort Liberté, Sites FL-11, FL-14, FL-15, were relatively similar in shoot density, blade length, condition, and invertebrate diversity. The condition of seagrass at these sites was healthy and dense (Braun Blanquet 5) with low presence of fleshy macroaglae. Species diversity of benthic invertebrates was higher at these sites compared to other seagrass sites. The greater exposure and strong daily tidal currents that influence these outer sites provides higher water qualilty and flushing compared to more sheltered interior bay sites.

Figure 66. Small recruits of sea urchins, *Echinometra* sp. (left) and *Diadema antillarum* (right) at site FL-11 in 3BNP.

Mangrove Habitats: The overall richness of sessile-benthic invertebrates in 3BNP was lowest around mangrove habitats (39 species). There were many times during which no benthic organisms were observed within a 20m transect. Sponges had the highest richness with 22 species identified, followed by tunicates (11 species), and hydroids (2). The most frequent sponges identified were *Tedania klausi* (at all 6 sites), *Dysidea janiae* (6 sites), *Clathria curacaoensis* (5), *T. ignis* (5), and *Mycale microsigmatosa* (5). The most common tunicate was *Polycarpa spongiabilis* (5 sites) and *Botrylloides nigrum* (5). No corals, corallimorphs, octocorals, or zoanthids were observed inhabiting any mangrove roots. Echinoderms were absent at many sites, except at two sites in Fort Liberté. Species richness of benthic invertebrates was higher within the patchy fringing mangrove communities of Fort Liberté bay (32 species) compared to the more extensive mangrove forests of Caracol Bay (24 species). Mangrove areas of higher diversity were located at Site FL-15 in Fort Liberté (19 species), and CAR-3 in Caracol (18 species). As with seagrasses, these mangrove sites were located in more exposed outer areas of the Bays with greater exposure and flushing compared to interior sites. Mangroves located along interior lagoons and tidal channels contained the lowest invertebrate richness (5 species). One site was located within the mangrove channel in Caracol (Site 4) and the other site was located on a small little island within Fort Liberté (FL-12). The mangrove roots at Site FL-12 were not as well developed and did not have as extensive root growth (median length 11cm) as the other sites surveyed, which exhibited a median root length of 70cm.

Figure 67. Sponge and tunicate species common on the mangrove roots in 3BNP. Sponges listed from left to right are: *Clathria curacaoensis*, *Dysidea janiae*, *Tedania ignis, Mycale microsigmatosa*, and tunicate species, *Botrylloides nigrum*.

Species of Special Concern in Magrove Habitats: Mangrove oysters (*Crassostrea gasar*) serve important functions in a mangrove habitat, as they create space for other organisms to take refuge, reduce erosion, serve as a natural filtration system, and are an important fishery for many Caribbean islands. Even though bivalves were not included in this assessment, the presence of mangrove oysters were noted. Mangrove oysters were virtually absent from the mangrove sites in Caracol; however, there were high abundances of oysters at all sites surveyed in Fort Liberté. There was an attempt to commercially culture shellfish in Fort Liberte in the past.

Mangrove Habitats of Importance: Site FL-13 in Fort Liberté displayed the highest invertebrate richness per site and per mangrove root. Many times, 7 to 8 different species of invertebrates were observed on one root, and sponge cover reached as high as 80-90%. There were also other interesting organisms present within the root system, like sea horses and warty dorid (*Doris verrucosa*) (Figure 68).

Comparisons to Previous Studies

There is little information available on the benthic invertebrates of marine ecosystems in Haiti, especially in the park. In 3BNP, the species richness of benthic invertebrates was relatively high (307 species). Sessile-benthic invertebrate richness in 3BNP was higher than reported in Caribbean-wide study, which assessed the benthic biogeography of deep forereefs (*Orbicella* reefs) at 11 Caribbean countries (Williams et al. 2015).

Figure 68. *Doris verrucosa* (warty dorid).

Threats to benthic invertebrates: Benthic invertebrate richness significantly varied between areas (PERMANOVA, Pseudo-F=3.21, p<0.001). The species richness of marine benthic invertebrates was the lowest in Limonade and nearshore waters in Caracol, and the concentration of fishers that fish in these zones is much higher compared to Fort Liberté. Threats to benthic invertebrates in 3BNP have been synthesized by Kramer et al., 2016 and include destructive fishing practices and over fishing of herbivores, coastal development for tourism and industrial/commercial activities, and declines in water quality. Destructive fishing practices are probably the most direct impact to benthic habitats. In extreme cases, this might include dynamite fishing or trawling which damage the benthic invertebrate community and require years to recover- fortunately, neither of these fishing practices is currently practiced within 3BNP. Trap fishing and sein netting are probably the next most destructive gear types being deployed in 3BNP. Fish traps can be highly unselective with a lot of by catch and secondary impacts to habitats as abandoned traps that can end up on coral reefs and in mangroves. Fortunately, fish traps in 3BNP are largely made from biodegradable thatch and bamboo as opposed to steel or plastic materials commonly used in other Caribbean Islands which reduces the current level of secondary impacts. However, the mesh sizes are very small and there are no escape holes to allow juveniles out. Sein nets are typically set over seagrasses and around mangrove areas**.** Repeated sets over sensitive coral bottom areas can damage and flatten the seabed.

Conclusion

Coral reefs presented the highest species diversity of benthic invertebrates. Out of all the coral reef habitats surveyed, *Orbicella* reefs exhibited the highest benthic diversity. These reefs were located on the outside of Fort Liberté Bay, to the east of the bay opening. A coral reef site of special concern was at site FL-12 (*Orbicella* reef). The structural complexity at the reef crest was high, which dropped sharply to a well-developed *Orbicella* reef. The coral diversity was the highest at this reef and all the corals listed under ESA were located on either the reef crest or at deeper *Orbicella* reef. In addition, live coral cover was high (>60%) on the *Orbicella* reef and corals located at this site were relatively healthy (low disease).

Overall, the marine habitats within and outside the bay of Fort Liberté exhibited the highest species richness of sessile- and motile-benthic invertebrates. Therefore, habitats close to the channel and outside the bay should be designated as areas of importance. Fort Liberté is an area that offers many options, historically and ecologically, for visitors to appreciate. Coral reefs, especially *Orbicella* reefs on the outside of the bay, are well-developed (high coral cover) and relatively healthy. Likewise, the middle patch reefs (Site 22) of Limonade are another area of interest, because of the diversity and size of organisms. Anemones, corallimorphs, and echinoderms were large in size compared to other sites in this study. The composition of the leeward side of Site 22 was similar to a "typical" deep reef in the Caribbean, even though the reef surveyed was at 2-3m. The coral composition was characterized by *Agaricia* species, such as *Agaricia lamarcki*. The north side of the patch reef was a relic *Acropora palmata* reef and some living colonies of *A. palmata* and *A. prolifera* were observed.

As seen in Schill et al. (2015) report, there is a strong demographic connectivity between the coral reefs along the north coast of Haiti and Cuba, Bahamas, Dominican Republic, and Puerto Rico. The exchange of larvae between these countries will influence the demographics and dynamics of marine populations. Coral cover was low throughout 3BNP, except in the Fort Liberté region. *Orbicella* reefs of Fort Liberté were relatively healthy and were characterized by a high coral diversity. These reefs are important because they may be providing a source of larvae to other coral reefs in Haiti and neighboring countries. This is especially true for the hard corals listed under ESA, which were all observed in this area. However, there were not a lot of coral recruits and juveniles in 3BNP. The lack of recruitment could be due to the high abundance of fleshy macroalgae on most reefs in the park. Therefore, habitat enhancement by protecting herbivorous fish and sea urchins should be a management priority.

VI. Marine Fish

There have been drastic declines in fish abundance on coral reef communities throughout the Caribbean. Few qualitative and quantitative assessments have been conducted on the coral reef fish populations in Haiti. In 1927, William Beebe was the first ecologist to visit Haiti and he published the first quantitative assessments of the marine environment in the Bay of Port-au-Prince (Beebe 1928). This expedition was undertaken by the Department of Tropical Research of the New York Zoological Society. The main objectives of Beebe (1928) were to prepare a list of fish species present in coastal waters and to obtain photographs of the coral reef life. He recorded the coral reefs to be full of life, with high abundances of fish and corals, and observed 270 different fish species in just the bay alone.

Historically, Haitian people have heavily relied on natural resources, especially the resources from the sea, and overfishing was evident in 1983 when Jacques Cousteau visited Haiti. In Cousteau's documentary, he recorded a low abundance of reef fish at all coral reef sites visited.

In 2003, Reef Check carried out quantitative surveys at a number of coral reefs (total 400), which spanned around 95% of the entire coastline. Fish populations were low at all sites surveyed by Reef Check, ranging from 0.5 to 5 per 100m^2. Grunts (Haemulidae) were the most observed family of fish, followed by snappers (Lutjanidae). Predatory fish (groupers and sharks) were absent from their surveys, indicating overfishing. There were fish vessels actively fishing at all sites surveyed. He also observed fishers standing on coral reefs and using destructive fishing practices such as dynamite.

Description of Marine Fish Habitats

Our surveys were limited to the shallow (<30m) marine habitats of 3BNP, we used the same classification scheme as for the benthic invertebrates.

Fish species diversity: There were a total of 183 fish species identified in mangrove, seagrass, and coral reef habitats within 3BNP (Appendices 17-19). Coral reef habitats, especially forereefs and reef crests displayed the highest species richness and therefore were identified as areas of importance. In assessing the different bays, the highest species richness of benthic organisms and reef fish was observed in Fort Liberté with a total of 153 species, then Caracol (125 species), and Limonade (112). The species richness varied between sites, with the highest species richness at FL-12 in Fort Liberté with 87 species identified, followed by a site in Caracol (CAR-32) with 77 species, and the lowest species richness was measured in Caracol at sites CAR-05 (8 species) and CAR-03 with 10 species (Figure 71).

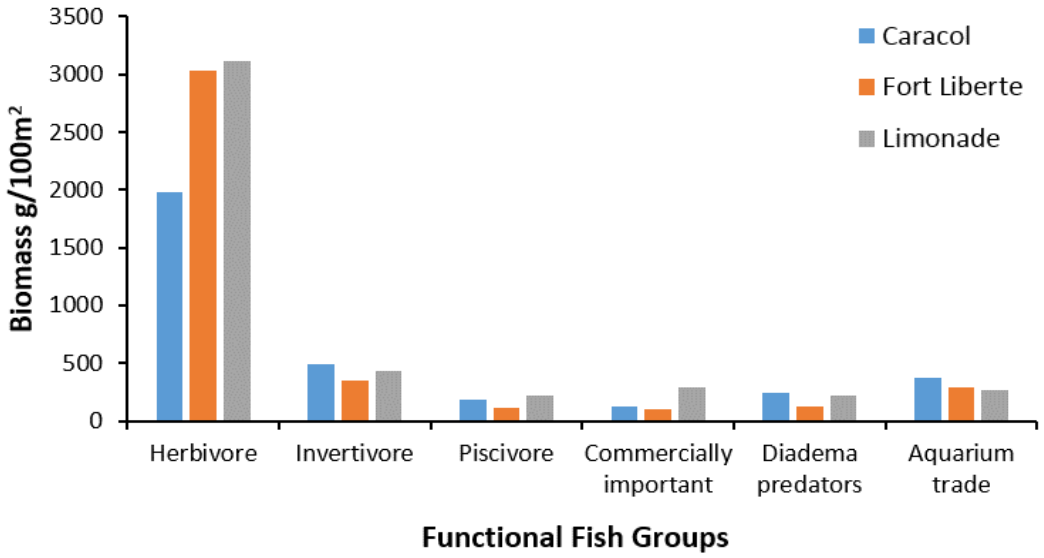

Figure 69. Mean biomass (g/100m^2) of functionally important reef at each region in 3BNP.

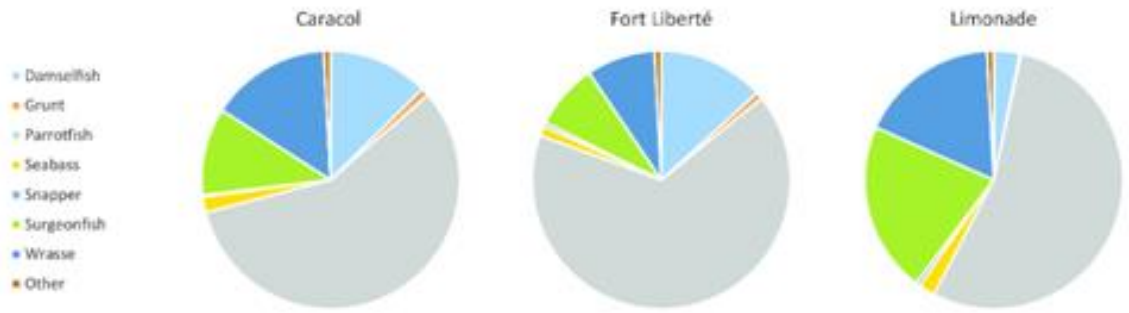

Figure 70. Densities of reef fish assemblages on forereefs in Caracol, Fort Liberté, and Limonade in the 3BNP.

Coral Reef Habitats: Fish richness varied between coral reef sites, ranging from 18 species on a back reef in Caracol (CAR-30) and patch reef in Limonade (L-18), to 87 species on a deep forereef (*Orbicella* reef, FL-12) in Fort Liberté (Figure 70). Overall, the coral reefs of Fort Liberté presented high richness of reef fish, especially at a deep forereef site, FL-26 (71 species) and FL-13 (69 species), which was characterized by hardground that ended abruptly into a reef wall. Fishing pressure is the most concentrated around Caracol, which could explain the high variation of fish richness between sites. A reef wall site in Caracol exhibited relatively high species richness, with 77 species. Geomorphology of the site (contour and depth) has led to the maintenance of relatively high fish richness at this site. The average richness observed at coral reef sites in Limonade was around 46 species. This was lower than in Fort Liberté (~60 species) and Caracol (~49 species). The overall low fish richness observed in Limonade could possibly be due to the lack of visibility at many of the reef sites. River outputs have led to high turbidity at many of the inshore patch reefs, therefore making it difficult to accurately survey fish richness. The most frequent fish species identified at coral reef sites was the striped parrotfish (*Scarus iseri*), which was observed at every coral reef site, followed by stoplight parrotfish (*Sparisoma viride*), redband parrotfish (*Sparisoma aurofrenatum*), and blue tang (*Acanthurus coeruleus*) (Figure 71).

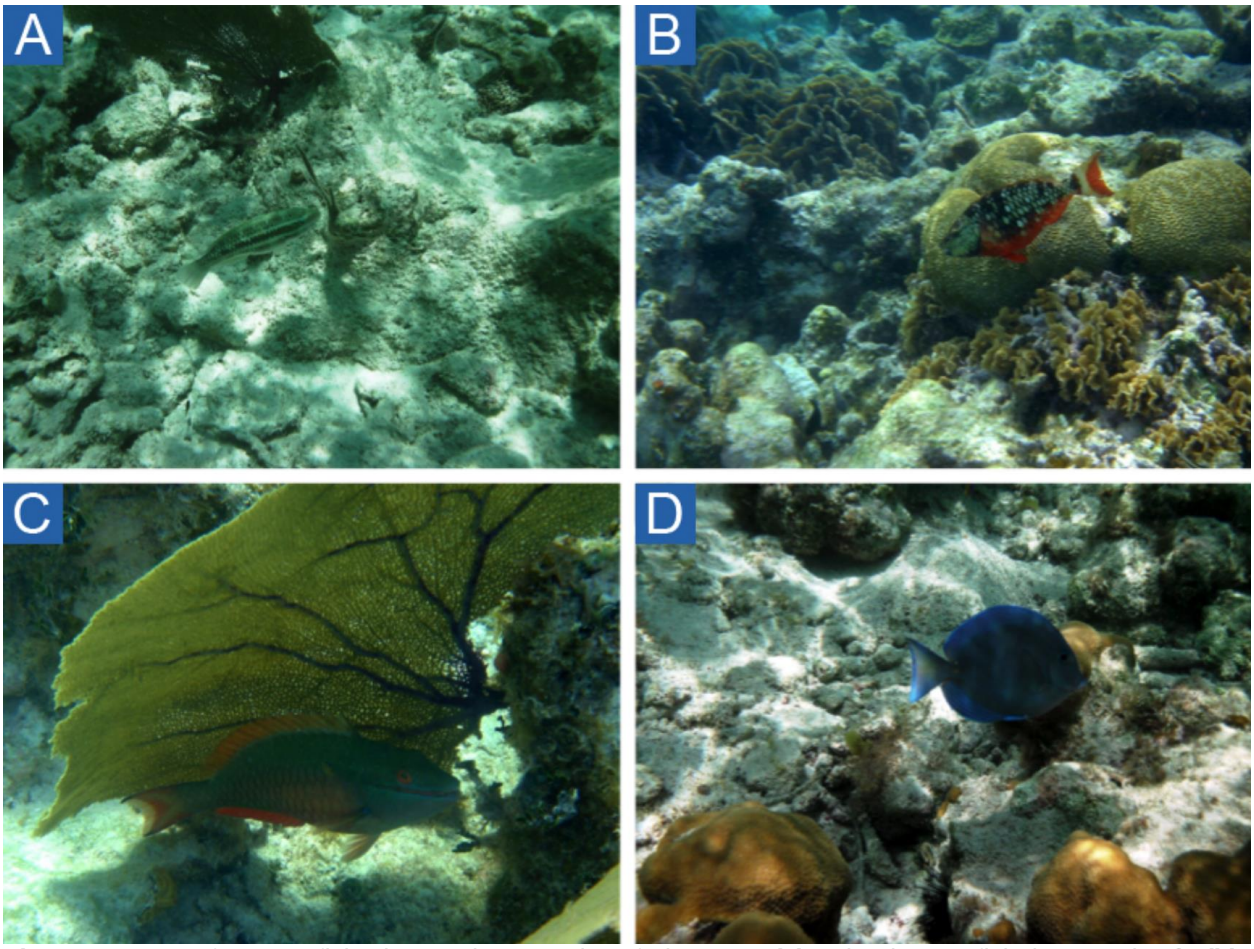

Figure 71. Most frequent fish observed on coral reefs in3BNP: **(a)** striped parrotfish (*Scarus iseri*), **(b)** stoplight parrotfish (*Sparisoma viride*), **(c)** redband parrotfish (*Sparisoma aurofrenatum*), and **(d)** blue tang (*Acanthurus coeruleus*). (Photo credit: Rumya Sundaram)

Seagrass and Mangrove Habitats: Fish richness in seagrass and mangrove habitats was low (82 species) compared to coral reef habitats. Fish richness ranged from 8 species at CAR-05 in Caracol to 41 species at FL-15, in Fort Liberté (Figure 72). The most common fish species observed in seagrass and mangrove habitats were the bucktooth parrotfish (*Sparisoma radians*), striped parrotfish (*S. iseri*), and yellowfin mojarra (*Gerres cinereus*) (Figure 74). There were four species of reef fish that were only observed in seagrass/mangrove habitat: almaco jack (*Seriola rivoliana*), crested goby (*Lophogobius cyprinoides*), sea bream (*Archosargus rhomboidalis*), and an unidentified needlefish (Figure 74). A possible new species of hamlet was observed only in the bay of Fort Liberté (Figure 75). A specimen was collected and is currently being genetically analyzed.

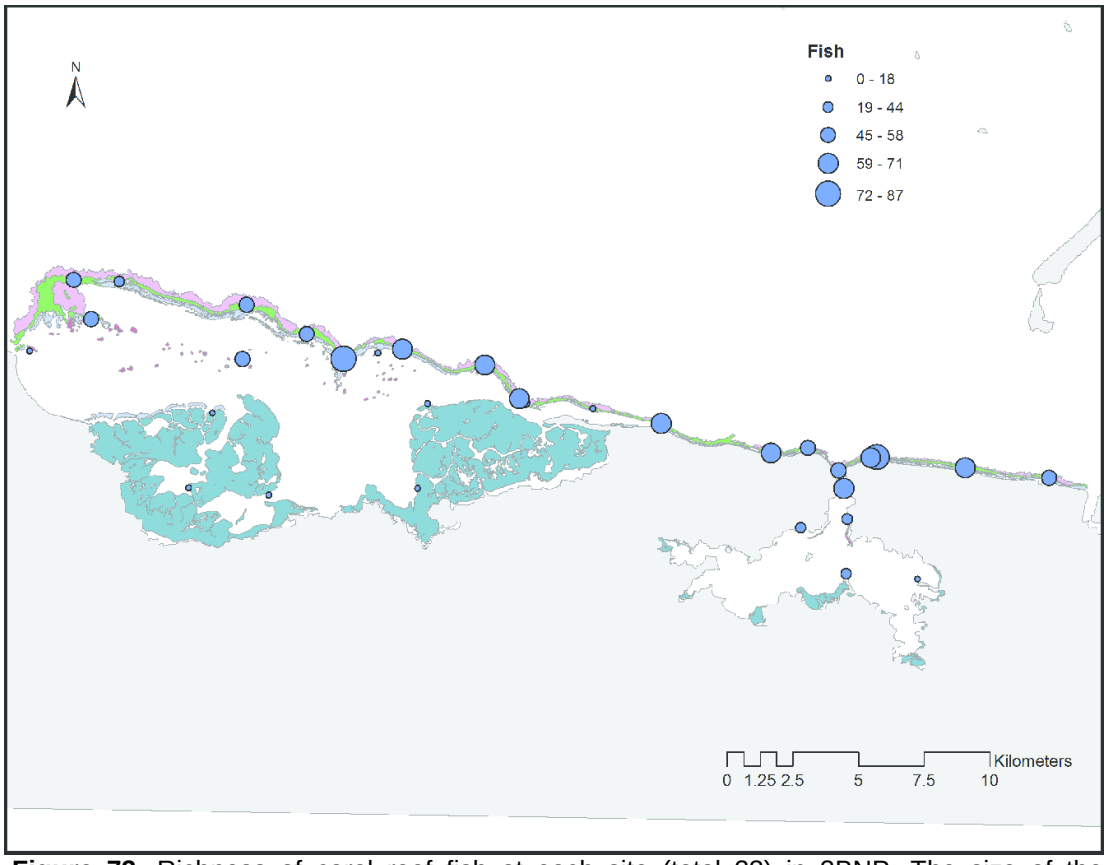

Figure 72. Richness of coral reef fish at each site (total 23) in 3BNP. The size of the bubbles is proportional to the total richness for that site.

Fish Biomass and Density: Average total density and biomass of reef fish on forereefs in 3BNP was 7.4individuals/100m^2 and 250.5g/100m^2, respectively. As seen in Figure 73, parrotfish were the most abundant group of reef fish in 3BNP; however, as indicated by the graph, the majority of parrotfish were small in size, ranging from 933.8g/100m^2 at CAR-30 in Caracol to 2,897.2g/100m^2 at FL-25 in Fort Liberté. Commercially important fish species (snappers, seabass, parrotfish) were practically absent at many of the sites surveyed within 3BNP (Figure 69). The biomass of *Diadema antillarum* (long-spined sea urchin) predators was also low, which could explain the high densities of *D. antillarum* and other sea urchins in Limonade and Fort Liberté. Fish communities significantly varied between locations (PERMANOVA, Pseudo-F=8.46, p=<0.001). Comparing regions, the average fish biomass ranged from 203.96g/100m^2 in Caracol Bay to 289.95g/100m^2 in Limonade. There were more parrotfish and damselfish in Fort Liberté, compared to Caracol and Limonade, while surgeonfish densities were the highest in Limonade (Figure 70).

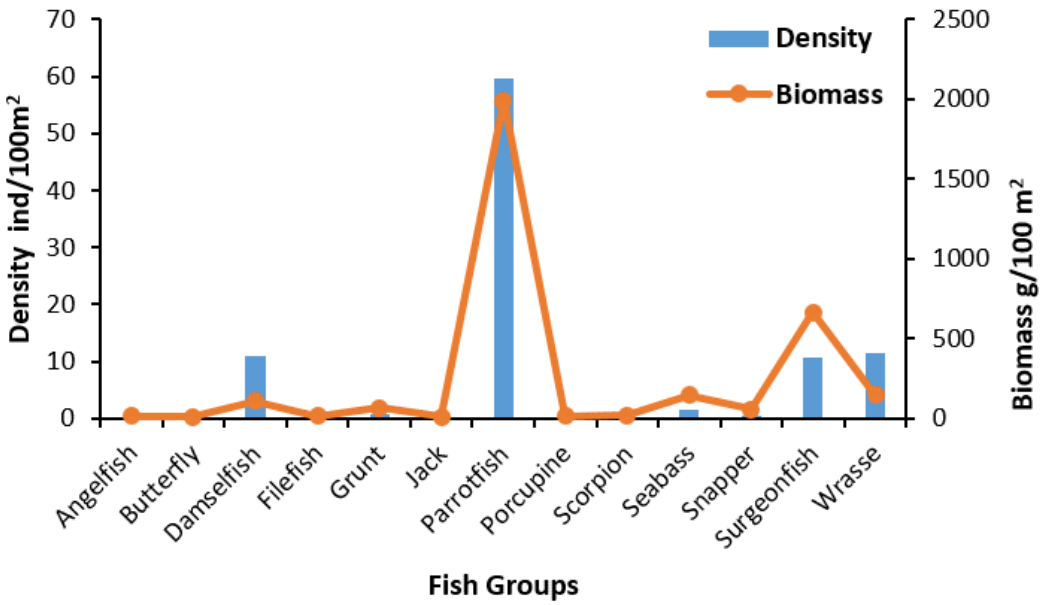

Figure 73. Average biomass (g/100m^2) and density (individuals/100m^2) of fish groups on the outer forereefs in 3BNP.

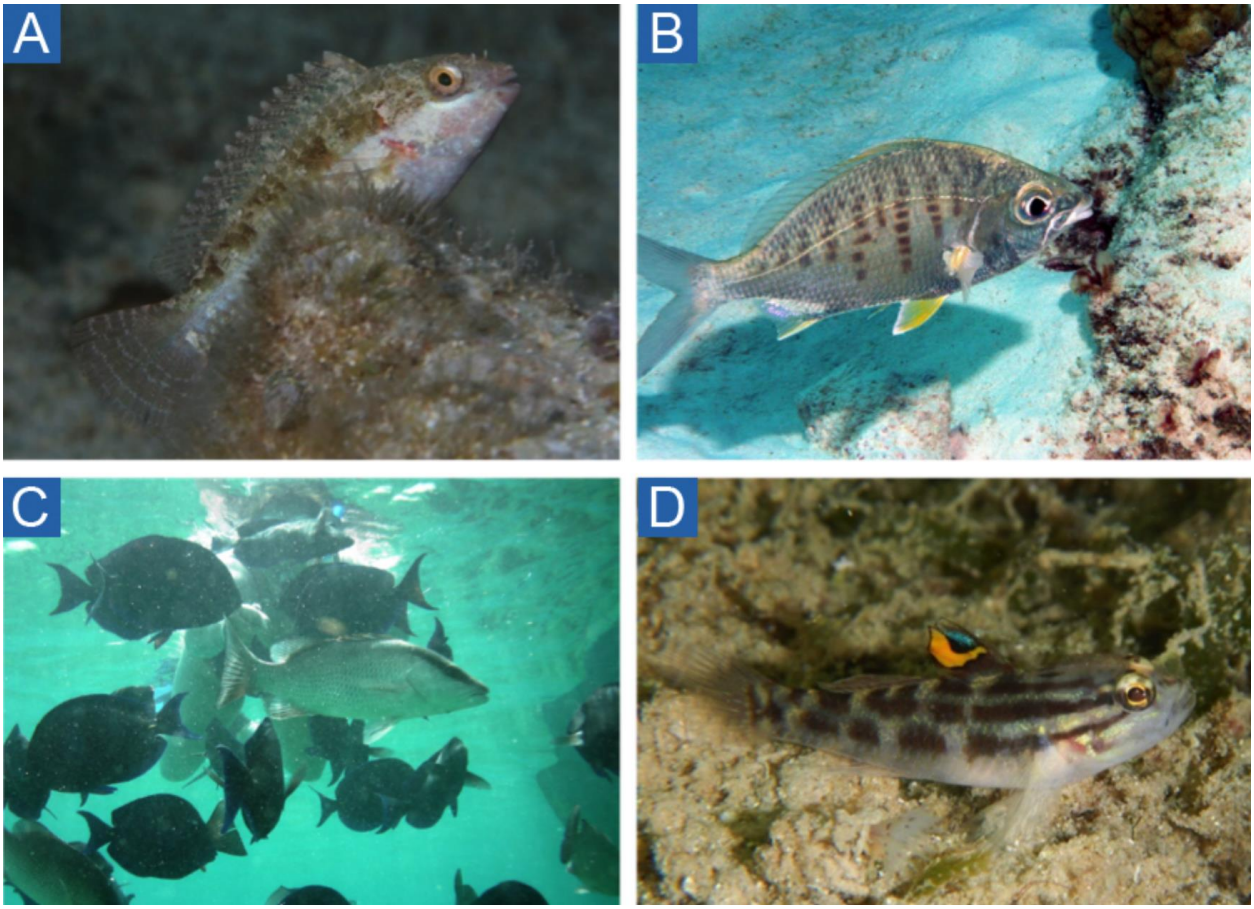

Figure 74. Most frequent fish observed at seagrass and mangrove habitats in 3BNP: **(a)** bucktooth parrotfish (*Sparisoma radians*), **(b)** yellowfin mojarra (*Gerres cinereus*), **(c)** almaco jack (*Seriola rivoliana*), and **(d)** crested goby (*Lophogobius cyprinoides*).

Figure 75. A new species for science: the Haitian Barred Hamlet (Serranidae).

Comparisons to Previous Studies

In 3BNP, the marine fish species richness was higher than expected given the high level of human fishing impacts on these important marine ecosystems. However, fish richness was low (183 species) when compared to a neighboring country, Cuba. Alcolado et al. (2003) reported a total of 350 fish species on shallow-water coral reefs in Cuba. The most noticeable difference between these two countries was the complete absence of apex predators, such as elasmobranchs and groupers during the surveys. However, nurse sharks have been sited previously inside the park, usually in deeper water (>30m). In 3BNP, the fishing down effect has caused a decrease and shift in functional diversity, where the top predators are now coneys (*Cephalopholis fulva*), graysby (*Cephalopholis cruentata*), and red hind (*Epinephelis guttatus*) (Figure 76).

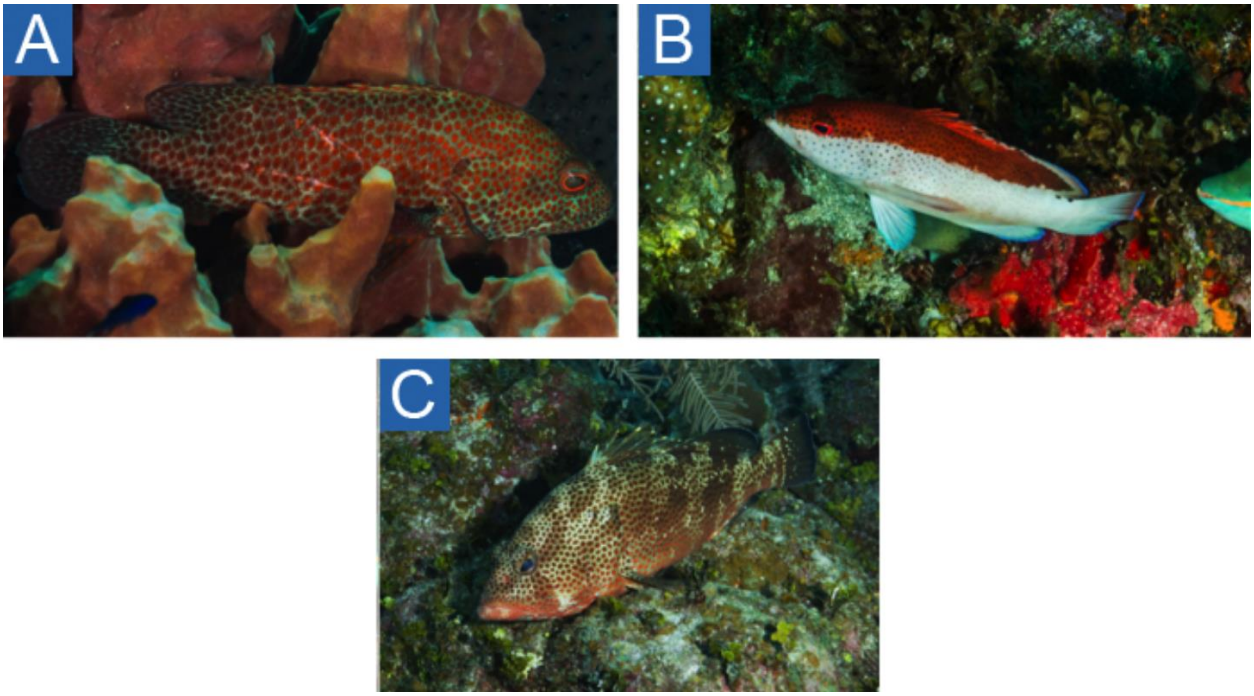

Figure 76. Top predators in 3BNP: **(a)** graysby (*Cephalopholis cruentata*), **(b)** coneys (*Cephalopholis fulva*), and **(c)** red hind (*Epinephelis guttatus*). (Photo credit: Fran Grenda)

The recent richness numbers were also low compared to an older report by Beebe (1928), who surveyed reefs in the Bay of Port-au-Prince. The discrepancy in species richness observed between the this survey and Beebe (1928) is most likely due to the unregulated fishing and the exploitation of most marine resources. Fish richness reported above does not account for brackish/estuarine fish species. Dr. Raymond Grizzle (see Section IV) observed four other brackish/estuarine fish species that have direct links to the marine environment in 3BNP. Samples are still being processed; therefore this number may be conservative.

Coral reefs presented the highest species diversity of reef fish. In this study, there was a greater variation in fish richness between coral reef sites, ranging from 17 to 77 species, than that reported by Reef Check (2013), with ranges from 27 to 46 fish species. Overall, the coral reefs in Fort Liberté exhibited the highest species diversity of fish. The lowest fish richness was located in Caracol Bay, the area with the most fishers. Out of all the coral reef habitats surveyed, *Orbicella* reefs exhibited the highest fish diversity. These reefs were located on the outside of Fort Libert Bay, to the east of the bay opening. A coral reef site of special concern was at a forereef site FL-12 (*Orbicella* reef). The structural complexity at the reef crest was high, which dropped sharply to a well-developed *Orbicella* reef. The fish diversity was the highest at this reef and all the corals listed under ESA were located on either the reef crest or at deeper *Orbicella* reef. In addition, live coral cover was high (>60%) on the *Orbicella* reef. Mangroves and seagrass habitats are known refugia for many fish juveniles. However, in 3BNP fish juveniles were nearly absent in these ecosystems.

In 3BNP, the overall fish biomass was low (2.5g/m^2) compared to other countries, such as Bonaire (~120g/m^2) where fisheries are effectively managed (FORCE unpublished data) and Grand Cayman (71.78g/m^2) where they are fully protected (McCoy et al. 2009) (Figure 77). The size frequency of fish in the park was positively skewed, therefore the fish assemblages were dominated by smaller size classes. Again, the lack of commercially important fish species is of major concern.

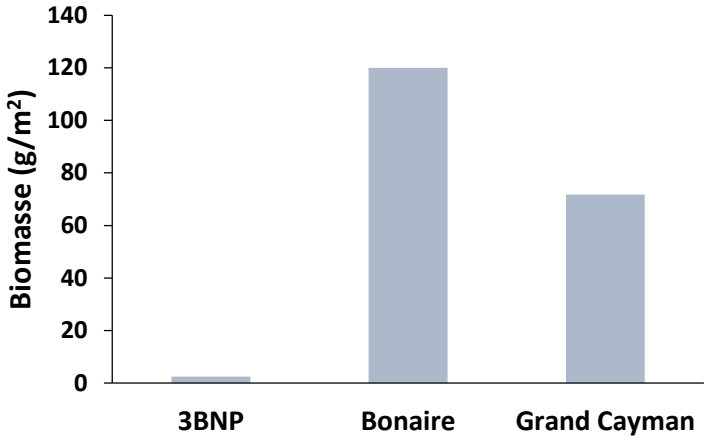

Figure 77. Average fish biomass in the 3BNP, Bonaire (FORCE unpublished), and Grand Cayman (McCoy et al. 2009). Coral reef fisheries are managed in both Bonaire and Grand Cayman.

Species of special concern: Apex predators help regulate and maintian the balance of marine ecosystems. Studies have shown that marine ecosystems with apex predators present have a higher biodiversity and abundance of marine organisms. The removal of these organisms have cascadal effects on ecosystem function on a reef. What is most conserning was that apex predatory fishes such as sharks and groupers were absent from all our surveys. However, there have been conistent reports of nurse sharks present in deeper waters and reef check observed a nassau grouper offshore in the 3BNP. The protection of apex predators and allowing them to recruit and recover is essential in the management plan of the 3BNP.

Parrotfish are species of special concern due to their functional importance on coral reef ecosystems. They graze on fleshy macroalgae, which could otherwise overgrow, smother corals, and eliminate available space for benthic organisms to settle if not controlled. In 3BNP, although parrotfish were still the most common fish in all marine ecosystems, overfishing of apex predators has resulted in fishers now targeting other important functional groups (i.e. parrotfish). Now overfishing of herbivorous fish is evident in 3BNP, thus also resulting in a reduction in size and a decrease proportion of terminal males. Male parrotfish are transitioning to terminal phases at 20cm in size, in a desperate attempt to reproduce. Parrotfish biomass in 3BNP (1.99g/m^2) was lower than in Jamaica (2.20g/m^2, FORCE unpublished data), a neighboring country with highly overfished reefs. Fishing of parrotfish needs to be banned in the park, in order for populations to rebound. O'Farrell et al. (2015) observed an increase in size from 42cm

to 56cm in parrotfish average length after taking of parrotfish was completely banned in 1993 in Bermuda.

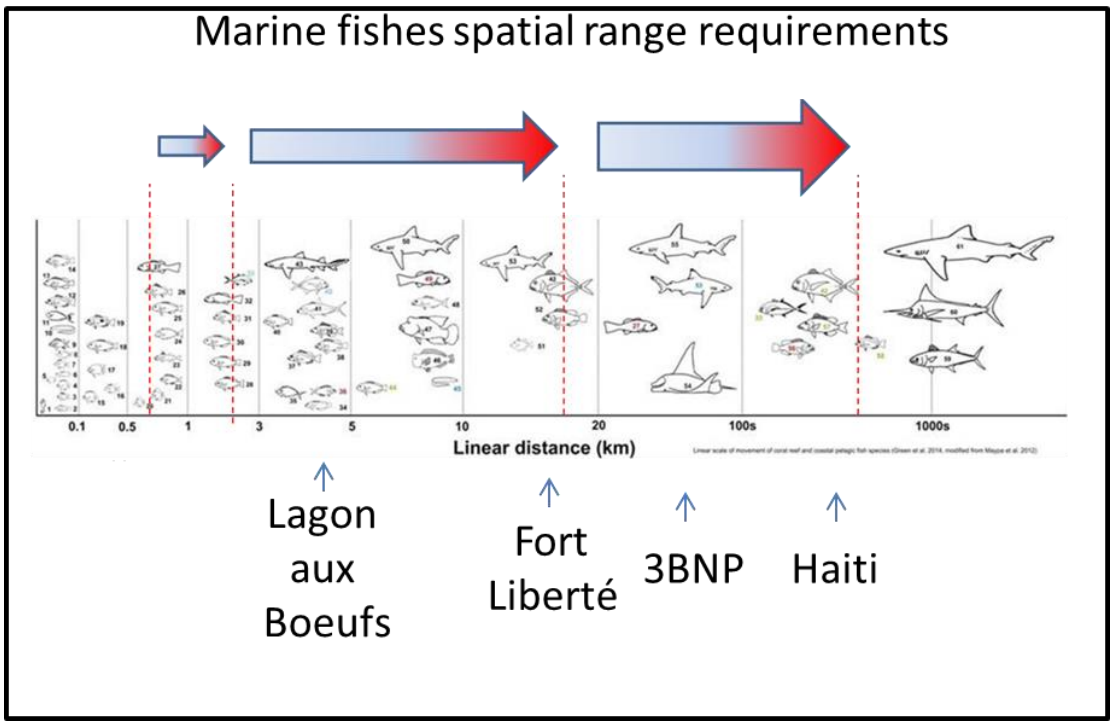

Figure 78. Schematic illustrating the spatial range (in km) requirements for a variety of reef fish. Larger species require larger areas.

Biological connectivity: As seen in Schill et al. (2015), there is a strong demographic connectivity between the coral reefs along the north coast of Haiti and Cuba, Bahamas, Dominican Republic, and Puerto Rico. The exchange of larvae between these countries will influence demographics and dynamics of marine populations. There were a great deal of small reef fish in 3BNP (see Figure 73), and very few adults. Therefore, the source of fish larvae in 3BNP is from countries other than Haiti, which makes 3BNP vulnerable to fisheries collapse. Whether, it is managing human activities and/or creating alternative livelihoods for fishers, effective management is needed for these systems to persist in the future. Sustainable fisheries will continuously support the normal range of species, and protecting fish populations will significantly enhance productivity in the marine ecosystem and prevent fisheries collapse.

Figure 79. Fisherman in Fort Liberté, Limonade and Caracol (left to right) in the 3BNP.

Many of the livelihoods of Caribbean people depend directly or indirectly on the services provided by the marine ecosystems (Figure 79). Overfishing is characterized as being the greatest threat in 3BNP (Kramer et al. 2016). Fishing in Haiti is unregulated and therefore has led to the overfishing of the marine ecosystems. Threats to fishes in 3BNP have been synthesized by Kramer et al., 2016 and include destructive fishing practices and over fishing of herbivores, coastal development for tourism and industrial/commercial activities, and declines in water quality. Destructive fishing practices such as seine netting, fish traps and spear fishing are the most destructive gear types being used in the 3BNP. The mesh size of both the sein nets and fish traps is very small, trapping a wider variety of fish species and juvenile fishes. The fish richness significantly varied (PERMANOVA, Pseudo-F=2.99, $p<0.001$) between the different areas (Schill et al. 2015). Fish richness of Fort Liberté was significantly different from all other zones within the park. There was an inshore to offshore pattern of fish richness, as fish richness at inshore zones significantly varied from offshore zones . This could be due to the seine fishing that occurs mostly at inshore over seagrass or patch reef habitats. Coral reef habitats were located at these offshore zones, therefore explaining the high species richness of these zones. As shown in the fishing pressure model (Schill et al. 2015), the fishing intensity is concentrated in Caracol and Limonade region. Fish biomass was the highest at outer forereefs in Fort Liberté, therefore in line with the fishing pressure model.

Conclusion

In conclusion, coral reefs presented the highest species diversity of fish species. Out of all the coral reef habitats surveyed, *Orbicella* reefs exhibited the highest fish diversity. These reefs were located on the outside of Fort Liberté Bay, to the east of the bay opening. A coral reef site of special concern was at site FL-12 (*Orbicella* reef). The structural complexity at the reef crest was high, which dropped sharply to a well-developed *Orbicella* reef. The high structural complexity and the high overall coral cover allowed for the high fish diversity at this site. Overall, the marine habitats within and outside the bay of Fort Liberté exhibited the highest species richness coral reef fishes. We observed a new species of hamlet that was only observed in bay of Fort Liberté. In accordance with benthic invertebrates, the habitats of Fort Liberté should be designated as areas of importance.

As seen in Schill et al. (2015) report, there is a strong demographic connectivity between the coral reefs along the north coast of Haiti and Cuba, Bahamas, Dominican Republic, and Puerto Rico. The exchange of larvae between these countries will influence the demographics and dynamics of marine populations. Given the size frequency of the reef fishes in 3BNP, there is a high larval connectivity with downstream coral reefs. Fish larvae from other sources, not within 3BNP, are recruiting to the marine habitats of 3BNP. Therefore, it is essential to properly manage the fisheries resources to avoid a fisheries collapse. Strict protective measures are needed for parrotfishes and apex predators. Outer corals reefs in Caracol and Limonade exhibited high fleshy macroalgal abundance, indicative of an unhealthy reef state. Increasing herbivore abundance and biomass by protecting parrotfish should be a management priority.

Synthesis and Recommendations

Despite continuous human activity within 3BNP over many centuries, significant native biological flora and fauna still occur in the area and within the Park. Our surveys documented 179 native vascular plant species, 37 species of wetland plants, 95 species of birds, 4 species of amphibians, 11 species of reptiles, 14 species of freshwater fish, 33 species of invertebrates, 301 species of marine sessile- and motile-benthic organisms, and 183 different species of marine fishes. Furthermore, several rare and endemic species that were either verified or reported for the first time within the Park. This includes 5 IUCN redlisted plant species, a freshwater fish (*Limia pauciradiata*) within the Rivière Trou du Nord (TDN), and a reef fish (*Hypoplectrus spp.*) found only within Fort Liberté Bay (FLB). The total species numbers are comparable to species inventories from other Caribbean Islands despite the absense of native land mammals, marine mammals (manatees, dolphins, whales), sea turtles, elasmobranchs (sharks), and larger-bodied groupers and snappers. Most slow-growing and large-bodied species are likely now ecologically extinct (e.g. nonbreeding populations) within the Park.

A detailed description of the threats to 3BNP can be found in Kramer et al. (2016). Here we highlight a few of the key threats and describe how these threats are playing out in the four principal ecolgical systetms (Caracol, Limonade, Fort Liberté, and Lagon aux Boeufs).

Management Recommendations

While threats continue to put both habitats and species at risk, there are good reasons for optimism that the remaining biodiversity can be preserved and even restored, provided that human use within the Park boundaries can be managed to balance ecological and human interests. The following is a summary of the recommendations for the management of 3BNP to protect its biodiversity into the 21st century. The management recommendations are grouped into 3 distinct tiers with different scales and actions associated with each: 1) large-scale physical and ecological processes; 2) habitats; 3) species.

1. Recommendations for large-scale physical and ecological processes

Fresh water flows: The seasonal flows of freshwater through the Haitian northern coast floodplains of 3BNP are an essential feature that supports the estuarine conditions and many of the habitats, marine species, and other freshwater and terrestrial species that utilize the rivers and riparian corridors. The freshwater flows are the lifeblood of the estuaries. Fortunately, freshwater flows on the north coast of Haiti are, for the most part, currently unimpeded as large dams and other water impoundments and diversions are few. However, increasing demand for controlling freshwater flows to support hydropower, agriculture, and coastal development and reduce storm related flooding are creating more and more pressures to alter the natural flows. From a biodiversity perspective, maintaining freshwater flows and the hydrologic connectivity that allow

species to move through the rivers is an essential process that allows many populations to persist. The freshwater flows also provide freshwater and nutrients into the coastal waters. Shallow water seagrass communities and mangroves benefit from the freshwater flows which create brackish water gradients near the river mouths. This type of habitat is essential for many estuarine species to reproduce. While estuarine conditions depend on the amount of freshwater entering, they also depend on the morphology of the bay – Caracol Bay has reduced flushing/long residence times of estuarine conditions because of its semi-closed morphology and extensive shallow waters that limit tidal exchange. In contrast, the geomorphology at the mouth of the Grande Rivére du Nord (GRDN) in Limonade is more open and deep, resulting in high flushing rates of tidal marine waters and shortened residence times despite the much greater volumes of freshwater. Recommendations for freshwater flows include:

- Conduct a detailed hydrological assessment of each of the river systems of 3BNP and identify existing and potential water uses.
- Regulate or limit the construction of major dams, impoundments, or diversions from the river systems of 3BNP, particularly for the TDN river system as it directly supports the rich estuarine fishery of Caracol Bay.
- In cases where freshwater diversions or barriers already exist, or where human and economic interests (e.g. hydropower) outweigh ecological interest, implementing an integrated water management framework to regulate freshwater discharges both upstream and downstream in support to the natural estuarine processes is highly recommended. Olson et al. (2006) has an overview of the methods.

Biological connectivity: Permitting free movement of adult animals through the waters and lands of 3BNP allows migration, mating, and reproduction – processes essential for species to persist. Fragmentation and barriers to movement are particularly problems on the terrestrial side. The waters of 3BNP remain largely connected, but trammel fishing nets, roads, or footpaths associated with expanding coastal development that occur across tidal channels and small rivers pose a threat to connectivity. Fences, roads, and habitat loss on land have fragmented much of the terrestrial areas and limited species movements. For marine areas, biological connectivity also includes the exchange of larvae from outside of the Park. External sources of larval input may come from less exploited deeper reefs and better managed areas in the Dominican Republic and Cuba. Connectivity should be managed with the following recommendations:

- Manage public lands (mostly found around Fort Liberté and Lagon aux Beoufs) to allow the movement of species by limiting fences and keeping corridors for movement open.
- Prohibit laying fishing nets (e.g. trammel, gill, seines) or other impediments to migration across an entire water body, particularly at river mouths and in tidal channels.
- Conduct more detailed scientific studies to characterize the movement of different species particularly inside and outside of the estuarine/freshwater complex.

Water quality: Water quality is critical for the health and survival of much of the biota of 3BNP, and this includes humans. Land based sources of pollution (LBSP) such as sediments eroded from hillsides, nutrients, pesticides, plastics, sewage, and a variety of chemicals mostly derive from human activities within the watersheds. Hundreds of tons of sediment and pollutants may be carried by rivers into the bays and estuaries of 3BNP each year. While nutrients are essential to support estuarine production, too much nitrogen or phosphorous can overwhelm a system and cause large algal blooms and fish die offs. Similarly, large amounts of pollutants like heavy metals and other toxins can cause human and environmental health issues. Freshwater ecosystems and nearshore marine waters are most at risk, but the mobile nature of pollutants also puts the entire park at risk.

At the moment, land management policies and economic incentives for reducing LBSP are not actively practiced in 3BNP to keep/produce clean water for freshwater and estuarine/marine species. Inland lagoons such as Lagon aux Boeufs are particularly sensitve to water quality and hydrological balances given their semi-closed nature. Sheet flow from surrounding lands during large storm events bring pulses of nutrients and other pollutants into the lagoon causing a nearly perpetual algal bloom. Regular algal blooms threaten fisheries, livelihoods, and other critical ecosystem services. During the June 2015 site visit, the system appeared to be undergoing a eutrophic period. Water quality was poor (oxygen was measured at 1.3mg/L ±0.6mg/L) and clouded with dense algae that emitted a foul odor, likely associated with a dense bloom of the green algae, *Chara* sp. Community members informally interviewed confirmed the algal bloom and its impact on fish, further indicating their concern for unregulated mangrove cutting and the potential danger of the dense proliferation of nuisance algae. Water quality management recommendations include:

- Undertake a more detailed assessment to identify point sources of sewage, toxins, or other pollutants within each of the river systetms of 3BNP.
- Prioritize areas with the greatest pollution problems and implement actions (e.g. setbacks, water treatment, holding ponds, trash clean-ups, banning car washing, etc.) to improve water quality.
- Develop abiotic and biotic indicators of water quality within the Park and implement a monitoring program to track trends (see separate 3BNP monitoring report)
- Limit industrial activities within the Caracol Industrial Park (PIC) so that the discharge of industrial waste waters with potentially toxic components are not allowed. Ensure the PIC is implementing a rigorous water quality monitoring program that prevents excessive pollutants from entering the TDN river and adjacent Caracol Bay.

2. Recommendations for habitats

Healthy and connected habitats are essential to supporting the biological communities and individual species that form the basis of biodiversity. Habitats are often more

resilient than some of the individual species that engineer them or reside in them. Well over 20 distinct natural habitat types were mapped as part of this assessment. Protecting and maintaining remaining patches of intact natural habitat by reducing destructive activities should be an overarching goal for the management of the Park. On land, native habitats have been heavily altered by human activity and no longer support the communities and species that they once did. In these cases, management goals should include restoration of native habitats through rehabilitation. More detailed recommendations within the 3 principal relms based on our assessment are provided below.

Terrestrial/Mangrove:

- **Protect diversity hotspots:** Terrestrial diversity hotspots occur in a few places of 3BNP that have experienced only minor alterations or that support a large number of species that forage or breed. Implemeting zoning and management around these areas will reduce further loss and in some cases allow populations to be stabilized and expanded. Based on this assessment, priority areas should include:
    - Morne Deux Mamelles between Fort Liberté and Caracol Bay.
    - The outer portions of the Fort Liberté Peninsula, east from the bay to the Haitian/Dominican border. These areas contain relatively intact Dry Broadleaf Evergreen-Shrubland habitat.
    - The tidal brackish community near the mouth of the Grande Rivière du Nord at the western edge of the Park.
    - The well-developed mangrove forest around Lagon aux Boeufs.
    - Grand saline and similar ephemeral ponds and lagoons
- **Designate selective harvest areas:** Given the inevitability of present and future unmanaged harvesting for charcoal production, consider identifying locations for selective harvest. These should be in areas with low biodiversity dependence (fish, birds, other) and where harvesting can be controlled. This approach could be done in tandem with a rigorous enforcement and restoration efforts.
- **Develop reforestation plans:** Identify altered or degraded sites for restoration. Criteria may include ease of access, quality of habitat, ecological significance, likelihood of success, engagement of local or nearby community/leadership, etc.
- **Control the spread of invasive plant species:** Encourage the use of *A. farnesiana* as a fuel source for charcoal, while reducing usage of native species – in particular species which may be at risk, such as *Guaiacum sanctum* and mangroves. In altered agricultural areas, encourage the removal of non-native and/or invasive species.

Freshwater:

- **Protect riverine corridors:** Conservation zones along the edges of the rivers should be created to act as buffers for erosion and to enhance water quality.
- **Restore riparian vegetation:** Most of the native riparian vegetation within river corridors has been removed and replaced with non-native species (e.g. mango trees) that flourish in the rich soils. This has had detrimental effects on native amphibians and reptiles. Efforts should be made to re-establish more of the

native vegetation along the riparian corridors and reintroduce locally extinct species.

- **Control sand mining:** Sand mining after high water events removes much of the sand from the river bed in areas that are accessible via roads. Removal of sand and changing the river bed can affect freshwater invertebrates and fishes that utilize the bottom. It also can increase bed loads downstream of the mining. The practice should be banned within 3BNP and regulated for areas upstream of the Park.
- **Protect and maintain deep water pools:** During the dry season, flows of freshwater in many of the rivers drop to the point where river beds become dry. Many of the freshwater fishes and invertebrates retreat to the deepest pools where water may persist for months. Protecting these pools from intense fishing during the dry season is recommended. In some cases, deepening these pools to allow more water can also ensure that species will survive the dry season.

Marine:

- **Protect diversity hotspots:**
  - *Fort Liberté Bay and surrounding reefs*: Marine habitats within and outside the bay of Fort Liberté exhibited the highest species richness of sessile- and motile-benthic invertebrates. Coral reef habitats close to the channel and outside the bay should be designated as areas of importance. These reefs should be protected from fishing and other anthropogenic pressures. Consider designating multiple-use zones, such as no-take areas, snorkeling, and/or diving zones for this area.
  - *The western edge of 3BNP*: Near Limonade, the western edge of 3BNP contains an unusual assemblage of inshore patch reefs that are heavily influenced by adjacent delta sediments from the Grande Rivière du Nord. Despite their marginal reef environment, there is unusually high diversity of marine invertebrates (e.g. sponges, anemomies, and soft corals) and should be zoned for greater levels of protection.
- **Restrict dredging and infilling:** Nearshore waters, particularly around Fort Liberté Bay, are prone to habitat loss caused by coastal development. Management plans should closely regulate coastal development activities within 3BNP to minimize impacts to shallow marine habitats.
- **Control and eliminate destuctive fishing practices:** Some of the fishing practices within 3BNP cause damage to the sea bed. These include trawling, dragging seine nets over reef areas, and using fish pots on hard-bottom/reef areas. Dynamite fishing is another practice that has the potential to cause tremendous habitat destruction. These destructive practices should be heavily regulated and eventually eliminated within the waters of 3BNP.

3. Recommendations for species

Maintaining the biodiversity of 3BNP not only depends on healthy and connected habitats that are essential to supporting the biological communities and individual species, but also managing the individual species themselves. Within 3BNP, 216

species of plants and 641 species of terrestrial, freshwater, and marine organisms were identified. Protecting and maintaining these species, and possibly increasing the number of species by reducing the hunting/harvesting, habitat destruction, and other activities which are obstructive to their growth should be one of the main goals for the management of the Park. As mentioned earlier, human activity has heavily altered native land habitats and they no longer support the communities and species they did previously. Management goals which include restoration of native habitats will help to also restore native species that rely on these habitats. More detailed recommendations within the 3 principal relms based on our assessment are provided below.

Terrestrial:

- **Control human harvesting or hunting of native species:** The threats assessment found that killing of birds for sport and consumption continues to occur within 3BNP (although it does not appear to be that widespread). For larger, slow-growing bird species, hunting can not only extirpate them but also create a challenging environment for them to be reintroduced. Within the management plan, hunting of all birds within 3BNP should be prohibited. Efforts should be made to enforce no hunting policies particularly in and around Lagon aux Boeufs.
- **Control the spread of invasive predators:** Cats, dogs, and mongoose are all non-native predators that occur throughout 3BNP. In a feral state, they will consume what ever they can to survive – often this results in the extirpation of smaller native prey including reptiles and amphibians, as well as native mammals. Extirpation of these non-native predators is costly and unrealistic given that many of them are very well established. However, controlling them in sensitive areas of 3BNP with the use of trapping programs should be included as part of the management plan.

Freshwater:

- **Protect endemic freshwater fish:** One of the freshwater fish, *Limia pauciradiata*, was only found within the TDN river system although it was previously reported in the GRDN. Efforts should be made to understand its life cycle and distribution, and human activities that put it at risk. The management plan should focus on minimizing impacts to the TDN river system where it is presently found.
- **Regulate fresh water fish farming:** Fish farming of non-native freshwater fish including Tilapia is already widespread and appears to be expanding on the north coast. The non-native species have the potential of displacing native species and in many cases are directly competing with them for food and habitat resources. Limiting fish farming operations to “closed system” farms rather than utilizing existing natural water bodies within the Park is recommended.
- **Control the spread of invasive species:** Freshwater systems and associated riparian buffer areas already contain a large number species. Many of these are non-native and displace or consume native species. Although some of these species are already well-established and removing them will be very difficult,

efforts should be made to control undesirable species. This may be done by setting up an incentive program with local fishermen.

Marine:

- **Reduce overfishing of reef fish:** Overfishing has already affected the species richness, abundance, and size of reef fish in the Park. Whether managing human activities and/or creating alternative livelihoods for fishers, effective management of fishing within 3BNP is needed for these systems to persist in the future.
- **Protect and reintroduce rare and locally extinct species:** Efforts should initially be focused on large species – sea turtles, manatees, dolphins, whales, sharks, and rays – that are currently almost absent within 3BNP. The endemic hamlet reef fish found only within Fort Liberté Bay is another high priority species for management.
- **Educate fishers:** Fishers need to be educated and offered more resilient and adaptable livelihoods that are tailored to their existing skill set and knowledge (Mumby et al. 2015). For example, fishers can be trained to give guided tours for tourists visiting the marine park, which can include snorkeling on the coral reefs and/or kayaking through the mangrove channels.
- **Provide alternative livelihoods to fishers:** Aquaculture, or fish farming, could diversify the livelihoods of fishers. Mariculture, which is the cultivation of marine organisms in (an enclosed section of) the ocean, and closed-contained systems are possibly viable options to increase income and job sustainability of Haitians. There are some environmental risks such as nutrification when employing these types of fish farming. However, there is a new generation of aquaculture technology that could be considered. It operates entirely on land in a closed-contained system and expels zero waste (see research by Dr. Yonathan Zohar at Institute of Marine and Environmental Technology).
- **Control non-native species:** Lionfish (*Pterois volitans*) is a highly invasive, predatory fish species that has been shown to negatively impact the natural communities on coral reefs all around the Caribbean. Lionfish abundance in the marine park was low and apparently fishers actively catch these fish. Fishers should be encouraged to continue landing lionfish, in order to keep the numbers low.

Scientific gaps of 3BNP

The baseline species inventories carried out during this assessment provide an initial characterization of the habitats and some of broad patterns of diversity and the presence of threatened and endemics species. This scientific information forms a preliminary scientific input to the development of the management and zoning plan for the Park. However, scientific knowledge of 3BNP remains in the early stages and many gaps still need to be filled. These include:

- **Deep water areas (>30 m):** The deeper waters of 3BNP constitute a large proportion of the area and bisect the Septarian fault trench, but remain largely uncharacterized. Mapping these deep water areas systematically using deep

water acoustic techniques would provide information on a variety of species living at depths greater than 30m. Investigating these seafloor habitats will improve management and zoning plans for the Park.

- **Other taxa:** Investigations were limited to the more charasmatic flora and fauna, but a large proportion of the total species biodiversity remain to be characterized. Gaps include the infaunal communities found within sediment and sand habitats (mollusks, gastropods, polychaete worms), insects (arachnids, butterflies, beetles), submerged aquatic vegetation (marine algae), and also microbial communities.
- **Biolgical community structure and function:** For many of the species identified during this assessment, there remains gaps in our understanding of the population size, age distribution, reproductive output, survivorship, and interactions with other species. More detailed biological investigations of communities targeting rare or endangered species should include quantitative sampling, tagging, and tracking of movement and reproduction.
- **Genotypic diversity:** The majority of the scientific inventories conducted within 3BNP have relied on phenotypic characteristics to identify and document species. Differences between and within species could be further developed by employinig laboratory genotyping for many of the taxa, particularly in cases where a solid genotypic library already exists (e.g. for acroporid corals, selected reef fish, most birds and reptiles, selected freshwater fish, and invertebrates).
- **Other:**
    1) More detailed studies that quantitatively characterize the various human activities occurring in the rivers and streams are needed.
    2) The overall water quality of the Lagon aux Beoufs needs to be characterized and studies directed to the sources of its eutrophication need to be implemented.
    3) A more systematic characterization of the different fisheries and the extent of human harvest of fish and invertebrates in 3BNP is greatly needed. Quantitative data on landings (daily, weekly, monthly) by species, locations (where harvested), and other information are needed for policy development.
    4) The impacts of deforestation and other human activities in the uplands need to be characterized and assessed to determine how existing and future changes in the watershed are affecting the water quality and hydraulic flow of the rivers and streams.

*Monitoring Plan***:** Understanding the trends across the tiers of threats, habitats, biological communities, and species within 3BNP are essential elements for management. While this assessment provides a valuable baseline for all of these components, to get an understanding of trends requires repeat monitoring over several time periods. This information can then be fed back and incorporated into management actions.

Conclusion

The biodiversity inventories of 3BNP have revealed that significant species richness remains in each of the three major relms; the largest and most intact biodiversity is found in the marine areas. Furthermore, a number of rare and endemic species appear to occur only with 3BNP and should be prioritized in the management plan to ensure their populations persist. Many species and their habitats provide essential services to the communities around the Park and have the potential to be the basis for future ecotourism developments. Extensive human use going back hundreds of years has removed or seriously depleted a number of native species from the area, while current and continuing threats put the remaining species and their intact habitats at risk. Essential to the continued persistence of the remaining biodiversity is the preservation of remaining intact habitats and the establishment of a functioning park with a management plan, zoning, and enforcement to regulate human use within the Park boundaries.

The management recommendations outlined here are directed towards maintaining the processes, habitats, and populations of native species found within 3BNP. Recommendations are designed to inform the management and zoning plans. All of the information will be made available in standardized digital format. GIS maps of terrestrial and benthic habitats along with mapped and modeled threats provide a standardized and up-to-date baseline for the Park. Furthermore, documented species occurences encountered during the field surveys have been published into a standardized biodiversity systematics database (Darwin Core Archive) (http://tools.gbif.org/dwca-assistant/). It is our hope that this information will form the beginning of a comprehensive ecological database for 3BNP that can be used to guide decision-making, as well as future scientific studies for the area.

References

Acevedo-Rodríguez, P and MT Strong (2012) Catalogue of the seed plants of the West Indies. Smithsonian. *Contributions to Botany*. **98**: 1192

Alcolado, PM, R Claro-Madruga, G Menéndez-Macías, P García-Parrado, B Martínez-Daranas, M Sosa (2003) The Cuban coral reefs. Cortés J ed In: Latin American coral reefs, Elsevier Science

Allen, JD and MM Castillo (2007) Stream ecology, structure and function of running waters. *Springer.* 436p

Alongi DM (2008) Mangrove forests: Resilience, protection from tsunamis and response to global climate change. *Estuarine Coastal and Shelf Science.* **76**: 1-13

Anderson, MJ, RN Gorley, KR Clarke (2008) PERMANOVA+ for PRIMER: guide to software and statistical methods. PRIMER-E, Plymouth, UK

Areces-Mallea AE, A Weakley, X Li, RG Sayre, JD Parrish, CV Tipton, T Boucher (1999) A Guide to Caribbean Vegetation Types: Preliminary Classification Systems and Descriptions. *The Nature Conservancy*, Arlington VA.

Aube M and L Caron (2001) The mangroves of the north coast of Haiti. *Wetlands Ecology and Management*. **9**: 271-278

Beebe, W (1928) Beneath Tropic Seas: A record of diving among the coral reefs of Haiti. G P Putnam's Sons, New York. 134, 199

Bond J (1928) The Distribution and Habitats of the Birds of the Republic of Haiti. *Proceedings of the Academy of Natural Sciences of Philadelphia*. **80**: 483-521

Braun-Blanquet J (1965) Plant Sociology: The Study of Plant Communities. London: Hafner, 439p

Chace Jr., FA, and HH Hobbs Jr (1969) The Freshwater and Terrestrial Decapod Crustaceans of the West Indies with Special Reference to Dominica. Washington, D.C. *United States Bulletin* 292p

Chambers J (1987) The cyprinodontiform gonopodium, with an atlas of the gonopodia of the fishes of the genus Limia. *Journal of Fish Biology*. **30**: 389-418

Clarke HD, DS Seigler, JE Ebinger (1989) *Acacia farnesiana* (Fabaceae: Mimosoideae) and Related Species from Mexico, the Southwestern U.S., and the Caribbean. *Systematic Botany*. **14**: 549-564

Cline JD (1969) Spectrophotometric determination of hydrogen sulfide in natural waters. *Limnology and Oceanography*. **14**(3): 454–458

Cohen, SN, JU Regus, Y Reynoso, T Mastro, DN Reznick (2015) Comparative life histories of fishes in the subgenus Limia (Pisces: Poeciliidae). *Journal of Fish Biology*. **87**: 100-114

Collar NJ, LP Conzaga, N Krabbe, A Madrono Nieto, LG Naranjo, TA Parker III, DC Wege (1992) Threatened Birds of the Americas: the ICBP/IUCN Red Data Book. International Council for Bird Preservation, Cambridge, UK, 1150p

Crowl, TA and AP Covich (1994) Responses of a freshwater shrimp to chemical and tactile stimuli from a large decapod predator. *Journal of the North American Benthological Society*. **13**(2): 291-298

De Grave, S, CHJM Fransen (2011) Carideorum catalogus: the recent species of the dendrobranchiate, stenopodidean, procaridid ean and caridean shrimps (Crustacea: Decapoda). *Zoologische Mededelingen Leiden.* **85**(9): 195-589

Ellison AM and EJ Farnsworth (1997) Simulated sea level change alters anatomy, physiology, growth, and reproduction of red mangrove (*Rhizophora mangle* L.). *Oecologia*. **112**: 435-446

Ellison AM and EJ Farnsworth (1996) Anthropogenic disturbance of Caribbean mangrove ecosystems: Past impacts, present trends, and future prediction. *Biotropica*. **28**: 549-565

FAO (2007) *The World's Mangroves, 1980-2005 : A Thematic Study in the Framework of the Global Forest Resources Assessment 2005*. Rome, Italy: Food and Agriculture Organization of the United Nations, 77p

Farnsworth EJ, AM Ellison, WK Gong (1996) Elevated CO_2 alters anatomy, physiology, growth and reproduction of red mangrove (*Rhizophora mangle* L.). *Oecologia.* **108**: 599-609

Froese, R and D Pauly (2015) FishBase. World Wide Web electronic publication. www.fishbase.org

Grizzle, RE (1994) Thinking of Biology: environmentalism should include human ecological needs. *Bioscience*. **44**(4): 263-268

Hadden, RL and SG Minson (2010) The Geology of Haiti: an annotated bibliography of Haiti's Geology, Geography and Earth Science. US Army Corps of Engineers, Army Geospatial Center. Alexandria, VA. 256p

Hart JR, CW (1961) The Freshwater Shrimps (Atyidae and Palaemonidae) of Jamaica, W.I.: With a Discussion of Their Relation to the Ancient Geography of the Western Caribbean Area. *Proceedings of the Academy of Natural Sciences of Philadelphia*. **113**: 61-80

Hay, ME (1984) Patterns of fish and urchin grazing on Caribbean coral reefs: Are previous results typical? *Ecology*. **65**: 446-454

Hedges SB (2015) Caribherp: West Indian amphibians and reptiles. Pennsylvania State University, University Park, Pennsylvania. Address URL: http://www.caribherp.org/index.php?il=Haiti&so=class,%20ord,%20subord,%20family,%20species&vw=y&dd=n&mob=y Consulted on 22/01/15

Hedges SB and CE Conn (2012) A new skink fauna from Caribbean islands (Squamata, Mabuyidae, Mabuyinae). *Zootaxa*. **3288**: 1-244

Hoegh-Guldberg, O, and JF Bruno (2010) The impact of climate change on the world's marine ecosystems. *Science*. **328**: 1523-1528

Howard RA (1952) The Society of Plant Taxonomists' Plaque Honoring Erick L. Ekman. *Bulletin of the Torrey Botanical Club*. **79**(1): 80 – 84

IPCC (2013) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 153p

IUCN (2015) www.iucnredlist.org/search

Kramer, P, M Atis, and S Schill (2016) Threat assessment for Three Bays National Park, Haiti. *The Nature Conservancy: Report to the Inter-American Development Bank.* Pp.1-58

Lara, A, JLP de Leon, R Rodriguez, C Dider, G Cote, L Bernatchez, E Garcia-Machado (2010) DNA barcoding of Cuban freshwater fishes: evidence for cryptic species and taxonomic conflicts. *Molecular Ecology Resources.* **10**: 421-430

Latta S, C Rimmer, A Keith, J Wiley, H Raffaele, K McFarland, E Fernandez (2006) Les oiseaux d'Haïti et de la République Dominicaine. Princeton University Press, 279p

Lee, DS, SP Platania, GH Burgess (1983) Atlas of North American Freshwater Fishes. *North Carolina Biological Survey*. Contribution No. 1983-6

Lessa G and G Masselink (2006) Evidence of a mid-Holocene sea-level highstand from the sedimentary record of a macrotidal barrier and paleoestuary system in northwestern Australia. *Journal of Coastal Research*. **22**: 100-112

Lewis LA and WJ Coffey (1985) The continuing deforestation of Haiti. *Ambio*. **14**(3): 158-160

Logier AH (1981 – 2000) La Flora de la Espanola. *Phytologia Memoirs*. **1 – 9**

Lucinda, PHF (2003) Poeciliidae (Livebearers). In R.E. Reis, S.O. Kullander and C.J. Ferraris, Jr. (eds.) Checklist of the Freshwater Fishes of South and Central America. *Porto Alegre: EDIPUCRS, Brazil*. 555-581

Lugo AE and SC Snedaker (1974) The ecology of mangroves. *Annual Review of Ecology and Systematics.* **5**: 39-64

Lugo AE, S Brown, MM Brinson (1990) Concepts in Wetland Ecology. *In*: Lugo, AE, Brinson MM, Brown S (ed.), *Forest Wetlands: Ecosystems of the World*. Amsterdam, The Netherlands: Elsevier. **15**: 53-85

Lundahl M (2001) Poorest in the Caribbean: Haiti in the Twentieth Century. *Integration & Trade.* **5**: 177-200

Ménanteau L. & Vanney J.-R. (coord. scient. / *edi to rs),* 1997. *Atlas* côtier *du Nord-Est d'Haïti. Environnement* et *patrimoine culturel de la région de Fort-Liberté.* Port-au-Prince / Nantes. Ed. Projet "Route 2004".Ministère de la Culture (Haïti) / PNUD, iv+62 p.

McCoy, CMR, CR Dromard, JR Turner (2009) An evaluation of Grand Cayman MPA performance: A comparative study of coral reef fish communities. Proceedings of the 62nd Gulf and Caribbean Fisheries Institute, Cumana Venezuela

McKee K, K Rogers, N Saintilan (2012) Response of salt marsh and mangrove wetlands to changes in atmostpheric CO_2, climate, and sea level. *Global Change Ecology and Wetlands.* **1**: 63-69

McKoy, SA, EJ Hyslop, RD Robinson (2011) Associations between two trematode parisites, an ectosymbiotic annelid, and *Thiara* (Tarebia) *Granifera* (Gastropoda) in Jamaica. *Journal of Parasitology.* **97**(5): 828-832

McMahon K, C Collier, PS Lavery (2013) Identifying robust bioindicators of light stress in seagrasses: meta-analysis. *Ecological Indicators*. **30**: 7-15

Miller, J (2015) Rapid Fisheries Sector assessment-Three Bays National Park-North East Haiti. The Nature Conservancy, Carribean Marine Biodiversity Program. July 28-August 28, 2015, 41p

Miller, MW (2003) Status of reef resources of Navassa Island: Nov 2002. NOAA Technical Memorandum NMFS-SEFSC-501:119

Miller, MW, A Gleason, D McClellan, G Piniak, D Williams, JW Weiner, A Gude, J Schwagerl (2008) The state of coral reef ecosystems of Navassa Island. In: Waddell JE and AM Clarke (eds) The state of coral reef ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team, Silver Spring, MD. 114-128

Miller, MW, M Vermeij, DE Williams, DB McClellan, B Yoshioka (2003) Benthic habitats and community structure. In: Miller MW (ed) Status of reef resources of Navassa Island: Nov 2002. NOAA Technical Memorandum NMFS-SEFSC-501: 6-24

Miller, MW and DE Williams (2007) Coral disease outbreak at Navassa, a remote Caribbean island. *Coral Reefs*. **26**: 97-101

Moore GE (2014) Assessment of the mangroves and coastal wetlands of Ile a Vache, Haiti: Opportunities for ecosystem based adaptation and restoration. *Technical Report prepared for The Nature Conservancy, Central Caribbean Program.* 19p

Mori GM, MI Zucchi, I Sampaio, AP Souza (2015) Species distribution and introgressive hybridization of two *Avicennia* species from the Western Hemisphere unveiled by phylogeographic patterns. *BMC Evolutionary Biology*. **15**(1): 61

Moss, B (2010) Ecology of freshwaters, a view for the twenty-first century. Wiley-Blackwell Publishers. 470p

Nadia TDL, NL De Menezes, IC Machado (2013) Floral traits and reproduction of *Avicennia schaueriana* Moldenke (Acanthaceae): a generalist pollination system in the Lamiales. *Plant Species Biology.* **28**: 70–80

Neal, JW, CG Lilyestrom, TJ Kwak (2009) Factors influencing tropical island freshwater fishes: species, status, and management implications in Puerto Rico. *Fisheries*. **34**: 546-554

New, MB, WC Valenti, JH Tidwell, LR D'Abramo, MN Kutty (2010) Freshwater prawns, Biology and farming. Blackwell Publishing. 544p

Nogales ME, E Vidal, FM Medina, E Bonnaud, BR Tershy, KJ Campbell, ES Zavaleta (2013) Feral cats and biodiversity conservation: The urgent prioritization of island management. *Biosciences.* **63**: 804-810

O'Farrell, S, AR Harborne, Y Bozec, BE Luckhurst, PJ Mumby (2015) Protection of functionally important parrotfishes increases their biomass but fails to deliver enhanced recruitment. *Marine Ecology Progress Series*. **522**: 245-254

Olson, SB, TV Padma, BD Richter (2006) Managing Freshwater Inflows to Estuaries: A Methods Guide. *USAID*. 1-52

Perera, AAV, SP Valderrama (2011) Endemic Freshwater molluscs of Cuba and their conservation status. *Tropical Conservation Science*. **3**: 190-199

Perkis, S. (2015) Sumary Report of WorldView-2 satellite Mapping of Benthic Habitat and Bathymetry for Caracol and Ft. Liberte Bay, Haiti. Contract report to The Nature Conservancy. 17 pages.

Perez-Reyes, O (2015) Population and Community Dynamics of Freshwater Decopods in Response to Ecological and Anthropogenic Factors in Subtropical Streams in the Caribbean. All Graduate Theses and Dissertations. Paper 4501.

Pezold, F and B Cage (2001) A review of the spinycheek sleepers, genus *Eleotris* (Teleostei: Eleotridae), of the western hemisphere, with comparison to the West African species. *Tulane Studies in Zoology and Botany.* **32**: 12-57

Pezold, F, J van Tassell, KA Aiken, L Tornabene, JL Bouchereau (2015) Eleotris perniger. The IUCN Redlist of Threatened Species 2015: http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T185990A1799642.en.

Pointier, JP (2008) Guide to the freshwater molluscs of the Lesser Antilles. Hackenheim, Germany: ConchBooks.

Pointier, JP, M Yong, A Gutierrez (2005) Guide to the freshwater molluscs of Cuba. Hackenheim, Germmany: ConchBooks.

Polidoro B, K Carpenter, L Collins, N Duke, A Ellison, J Ellison, E Farnsworth, E Fernando, K Kathiresan, N Koedam, S Livingstone, T Miyagi, G Moore, V Nam, J Ong, J Primavera, S Salmo, J Sanciangco, S Sukardjo, Y Wang, J Yong (2010) The Loss of Species: Mangrove Extinction Risk and Failure of Critical Ecosystem Services. *PLoS One*. **5**(4): 1-10

Reef Check (2003) Reef Check training and coral reef monitoring in Haiti: A preliminary report. Reef Check

ReefFIX (2009) Rapid assessment of the economic value of ecosystem services provided by mangroves and coral reefs and steps recommended for the creation of a Marine Protected Area Caracol Bay, Haiti. Organization of American States (OAS) and the Inter-American Biodiversity Information Network (IABIN)

ReefFIX (2013) Toward the development of Haiti's system of marine protected areas (MPAs): An ecosystem services assessment for the creation of Haiti's system of MPSs rev. 1. Organization of American States (OAS) and Fondation pour la Protection de la Biodiversité Marine (FoProBiM)

Reis, RE, SO Kullander, CJ Ferraris (2003) Check List of the Freshwater Fishes of South and Central America. Family Poeciliidae (Livebearers). 555-581p

Remane, A and C Schlieper (1971) Biology of brackish water. John Wiley & Sons, New York. 372p

Rivas, LR (1980) Eight new species of poeciliid fishes of the genus *Limia* from Hispaniola. *Northeast Gulf Science.* **4**: 28-38

Scavia D, JC Field, DF Boesch, RW Buddemeier, V Burkett, DR Cayan, M Fogarty, MA Harwell, RW Howarth, C Mason, DJ Reed, TC Royer, AH Sallenger, JG Titus (2002) Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries*. **25**(2): 149-164

Schill, SR, GT Raber, JJ Roberts, EA Treml, J Brenner, PN Halpin (2015) No reef is an island: Integrating coral reef connectivity data into the design of regional-scale Marine Protected Area networks. *PLos ONE.* **10**(12): e0144199

Secades CF (2010) Analyzing human-wildlife conflict reports and public awareness and perceptions of *Solenodonparadoxus* and *Plagiodontia aedium*, Hispaniola's last endemic
mammals (West Indies). (MSc Thesis) Imperial College: London, 76p

Sergile F (2012) Haiti. Pp.193-204, in: Anadón-Irizarry, V, DC Wege, A Upgren, R Young, B Boom, YM León, Y Arias, K Koenig, AL Morales, W Burke, A Pérez-Leroux, C Levy, S Koenig, L Gape, P Moore. Sites for priority Biodiversity Conservation in the Caribbean Islands Biodiversity Hotspot. Birdlife International. 39p

Smith, DG and AM Weir (1999) On some Inland Crustacea and Their Habitats of Mona Island in the Northern Caribbean Region. *Crustaceana*. **72**(7): 635-646

Solomon S, D Qin, M Manning, RB Alley, T Berntsen, NL Bindoff, Z Chen, A Chidthaisong, JM Gregory, GC Hegerl, M Heimann, B Hewitson, BJ Hoskins, F Joos, J Jouzel, V Kattsov, U Lohmann, T Matsuno, M Molina, N Nicholls, J Overpeck, G Raga, V Ramaswamy, J Ren, M Rusticucci, R Somerville, TF Stocker, P Whetton, RA Wood, D Wratt (2007) Technical summary. In: Solomon, S, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, M Tignor, HL Miller (Eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Tercek, MR and JS Adams (2013) Natures Fortune: how business and society thrive by investing in nature. New York: Basic Books. 280p

Timyan J (1996) Bwa Yo: Important Trees of Haiti. *South East Consortium for International Development*. 429

Torati, LS, S De Grave, TJ Page, A Arthur (2011) Atyidae and Palaemonidae (Crustacea: Decapoda: Caridea) of Bocas del Toro, Panama. *Check List*. **7**(6)

Townsend JM, CC Rimmer, J Brocca, KP MacFarland, AK Townsend (2009) Predation of a wintering migrant songbird by introduced rats: Can nocturnal roosting serve as predator avoidance? *Condor.* **111**: 565-569

United State Army Corps of Engineers (USACE) (1999) Water resources assessment of Haiti. USACE, Mobile District, Mobile, AL. 93p

Valiela I, J Bowen, J York (2001) Mangrove forests: one of the world's threatened major tropical environments. *Bioscience*. **51**: 807–815

Weiner, J, G Cronin, T May, D Dubois (2013) Rapid Ecological Baseline Assessment Lower Trou du Nord River. Fondation pour la Protection de la Biodiversite Marine (FoProBiM). HA-T1184-SN1. www.FoProBiM.org

Weinstein, MP (2008) Ecological restoration and estuarine management: placing people in the coastal landscape. *Journal of Applied Ecology*. **45**: 296-304

Wetmore A and BH Swales (1931) Birds of Haiti and the Dominican Republic. *United States National Museum Bulletin Washington D.C.* **155**: 142-459

Williams, P, M Whitefield, J Biggs, S Bray, G Fox, P Nicolet, D Sear (2003) Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. *Biological Conservation.* **115**: 329-341

Williams, SM, I Chollett, G Roff, J Cortes, CS Dryden, PJ Mumby (2015) Hierarchical spatial patterns in Caribbean reef benthic assemblages. *Journal of Biogeography*. doi:10.1111/jbi.12509

Zanoni T, MM Mejía, JD Pimentel, RG García (1990) The Flora and Vegetation of the Haïtises, Dominican Republic. *Moscosoa.* **6**: 46-97

Appendices

Appendix 1. Materials and Methods

Ecological assessments, including 300 person survey days, were conducted June through November 2015 and focused on the following themes:

I. Terrestrial Vegetation
II. Mangrove and Coastal Wetlands
III. Birds and Terrestrial Mammals
IV. Freshwater Fauna
V. Marine Benthic Invertebrates
VI. Marine Fish

Site Description: Three Bays National Park is situated in the northeastern coast of Haiti, including the coastal watersheds and embayments of Grande Rivière du Nord at Bord de Mer de Limonade to the west, and Rivière du Massacre to the east (corresponding with the territorial boundary with the Dominican Republic). The Park includes major embayments at Caracol Bay, Fort Liberté, and Lagon aux Boeufs, each containing coastal wetland plant communities dominated by mangrove forests.

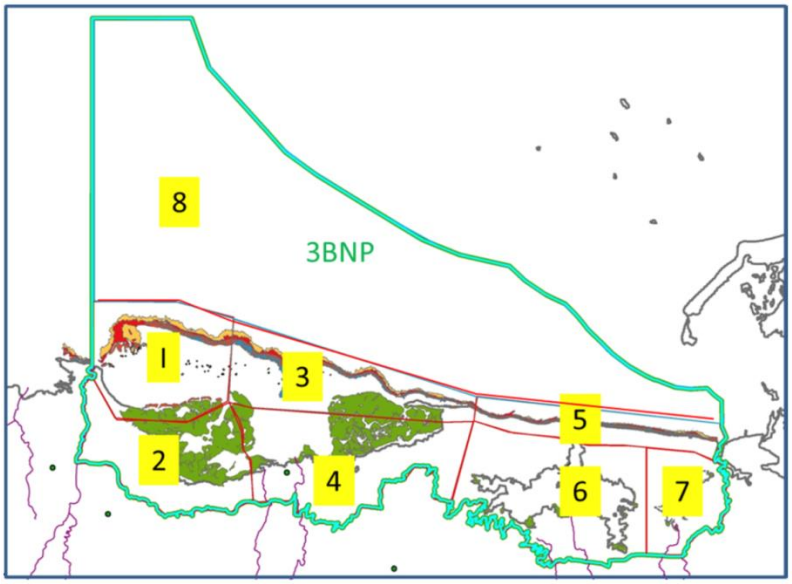

Figure A1-1 Regional subdivisions within 3BNP (Kramer et al. 2016).

For the REA, the area was divided into eight (8) regional subdivision zones based on geomorphology as defined by Kramer et al. (2016) (Figure A1-1). Zones 1 and 2 include the commune of Limonade (Bord de Mer de Limonade), comprising the eastern banks of the Grande Rivière du Nord, its watershed, and Limonade Bay; Zones 3 and 4 include the Commune of Caracol and Terrier Rouge, and Caracol Bay; Zones 5 and 6 include Fort-Liberté and Ferrier, and Fort Liberté Bay; Zone 7 includes Lagon aux Boeufs, a brackish lake of 450ha in the Commune of Ferrier (this brackish lake is

hydrologically linked to Rivière du Massacre, corresponding with the Haiti- Dominican Republic border); finally, Zone 8 covers the offshore section of the Park and thus, is not included in this report.

I. Terrestrial Vegetation

To provide a preliminary inventory and assessment of the flora and vegetation within 3BNP, a sampling plan for the area was developed that drew from satellite imagery coupled with site visits. Efforts were focused on identifying dominant vascular plants in the plant communities throughout 3BNP. Basic species lists for the park were produced using a walking transect methodology. Within each transect, each new plant species encountered was identified and recorded in a Rite in the Rain notebook. Digital imagery was taken of each habitat. Species nomenclature is based on Acevedo (2012). For species that could not be identified in the field, digital images were taken and sent to Herbaria for assistance with identification. No voucher specimens were collected during the August-September 2015 survey period. All species determinations should be considered preliminary.

Efforts were also made to determine if any IUCN Redlisted species were present within 3BNP. IUCN lists 53 species as Redlisted ranging from Criticially Endangered to Vulnerable (IUCN 2015). Removing those species that are merely vulnerable leaves 29 potential endangered species that may exist within Haiti. Of those 29, a desk survey of herbarium specimens and other population records eliminated 17 species as unlikely to occur in 3BNP based on their habitat requirements and previously known populations. Thus, there are 12 potential Redlist endangered plant species that have potential to be within the 3BNP area (Appendix 3).

***Land Use Land Class (LULC)*:** The REA-Botany focused on groundtruthing LULCs within 3BNP and describing the basic variation between them. A GPS was used to collect waypoints in as many different types of terrestrial vegetation types encountered during walking transects. Mangrove systems were purposely excluded from this assessment as they were investigated separately (see next section II: Mangroves and Coastal Wetlands). Natural habitats were all classified using standard approaches described by Areces et al. (1999).

To support the refined reclassification and mapping of LULC within 3BNP by The Nature Conservancy, a series of waypoints were taken in each identified mapable unit. For each point the vegetation type/cover, GPS coordinates (UTM), and four digital images (N, E, S, and W) were recorded.

Table A1-1. Land cover and distribution within each watershed that drains into the Three Bays National Park, including the area within the Park itself.

Grande Rivière du Nord watershed (627km^2)		**Rivière Trou du Nord watershed (428km^2)**	
Class	***Hectares***	***Class***	***Hectares***
Agriculture	1,954	Agriculture	1,954
Barren	1,186	Barren	1,186
Dwellings	34,095 (points)	Dwellings	34,095 (points)
Forest	25,572	Forest	25,572
Mining	11	Mining	11
Road	720 (km)	Road	720 (km)
Salt Ponds	0	Salt Ponds	0
Savanna	9,573	Savanna	9,573
Scrub/Shrub	18,696	Scrub/Shrub	18,696
Rivière Marion watershed (218km^2)		**Rivière Jassa watershed (434km^2)**	
Class	***Hectares***	***Class***	***Hectares***
Agriculture	1,101	Agriculture	1,101
Barren	427	Barren	427
Dwellings	9,429 (points)	Dwellings	9,429 (points)
Forest	7,728	Forest	7,728
Mining	4	Mining	4
Road	487 (km)	Road	487 (km)
Salt Ponds	10	Salt Ponds	10
Savanna	5,322	Savanna	5,322
Scrub/Shrub	5,319	Scrub/Shrub	5,319

II. Mangroves and Coastal Wetlands

For surveys of Mangroves and Coastal Wetlands, a series of site visits were conducted in June and November 2015 to document existing conditions within the mangrove and coastal wetland habitats of 3BNP. Site visits were conducted in Caracol Bay (including the outlet of the Grande Rivière du Nord at Bord de Mer de Limonade), Forte Liberté, and Lagon aux Boeufs to inventory coastal wetland plant communities, document mangrove stand characteristics and edaphic conditions, provide an overall assessment of habitat quality, identify ecological threats, and suggest opportunities for conservation, restoration and management.

Prior to site visits, all areas of likely coastal wetland habitat were identified from aerial imagery and review of available literature. Sampling locations were selected at random in the field. At each sampling location, sampling followed meandering transects in an attempt to characterize the flora of each site. Transect length varied based on site size and complexity. However, minimum transect length was 100m. All taxa encountered were identified to the species level where taxonomic features allowed. Taxa sampled included mangroves, mangrove associates, and other herbaceous halophytes from tidal

wetlands encountered. Determination of taxa was conducted in the field or subsequently at the lab using voucher specimens. All identified taxa were also photographed in the field.

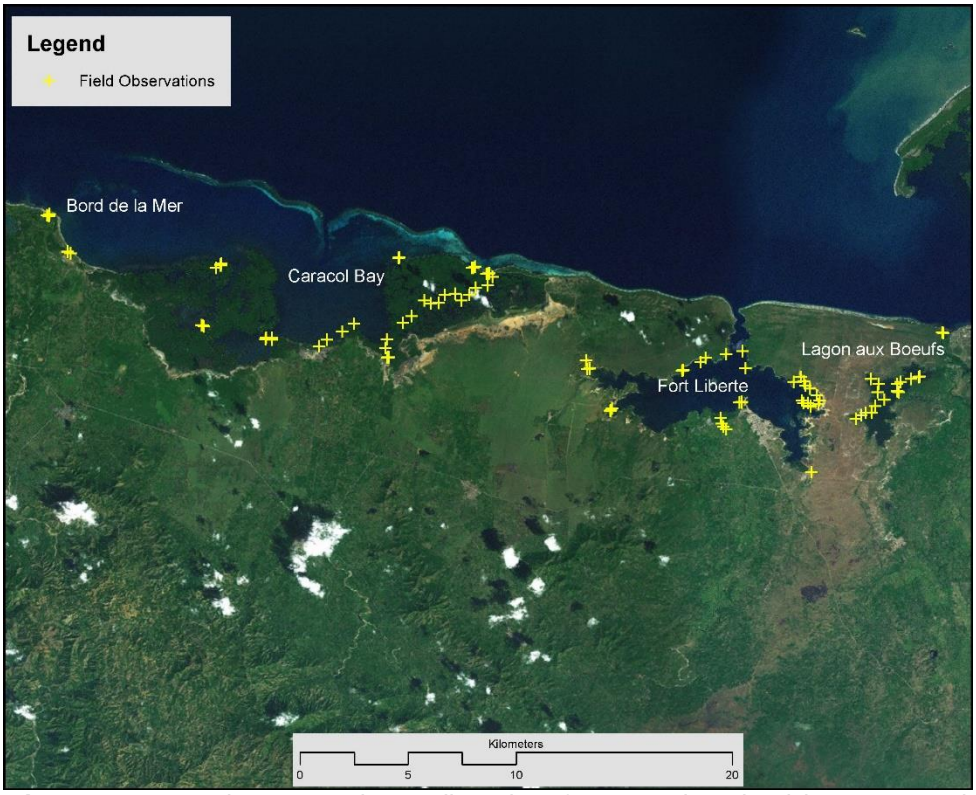

Figure A1-2. Study area and sampling sites for coastal wetland inventory and observations of stand characteristics within 3BNP from June to November 2015.

Mangrove Stand and Tidal Wetland Characteristics: Mangrove stand characteristics were sampled at a minimum of three observation points (plots) along linear transects initiated at the sampling locations described above. Each transect was at least 100m in length. At each plot, the following parameters were noted and/or sampled:

1) classification into one of five major mangrove habitat types including fringe, basin, riverine, scrub/dwarf, and hammock types;
2) stand height – an estimate of the average height of mangrove canopy height of tree or shrub forms within a circular area with a diameter of 10m for tree forms, or 5m for shrub forms;
3) DHB (diameter at breast height) – was sampled from the three largest canopy species, when present, estimated at rough 1.3m above the sediment surface, or at point just above height of dominant rhizophore attachment point in the case of *Rhizophora mangle*; and
4) species richness and percent cover (by species) – species noted and percent cover visually estimated within a circular area with a diameter of 10m (tree), 5m (shrub), and 1m (ground cover). Cover estimates followed a Braun Blanquet scale (1965).

Non-mangrove tidal wetland plant communities, when encountered, were assessed using similar approaches. However, cover estimates were limited to ground cover (1m) since no shrub or tree canopy cover classes were observed. These data were used to develop estimates of mangrove cover by habitat class and species type.

Water Quality and Edaphic Conditions: Similar to habitat characteristics, surface water quality and pore water chemistry was assessed in each mangrove area sampling plot. Surface water quality sampling was limited to areas with at least 30cm of standing water. When conditions were met, parameters measured in the field included dissolved oxygen concentration (mg/L), salinity (ppt), and temperature (^{o}C) using a YSI Model 556 Multiprobe handheld data logger that was calibrated daily. Pore water (i.e., the water found between soil/sediment particles) was sampled to document the edaphic conditions around the root zone of plants. Pore water was obtained using the sipper technique, consisting of a stainless 60cm steel tube with an ID of 1mm and a 60cc syringe used to draw up interstitial water. The sipper is inserted into the sediment to a depth of approximately 30-50cm, corresponding with the average live-root depth to determine conditions within the rhizosphere. Parameters measured from pore water included 1) salinity (ppt), 2) redox potential (mV), 3) pH, and 4) sulfide concentration (mM). The first three parameters were measured directly in the field using an Orion 5-Star Plus multimeter outfitted with a DuraProbe conductivity cell, platinum electrode and a Ross Sure-Flow temperature-corrected pH triode, while the sulfide samples were fixed in the field using a 2% zinc acetate solution and later determined colorimetrically (Cline 1969) at Jackson Estuarine Laboratory at the University of New Hampshire. All water quality and pore water chemistry sampling locations were geo-referenced.

Habitat Quality Assessment and Evaluation Threats to Coastal Wetlands: Documentation of habitat quality was estimated using a qualitative scale from 1-5 described in Moore (2014), where a score of 1 = poor and 5 = exceptional. Similarly, evidence of disturbance, including mangrove cutting or extraction, subsistence or commercial agriculture, land conversion, pollution, and proximity to settlements, barriers, and/or developed areas was also noted as described in Moore (2014). Additional observations were noted throughout each site in a random manner to fully document site conditions overall and to establish major categories of threats to coastal wetlands encountered. These data and observations were used to develop recommendations and associated opportunities for conservation, restoration and management.

Mangrove stand characteristics and pore-water parameters were analyzed over habitat type using a one-factor analysis of variance (ANOVA). Residuals were examined to ensure homogeneous variance and a normal distribution. If appropriate, transformations were conducted to meet assumptions of parametric statistics. Tukey's means comparison test was applied if the model was significant. Statistical significance for all tests was set at an alpha level of 0.05 to control type I error. All means are reported with standard error (s.e.).

III. Birds and Terrestrial Vertebrates

A preliminary selection of field sites was conducted using a general map of major vegetation types provided by The Nature Conservancy and Google Earth Pro. Once a site was selected, taxon specific surveys were performed as follows:

Birds: Birds were surveyed along 32 transects of variable length (from 0.3m to 5 km) with special emphasis in mudflats and wetlands in general, because wetland conservation has played a key role in justifying the declaration of the 3BNP as a protected area. The total area surveyed was 72km (58.5km walking and 13.5km by boat). Surveys were carried out from 5:30am to 10:00am and from 4:00pm to 6:30pm (Figure A1-2) for a total of 82 hrs. In some localities, surveys were conducted simultaneously by two teams of two observers led by an experienced ornithologist. Relevant records were supported with photographs or video clips when possible.
All data was uploaded on eBird, including photographs and video clips, to receive feedback from the birding community through Sean Christensen, regional data reviewer for eBird Haiti, as well as other professional contacts.

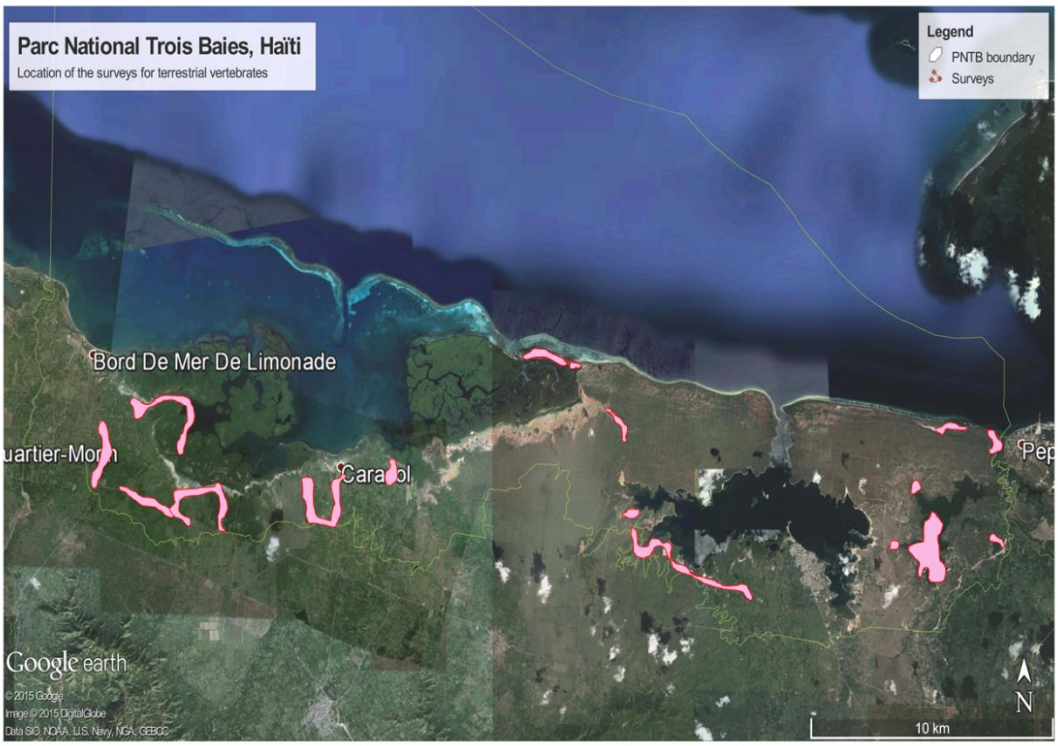

Figure A1-3. Map of Three Bays National Park (red lines indicate individual surveys).

Amphibians and Reptiles: A total of 12 amphibian and 14 reptile surveys were conducted by visiting 10 lagoons, streams, and other similar habitats favored by amphibians. Reptiles were searched in areas with large trees, home gardens, and along access roads. A local resident with knowledge of the area (named Marckinson Joeseph) was engaged in order to locate and capture amphibians and reptiles. A team of two people conducted an intensive search of amphibians from 6:00pm to 8:00pm, and

reptiles from 8:00am to 10:00am and from 4:00pm to 6:00pm. When possible each animal was captured, photographed on-site and released. A Panasonic LUMIX DMC-FZ70 camera with a powerful zoom was used to photograph elusive species that evade capture on the spot. Photographs were later shared with specialists (Sixto Inchaústegui and Christian Marte) to confirm species identifications.

Terrestrial Mammals: Only two species of terrestrial mammals are known to be endemic to the area, the Solenodon (*Solenodon paradoxus*) and the Hutia (*Plagiodontia aedium*), and their presences was assessed by conducting a survey (Secades 2010) from two target groups, resident students from the local chapter of the Université de l'Etat de Haïti in Limonade, and local residents from the community Garde Saline – the area where these species are most likely to occur based on the abundance of trees and home gardens. Interviewees were shown a series of pictures of both species and asked whether they could identify them as known species in the area. Special care was taken to avoid misidentification with introduced rats (*Rattus rattus* and *Rattus norvegicus*) and mongoose (*Herpestes auropunctatus*). A total of 92 interviews were carried out in Kreyol Haitiene. If more than one interviewee mentioned the presence of either species within 3BNP, searches in the specific area mentioned were conducted at sunset (from 6:00pm to 8:00pm) for two consecutive nights.

IV. Freshwater Fauna

The Freshwater Fauna study was designed to conduct qualitative sampling at sites that represent as much of the physical diversity of the target systems as practical, thereby characterizing the animal biodiversity in the fresh and brackish waters in 3BNP. Collections were made at a total of twenty (20) sites during two visits to the study area, June 4-7, 2015 and August 25-28, 2015 (see Appendix 11). It should be noted that collections from the five (5) sites in the Lagon aux Boeufs were consolidated in the field because most of the species came from a composite of fish and invertebrates purchased from a local fisherman and the location(s) of his catch within the lagoon was not determined. Thus, only fifteen (15) sites are reported in the overall study. A diversity of freshwater habitats occurred among the sites including permanent rivers (Grande Rivière du Nord and Rivière Trou du Nord; labeled GdN and TdN in figures and tables), small seasonal streams near the towns of Fort Liberté (FtL) and Malfety (Mal), and associated wetlands. Reduced-salinity habitats were sampled at several sites in the Lagon aux Boeufs (LaB), a permanently brackish lagoon, and in estuarine waters at the mouths of the two river systems (TdN 6 in Figure 48 and GdN 3 in Figure 49). For a habitat-based analysis, the sites were grouped following the IUCN Habitat Classification Scheme, version 3.1.

- *Permanent river* (*IUCN Wetlands Type 5.1*). A total of nine (9) sites were sampled in the two major rivers, Trou du Nord and Grande du Nord (TdN and GdN sites in Figure 48).
- *Seasonal/intermittent stream* (*IUCN Wetlands Type 5.2*). A total of three (3) sites were sampled in small, seasonal streams (Mal and FtL sites in Figure 48).

- *Permanent saline, brackish lake* (*IUCN Wetlands Type 5.14*) (LaB sites in Figure 48)
- *Estuary* (*IUCN Marine Neritic Type 9.10*) (TdN6 and GdN3 in Figure 48)

To survey the freshwater fauna of 3BNP, several types of sampling gear were utilized. The primary gear was a Smith-Root LR-24 Elecrofisher in combination with small mesh (~5mm) dipnets. Approximately 15 to 30 minutes was spent fishing at each site, and covering a linear distance of ~100m where possible. Brackish sites (all in the Lagon aux Boeufs) were sampled with dipnets only. Additionally, fish and invertebrate specimens were also purchased in several areas from local fishermen who mainly fished with nets and traps. All micro-habitats (e.g. rocky riffles, pools, vegetated bottoms) present at each site were thoroughly fished. Representative specimens of all species encountered were preserved in ethanol and returned to the laboratory for identification. Notes were made in the field on taxa captured, taxa observed but not captured, and other relevant information. The overall design was a rapid, qualitative ecological assessment.

V. Marine Benthic Invertebrates

Benthic survey sites were randomly selected in areas of interest, such as potential impact zones (close to urbanization or river). A total of 32 sites within 3BNP were surveyed; 13 sites were located in Caracol and 13 in Fort Liberté and 6 in Limonade (Appendices 14-16). The sites surveyed within each marine benthic habitat varied, with 6 sites surveyed in mangroves, 8 in seagrass, 28 shallow-water coral reef, which included reefal habitats such as reef crest, backreef, deep forereef, and reef wall. Sampling methodology varied depending on the marine habitat. Landscape photographs were taken at each site and species of benthic invertebrates were reported for each site. Species were identified from the following categories of sessile- and motile-benthic organisms: anemones, bryozoans, corals, corallimorphs, echinoderms, hydroids, octocorals, sponges, tunicates, and zoanthids. Samples were collected and photographs taken of any unidentified organism.

Coral Reef Habitats: Benthic species richness was assessed on five random 20m^2 belt transects at each coral reef site. Roving surveys were also conducted to identify other benthic species not listed along each transect. The most common organism and/or substrate were recorded.

Seagrass Habitats: The composition and cover of seagrass and macroalgae were assessed using the Braun Blanquet method. A 10m transect was randomly placed parallel to the coastline. Then a 0.25m^2 quadrat was placed every 2m along the transect line (5 quadrats per transect). All species of seagrass, macroalgae and other benthic invertebrates occurring in the quadrat were recorded. In each quadrat, a score was given based on the density of macroalgal and seagrass species (Table A1-2). Seagrass blade length was also estimated. In addition, roving surveys were conducted to record the presence of other sessile- and motile-benthic invertebrates outside the transect lines. The most frequent species were recorded.

Table A1-2. Braun Blanquet density scores.

Score	Cover
0	Taxa absent from quadrat
0.1	Taxa represented by a solitary shoot, <5% cover
0.5	Taxa represented by a few (<5) shoots, <5% cover
1	Taxa represented by many (>5) shoots, < 5% cover
2	Taxa represented by many (>5) shoots, 5-25% cover
3	Taxa represented by many (>5) shoots, 25-50% cover
4	Taxa represented by many (>5) shoots, 50-75% cover
5	Taxa represented by many (>5) shoots, 75-100% cover

Mangrove Habitats: The methodology for determining sessile-benthic invertebrate richness was modified after Ellison and Farnsworth (1992). Twenty mangrove roots were randomly selected along a 20m transect line. Roots selected were submerged to a depth of at least 30cm. Abundance and species of sponges, bryozoans, tunicates and hydroids were recorded on each selected root. Median root length was estimated. In addition, roving surveys were conducted to identify the presence of additional species.

Data Analysis: For statistical analyses, a Permutational Multivariate Analysis of Variance (PERMANOVA) tests were run in PRIMER 6 (Anderson 2008) to assess the impacts of location and main threats on the species richness of benthic invertebrates. For species richness analyses, presence/absence data were analyzed to calculate Jaccard similarity indices.

VI. Marine Fish

Marine Fish Survey Sites were randomly selected in areas of interest, such as potential impact zones (close to urbanization or river). A total of 32 sites within 3BNP were surveyed; 13 sites were located in Caracol, 13 in Fort Liberté, and 6 in Limonade (Appendices 17-19). The sites surveyed within each marine benthic habitat varied, with 6 sites surveyed in mangroves, 8 in seagrass, 28 shallow-water coral reef, which included reefal habitats such as reef crest, backreef, deep forereef, and reef wall. Species of reef fish were reported for each site. Samples were collected and photographs taken of any unidentified organism.

Fish Surveys: The Roving Diver Technique (RDT) method was carried out at each site to record the biodiversity of reef fish. The RDT is a non-point visual survey method and all species of fish are recorded. Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol (www.agrra.org) was carried out to measure the abundance and size frequency of reef fish. At each site, fish abundance and size (estimated to the nearest centimeter) were recorded along ten belt transects which were 30m (long) x 2m (wide). Abundance and size measurements were only recorded on the outer forereefs. All data were converted to biomass per unit area of reef (g/100m^2) using species-specific length-weight equations (Froese and Pauly 2005):

$$W = aTL^{b}$$

where *W* is the weight in grams, parameters *a* and *b* are species-specific constants (Froese and Pauly 2005), and *TL* is the total length in centimeters.

Data Analysis: For statistical analyses, a Permutational Multivariate Analysis of Variance (PERMANOVA) tests were run in PRIMER 6 (Anderson 2008) to assess the impacts of location and main threats (see Schill et al. 2015) on the 1) species richness of fish and 2) biomass and density of reef fish. For species richness analyses, presence/absence data were analyzed to calculate Jaccard similarity indices. PERMANOVAs assessing fish biomass and densities were based on Bray-Curtis similarity measures.

Appendix 2. Vascular plants observed within 3BNP.

Family	Genus	Specific Epithet	Human Altered	Fort Liberté Peninsula
Acanthaceae	*Ruellia*	*brittoniana*	X	
Acanthaceae	*Oplonia*	*spinosa*		X
Aizoaceae	*Sesuvium*	*portulacastrum*		X
Amaranthaceae	*Achyranthes*	*aspera*	X	
Amaranthaceae	*Amaranthus*	sp.	X	
Amaranthaceae	*Chenopodium*			X
Anacardiaceae	*Spondias*	*mombin*	X	
Anacardiaceae	*Comocladea*	*cuneata*		X
Apocyanaceae	*Angadenia*	sp.	X	
Apocynaceae	*Catharanthus*	*roseus*	X	
Apocynaceae	*Cryptostegia*	*madagagascariensis*	X	X
Apocynaceae	*Echites*	*umbellata*	X	
Apocynaceae	*Angadenia*	sp.		X
Apocynaceae	*Echites*	*umbellata*		X
Apocynaceae	*Plumeria*	*obtusa*		X
Arecaceae	*Roystonea*	*hispaniola*	X	X
Asclepiadaceae	*Metastelma*	sp.	X	
Asclepiadaceae	*Calotropis*	*procera*		X
Asparagaceae	*Yucca*	*aloifolia*	X	
Asparagaceae	*Agave*	*sisilana*		X
Asparagaceae	*Agave*	*antillarum*		X
Asteraceae	*Chromoleana*	sp.	X	
Asteraceae	*Conzya*	*canadensis*	X	
Asteraceae	*Pluchea*	*symphytifolia*	X	
Asteraceae	*Parthenium*	*hysterophorus*	X	
Asteraceae	*Tridax*	*procumbens*	X	
Asteraceae	*Vernonia*	*cinerea*	X	
Asteraceae	*Wedelia*	*trilobata*	X	
Asteraceae	*Ambrosia*	*peruviana*		X
Bataceae	*Batis*	*maritima*	X	X
Boraginaceae	*Bourreria*	*succulenta*		X
Boraginaceae	*Cordia*	*globosa*		X
Boraginaceae	*Heliotropium*	*curassavicum*	X	X
Boraginaceae	*Heliotropium*	sp.	X	
Boraginaceae	*Tournefortia*	*gnaphalodes*		X
Boraginaceae	*Tournefortia*	sp.	X	X
Bromeliaceae	*Bromelia*	*pinguin*	X	
Bromeliaceae	*Tillandsia*	*balbisiana*		X

Family	Genus	Specific Epithet	Human Altered	Fort Liberté Peninsula
Bromeliaceae	*Tillandsia*	*recurvata*		X
Bromeliaceae	*Tillandsia*	*fasiculata*		X
Burseracae	*Bursera*	*simaruba*	X	X
Cactaceae	*Consolea*	*picardae*		X
Cactaceae	*Harrisia*	*nashii*		X
Cactaceae	*Hylocereus*	*triangularis*		X
Cactaceae	*Mammilaria*	*ekmanii*		X
Cactaceae	*Opuntia*	*taylorii*		X
Cactaceae	*Opuntia*	*antillana*		X
Cactaceae	*Pilocereus*	*polygnous*		X
Cactaceae	*Selenicereus*	*pteranthus*		X
Capparaceae	*Capparis*	*flexuosa*		X
Casuarinacea	*Casuarina*	*equisetifolia*	X	
Celestraceae	*Crossopetalum*	sp.		X
Celestraceae	*Maytenus*	sp.		X
Celestraceae	*Schaefferia*	*frutescens*		X
Cleomaceae	*Cleome*	*pilosa*	X	
Clusiaceae	*Clusea*	sp.		X
Combretaceae	*Conocarpus*	*erectus*		X
Commelinaceae	*Commelina*	*erecta*		X
Commelinaceae	*Tradescantia*	*spathacea*	X	
Convolvulaceae	*Evolvulus*	*alsinoides*		X
Convolvulaceae	*Evolvulus*	*convolvuloides*	X	X
Convolvulaceae	*Evolvulus*	sp.		X
Convolvulaceae	*Ipomoea*	*pes-capre*	X	X
Convolvulaceae	*Jacquemontia*	*havanensis*		X
Curcurbitaceae	*Momordica*	*charantia*	X	
Cyperaceae			X	
Cyperaceae	*Fimbrystylis*	*spadicea*	X	
Erythroxylaceae	*Erythroxylum*	*rotundifolium*		X
Euphorbiaceae	*Acalypha*	sp.	X	
Euphorbiaceae	*Arygthmania*	*candicans*		X
Euphorbiaceae	*Codium*	*varigaetum*	X	
Euphorbiaceae	*Croton*	sp.	X	
Euphorbiaceae	*Croton*	*flavens*		X
Euphorbiaceae	*Croton*	*humilis*		X
Euphorbiaceae	*Croton*	*linearis*		X
Euphorbiaceae	*Euphorbia*	*cyathophora*	X	
Euphorbiaceae	*Euphorbia*	*hyssopifolia*	X	
Euphorbiaceae	*Euphorbia*	*lactea*	X	X

Family	Genus	Specific Epithet	Human Altered	Fort Liberté Peninsula
Euphorbiaceae	*Chaemacyse*	*mesembrianthemifolia*		X
Euphorbiaceae	*Euphorbia*	sp.	X	
Euphorbiaceae	*Euphorbia*	*tirucalli*	X	X
Euphorbiaceae	*Hura*	*crepitans*	X	
Euphorbiaceae	*Jatropha*	*curcas*	X	
Euphorbiaceae	*Jatropha*	*gossypifolia*	X	X
Euphorbiaceae	*Ricinus*	*communis*	X	
Fabaceae	*Acacia*	*farnesiaiana*	X	X
Fabaceae	*Caesalpinia*	*bonduc*	X	X
Fabaceae	*Calliandra*	*haematomma*		X
Fabaceae	*Centrosema*	*angustifolia*	X	
Fabaceae	*Clitoria*	*ternatea*	X	
Fabaceae	*Crotolaria*	*incana*	X	
Fabaceae	*Dalbergia*	*ecastophylyllum*	X	
Fabaceae	*Galactia*	sp.		X
Fabaceae	*Haematoxylon*	*campechianum*	X	X
Fabaceae	*Indigofera*	*tinctoria*	X	
Fabaceae	*Leuceana*	*leucocephala*	X	
Fabaceae	*Lysiloma*	*latissiliiquum*		X
Fabaceae	*Mimosa*	*pudica*	X	
Fabaceae	*Pithecelliobium*	*unguis-cati*		X
Fabaceae	*Senna*	*bicapsularis*	X	
Fabaceae	*Senna*	*siamea?*		X
Fabaceae	*Stylosanthes*	*hamata*		X
Lauraceae	*Cassytha*	*filiformis*	X	
Malpighiaceae			X	
Malpighiaceae				X
Malpighiaceae	*Malpighia*	*polytricha*		X
Malvaceae	*Corchorus*	*hirsutus*		X
Malvaceae	*Corchorus*	*siliquosus*	X	
Malvaceae	*Herissantia*	*crispa*	X	X
Malvaceae	*Melochia*	*pyramidata*	X	
Malvaceae	*Melochia*	*tomentosa*	X	
Malvaceae	*Sida*	*acutifolia*	X	
Malvaceae	*Sida*	*ciliaris*	X	X
Malvaceae	*Thespesia*	*populnea*	X	
Malvaceae	*Helicteres*	*jamaicense*		X
Malvaceae	*Helicteres*	*semitriloba*		X
Malvaceae	*Hibiscus*	sp.		X
Meliaceae	*Azadirachta*	*indica*	X	X

Family	Genus	Specific Epithet	Human Altered	Fort Liberté Peninsula
Moraceae	*Ficus*	sp.		X
Moringaceae	*Moringa*	*oleifera*	X	
Muntingiaceae	*Muntingia*	*calabura*	X	X
Myrtaceae	*Eugenia*	*axillaris*		X
Myrtaceae	*Eugenia*	*foetida*		X
Myrtaceae	*Eugenia*	sp.		X
Nyctaginaceae	*Boerhavia*	*coccinea*	X	X
Nyctaginaceae	*Guapira*	*discolor*		X
Nyctaginaceae	*Pisonia*	*aculeata*	X	
Nyctaginaceae	*Pisonia*	*rotundata*		X
Oleaceae	*Jasminum*	*fluminense*	X	X
Onagraceae	*Ludwigia*	*erecta*	X	
Orchidaceae	*Broughtenia*	*domingensis*		X
Orchidaceae	*Vanilla*	*poitaei*		X
Passifloraceae	*Turnera*	*diffusa*		X
Poaceae	*Bambusa*	*vulgaris*	X	
Poaceae	*Bothriochloa*	*saccharoides*		X
Poaceae	*Lasiacis*	sp.		X
Poaceae	*Melinis*	*repens*	X	
Poaceae	*Paspulum*	sp.	X	
Poaceae	*Phragmites*	*australis*	X	
Poaceae	*Setaria*	sp.	X	
Poaceae	*Sporobolus*	*virginicus*		X
Polygonaceae	*Antigonon*	*leptopus*	X	
Polygonaceae	*Coccoloba*	*uvifera*	X	
Polygonaceae	*Polygonum*	sp.	X	
Polygonaceae	*Coccoloba*	*uvifera*		X
Portulaceae	*Portulaca*	*oleracea*	X	
Portulaceae	*Portulaca*	sp.		X
Pteridaceae	*Adiantopsis*	*reesii*		X
Rhamnaceae	*Colubrina*	*arborescens*		X
Rubiacae	*Borreria*	*laevis*	X	
Rubiacae	*Hamelia*	*patens*	X	
Rubiaceae	*Chiococca*	*alba*		X
Rubiaceae	*Erithalis*	*fruticosa*		X
Rubiaceae	*Exostema*	sp.		X
Rubiaceae	*Guettarda*	sp.		X
Rubiaceae	*Randia*	*aculeata*		X
Rubiaceae	*Psychoteria*	*ligustrifolia*		X
Rubiaceae	*Stenostomum*	*lucidum*		X

Family	Genus	Specific Epithet	Human Altered	Fort Liberté Peninsula
Rutaceae	*Zanthoxylon*	*fagara*	X	X
Rutaceae	*Zanthoxylon*	*flavum*		X
Sapotaceae	*Sideroxylon*	*celestrina*		X
Scrophulariaceae	*Capraria*	*biflora*	X	
Scrophulariaceae	*Stemodia*	*maritima*	X	
Scrophulariaceae	*Capraria*	*biflora*		X
Solanaceae	*Solanum*	sp.		X
Sterculiacae	*Waltheria*	*indica*	X	
Sterculiaceae	*Melochia*	*tomentosa*		X
Sterculiaceae	*Waltheria*	*indica*		X
Surianiaceae	*Suriana*	*maritima*		X
Typhaceae	*Typha*	*domingensis*	X	
Urticaceae	*Cecropia*	*peltata*	X	
Verbenaceae	*Lantana*	*involucrata*	X	X
Verbenaceae	*Phyla*	*nodiflora*	X	
Verbenaceae	*Pseudocarpidium*	sp.		X
Verbenaceae	*Stachytarpheta*	*jamaicensis*	X	
Vitaceae	*Cissus*	*sicyoides*	X	
Vitaceae	*Cissus*	*trifoliata*	X	X
Zygophyllaceae	*Guaiacum*	*sanctum*		X
Zygophyllaceae	*Kallstroemia*	*maxima*		X

Appendix 3. List of IUCN Redlisted botanical species known to occur in Haiti (those in red were found within 3BNP during the vegetation survey).

Potentially in 3BNP	Family	Genus	Species	Red List status
	ARECAEAE	*Attalea*	*crassispatha*	CR
X	ARECAEAE	*Coccothrinax*	*ekmanii*	DD
X	ARECAEAE	*Copernicia*	*ekmanii*	EN
	ARECAEAE	*Pseudophoenix*	*lediniana*	CR
	BIGNONIACEAE	*Catalpa*	*brevipes*	VU
	BIGNONIACEAE	*Ekmanianthe*	*longiflora*	EN
X	BROMELIACEAE	*Tillandsia*	*paniculata*	NT
	CACTACEAE	*Consolea*	*falcata*	CR
X	CACTACEAE	*Consolea*	*picardae*	DD
X	CACTACEAE	*Dendrocereus*	*undulosus*	DD
	CACTACEAE	*Leptocereus*	*paniculatus*	VU
	CACTACEAE	*Mammillaria*	*ekmanii*	DD
X	CACTACEAE	*Melocactus*	*lemairei*	NT
X	CACTACEAE	*Opuntia*	*acaulis*	DD
X	CACTACEAE	*Opuntia*	*taylorii*	DD
	CACTACEAE	*Pereskia*	*marcanoi*	VU
	CACTACEAE	*Pereskia*	*portulacifolia*	VU
X	CACTACEAE	*Selenicereus*	*pteranthus*	DD
	CUPRESSACEAE	*Juniperus*	*barbadensis*	VU
	CUPRESSACEAE	*Juniperus*	*gracilior*	EN
	FABACEAE	*Albizia*	*berteriana*	VU
	FABACEAE	*Albizia*	*leonardii*	VU
	FABACEAE	*Chamaecrista*	*caribaea*	VU
	FABACEAE	*Mimosa*	*domingensis*	VU
	FABACEAE	*Mora*	*ekmanii*	VU
	FABACEAE	*Senna*	*domingensis*	VU
	ICACINACEAE	*Mappia*	*racemosa*	VU
	JUGLANDACEAE	*Juglans*	*jamaicensis*	VU
	LAURACEAE	*Cinnamomum*	*parviflorum*	VU
	LAURACEAE	*Nectandra*	*caudatoacuminata*	CR
	LAURACEAE	*Nectandra*	*pulchra*	CR
	MAGNOLIACEAE	*Magnolia*	*domingensis*	CR
	MAGNOLIACEAE	*Magnolia*	*ekmanii*	CR
X	MAGNOLIACEAE	*Magnolia*	*emarginata*	CR
	MELIACEAE	*Cedrela*	*odorata*	VU
	MELIACEAE	*Guarea*	*sphenophylla*	VU
	MYRTACEAE	*Calyptranthes*	*ekmanii*	VU

Potentially in 3BNP	Family	Genus	Species	Red List status
	ORCHIDACEAE	*Acianthera*	*compressicaulis*	EN
	ORCHIDACEAE	*Psychilis*	*olivacea*	VU
	PINACEAE	*Pinus*	*occidentalis*	EN
	PODOCARPACEAE	*Podocarpus*	*buchii*	EN
	RUBIACEAE	*Stenostomum*	*radiatum*	VU
	SAPOTACEAE	*Manilkara*	*gonavensis*	CR
	SAPOTACEAE	*Manilkara*	*valenzuelana*	VU
	SAPOTACEAE	*Pouteria*	*hotteana*	EN
	SIMAROUBACEAE	*Picrasma*	*excelsa*	VU
	STAPHYLEACEAE	*Huertea*	*cubensis*	VU
	THEACEAE	*Cleyera*	*bolleana*	VU
	THEACEAE	*Cleyera*	*vaccinioides*	VU
	VERBENACEAE	*Vitex*	*heptaphylla*	DD
	ZAMIACEAE	*Zamia*	*pumila*	NT
X	ZYGOPHYLLACEAE	*Guaiacum*	*officinale*	EN
X	ZYGOPHYLLACEAE	*Guaiacum*	*sanctum*	EN

Appendix 4. List of vegetation waypoints taken during rapid botanical assessments in 3BNP.

WP#	Vegetation Descriptor	UTM COORDINATES	
1	Agroforestry	19Q0200000	2174231
2	Rice Field	19Q0199879	2174367
3	Abandoned Field	19Q0200006	2174388
4	Road	19Q0199943	2174219
5	Livestock Grazing	19Q0201692	2174257
6	Rice Field	19Q0201524	2173891
7	Open Field	19Q0201910	2174663
8	Salt Pond	18Q0812665	2180544
9	Salt Pond	18Q0812787	2180602
10	Mixed agriculture	18Q 0799656	2180768
11	Plantains	18Q0799722	2180813
12	Grazing land	18Q0799785	2180826
13	Old -field- Grazing	18Q0800127	2180834
14	Plantains	18Q0800746	2181649
15	Beach strand	18Q0802348	2184243
16	Open Field- Cows	18Q0800253	2186581
17	Bare earth, Cattle area	18Q0799945	2186670
18	Cow field	18Q1801236	2182810
19	Acacia Shrubland	19Q0206859	2176890
20	Acacia Shrubland- low	19Q0206598	2176727
21	Acacia Shrubland	19Q0206404	2176546
22	Acacia Shrubland	19Q0206763	2177023
23	Acacia Shrubland- low density	19Q0206207	2176514
24	Acacia Shrubland- low density	19Q0206039	2176370
25	Agriculture- no trees	18Q0808924	2177792
26	Acacia Shrubland - heavy grazing	18Q0808514	2177739
27	Dry Broadleaf Evergreen Formation - Shrubland	19Q0208294	2179935
28	DBEF-S with Acacia	19Q0208862	2180249
29	Dry Broadleaf Evergreen Formation - Shrubland	19Q0208925	2180487
30	Dry Broadleaf Evergreen Formation - Shrubland	19Q0208964	2180936
31	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209355	2180875
32	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209151	2181224
33	Dry Broadleaf Evergreen Formation - Shrubland	19Q0208723	2181289

WP#	Vegetation Descriptor	UTM COORDINATES	
34	Dry Broadleaf Evergreen Formation - Shrubland	19Q0210062	2179815
35	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209840	2180162
36	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209610	2180570
37	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209456	2180730
38	Dry Broadleaf Evergreen Formation - Shrubland	19Q0209381	2180819
39	Saline Flat	19Q0208442	2181137
40	Dry Broadleaf Evergreen Formation - Shrubland	19Q0206751	2181434
41	Dry Broadleaf Evergreen Formation - Shrubland	19Q0207204	2181301
42	Dry Broadleaf Evergreen Formation - Shrubland	19Q0207379	2180767
43	DBEF-S with Acacia	19Q0207165	2180191
44	Dry Broadleaf Evergreen Formation - Shrubland	19Q0194692	2183633
45	DBEF-S with Acacia	19Q0194900	2183389
46	DBEF-S with Acacia	19Q0194572	2183160
47	DBEF-S with Acacia	19Q0194837	2182934
48	DBEF-S with Acacia	19Q0195110	2182778
49	Dry Broadleaf Evergreen Formation - Shrubland	19Q0195988	2182826
50	Dry Broadleaf Evergreen Formation - Shrubland	19Q0196475	2182881
51	DBEF-S with Acacia	19Q197704	2182944
52	Dry Broadleaf Evergreen Formation - Shrubland	19Q0197019	2182458
53	Dry Broadleaf Evergreen Formation - Shrubland	19Q0196666	2182526

Appendix 5. Comparison of pore water parameters for mangrove areas of 3BNP measured in 2015, reporting mean and standard error (s.e.).

Pore Water Parameter	Regional Subdivision			
	1-4 Caracol Bay	1 (subset) Bord de Mer Limonade	5-6 Fort-Liberté	7 Lagon aux Bœufs
Salinity (ppt)	42.7	18.8	40.7	6.6
s.e.	*(1.9)*	*(7.5)*	*(3.9)*	*(0.9)*
Sulfide (mM)	2.0	1.1	2.5	2.7
s.e.	*(0.2)*	*(0.54)*	*(0.4)*	*(.78)*
Redox potential (mV)	-281.0	-136.0	-272.0	-289.0
s.e.	*(20)*	*(16.9)*	*(42.8)*	*(34.2)*
pH	6.9	6.9	7.2	7.4
s.e	*(0.1)*	*(0.5)*	*(0.1)*	*(0.1)*

Appendix 6. Summary of flora observed within coastal wetlands in 3BNP, including halophytes from saline (mangrove), brackish, and other tidal freshwater habitats.

Habitat	Scientific name	Regional Subdivision			
		1-4 Caracol Bay	1 (subset) Bord de Mer Limonade	5-6 Fort-Liberté	7 Lagon aux Bœufs
Saline	*Avicennia germinans*	x	x	x	x
Saline	*Avicennia schaueriana*			x	
Saline	*Conocarpus erectus*	x	x	x	x
Saline	*Laguncularia racemosa*	x	x	x	x
Saline	*Rhizophora mangle*	x	x	x	x
Brackish	*Acrosticum aureum*		x		x
Brackish	*Bacopa monnieri*				x
Brackish	*Chara spp.*				x
Brackish	*Najas marina*				x
Brackish	*Rhabdadenia biflora*		x		x
Brackish	*Ruppia maritima*		x		x
Tidal Fresh	*Commelina diffusa*		x		
Tidal Fresh	*Cyperus compressus*		x		
Tidal Fresh	*Cyperus esculentus*		x		
Tidal Fresh	*Cyperus luzulae*		x		
Tidal Fresh	*Cyperus polystachyos*		x		
Tidal Fresh	*Cyperus rotundus*		x		
Tidal Fresh	*Echinochloa colona*		x		
Tidal Fresh	*Eclipta prostrata*		x		
Tidal Fresh	*Eleocharis equisetoides*		x		
Tidal Fresh	*Eleocharis flavescens*		x		
Tidal Fresh	*Eleocharis geniculata*		x		
Tidal Fresh	*Eleocharis interstincta*		x	x	
Tidal Fresh	*Eleocharis mutata*		x		
Tidal Fresh	*Fimbristylis quinquangularis*		x	x	
Tidal Fresh	*Heteranthera reniformis*		x		
Tidal Fresh	*Limnocharis flavis*		x		
Tidal Fresh	*Ludwigia octovalvis*		x		
Tidal Fresh	*Ludwigia peruviana*		x		
Tidal Fresh	*Marsilea sp*		x		
Tidal Fresh	*Panicum hemitomon*		x		
Tidal Fresh	*Pluchea caroliniana*		x		
Tidal Fresh	*Polygonum punctatum*		x		
Tidal Fresh	*Rotala ramosoir*		x		

Habitat	Scientific name	Regional Subdivision			
		1-4 Caracol Bay	1-4 Baie de Caracol	1-4 Baie de Caracol	1-4 Caracol Bay
Tidal Fresh	*Saccharum gigantium*		X		
Tidal Fresh	*Sagittaria latifolia*		x		
Tidal Fresh	*Typha domingensis*		x		

Appendix 7. Checklist of birds recorded in 3BNP (BR – Breeding Resident, BM – Breeding Migrant, M – Migrant, P – Passage migrant).

Scientific Name	English Name	Status	Count		TOTAL
			Jun-Jul	Nov	
Anas discors	Blue-winged Teal	M	--	147	147
Anas bahamensis	White-cheeked Pintail	BR	18	13	31
Aythya affinis	Lesser Scaup	M	--	214	214
Numida meleagris	Helmeted Guineafowl	BR	2	9	11
Tachybaptus dominicus	Least Grebe	BR	1	2	3
Podilymbus podiceps	Pied-billed Grebe	BR	1	18	19
Phoenicopterus ruber	American Flamingo	M	14	15	29
Fregata magnificens	Magnificent Frigatebird	BR	2	--	2
Pelecanus occidentalis	Brown Pelican	BR	2	--	2
Ardea herodias	Great Blue Heron	BR, M	3	9	12
Ardea alba	Great Egret	BR, M	143	42	185
Egretta thula	Snowy Egret	BR, M	28	78	106
Egretta caerulea	Little Blue Heron	BR, M	4	15	19
Egretta tricolor	Tricolored Heron	BR, M	21	30	51
Bubulcus ibis	Cattle Egret	BR, M	185	79	264
Butorides virescens	Green Heron	BR, M	34	17	51
Nycticorax nycticorax	Black-crowned Night-Heron	BR, M	1	--	1
Nyctanassa violacea	Yellow-crowned Night-Heron	BR	1	--	1
Eudocimus albus	White Ibis	BR	6	--	6
Plegadis falcinellus	Glossy Ibis	BR, M	11	2	13
Platalea ajaja	Roseate Spoonbill	BR	22	1	23
Pandion haliaetus	Osprey	M	--	1	1
Rallus crepitans	Clapper Rail	BR	--	8	8
Gallinula galeata	Common Gallinule	BR, M	14	75	89
Fulica caribaea	Caribbean Coot	BR	1	25	26
Himantopus mexicanus	Black-necked Stilt	BR	58	689	747
Pluvialis squatarola	Black-bellied Plover	P, M	--	145	145
Charadrius nivosus	Snowy Plover	BR	1	40	41
Charadrius wilsonia	Wilson's Plover	BR	15	3	18
Sternula antillarum	Least Tern	BR	1	--	1
Charadrius semipalmatus	Semipalmated Plover	P, M	--	17	17
Charadrius vociferous	Killdeer	BR, M	25	111	136
Actitis macularius	Spotted Sandpiper	P, M	--	80	80
Tringa melanoleuca	Greater Yellowlegs	P, M	1	30	31
Tringa semipalmata	Willet	R, M	1	19	20

Scientific Name	English Name	Status	Count	TOTAL	Scientific Name
			Jun-Jul	Nov	
Tringa flavipes	Lesser Yellowlegs	P, M	--	47	47
Numenius phaeopus	Whimbrel	P, M	--	4	4
Arenaria interpres	Ruddy Turnstone	P, M	2	38	40
Calidris minutilla	Least Sandpiper	P, M	--	707	707
Limnodromus griseus	Short-billed Dowitcher	P, M	--	12	12
Gallinago delicata	Wilson's Snipe	P, M	--	4	4
Leucophaeus atricilla	Laughing Gull	R, M	13	--	13
Gelochelidon nilotica	Gull-billed Tern	P, M	5	--	5
Thalasseus maximus	Royal Tern	BR, M	5	9	14
Thalasseus sandvicensis	Sandwich Tern	BR, M	15	--	15
Columba livia	Rock Pigeon	BR	5	--	5
Patagioenas leucocephala	White-crowned Pigeon	BR	37	2	39
Patagioenas inornata	Plain Pigeon	BR	26	16	42
Columbina passerina	Common Ground-Dove	BR	63	50	113
Zenaida asiatica	White-winged Dove	BR	84	3	87
Zenaida aurita	Zenaida Dove	BR	114	--	114
Zenaida macroura	Mourning Dove	BR	94	8	102
Coccyzus minor	Mangrove Cuckoo	BR	--	1	1
Coccyzus longirostris	Hispaniolan Lizard-Cuckoo	BR	15	16	31
Crotophaga ani	Smooth-billed Ani	BR	62	54	116
Chordeiles gundlachii	Antillean Nighthawk	BR	18	--	18
Cypseloides niger	Black Swift	BR, M	5	--	5
Mellisuga minima	Vervain Hummingbird	BR	1	2	3
Anthracothorax dominicus	Antillean Mango	BR	1	--	1
Chlorostilbon swainsonii	Hispaniolan Emerald	BR	25	1	26
Todus subulatus	Broad-billed Tody	BR	54	25	79
Megaceryle alcyon	Belted Kingfisher	M, P	--	6	6
Melanerpes striatus	Hispaniolan Woodpecker	BR	8	1	9
Falco sparverius	American Kestrel	BR	15	3	18
Amazona ventralis	Hispaniolan Parrot	BR	2	--	2
Elaenia fallax	Greater Antillean Elaenia	BR	3	--	3
Myiarchus stolidus	Stolid Flycatcher	BR	--	2	2
Tyrannus dominicensis	Gray Kingbird	BR	45	58	103
Tyrannus caudifasciatus	Loggerhead Kingbird	BR	6	--	6

Scientific Name	English Name	Status	Count Jun-Jul	TOTAL Nov	Scientific Name
Vireo flavifrons	Yellow-throated Vireo	M	--	1	1
Vireo altiloquus	Black-whiskered Vireo	BM, BR	7	--	7
Corvus palmarum	Palm Crow	BR	5	3	8
Corvus leucognaphalus	White-necked Crow	BR	42	--	42
Petrochelidon fulva	Cave Swallow	BR	176	432	608
Mimus polyglottos	Northern Mockingbird	BR	77	61	138
Dulus dominicus	Palmchat	BR	80	3	83
Parkesia noveboracensis	Northern Waterthrush	P, M	--	1	1
Geothlypis trichas	Common Yellowthroat	M	--	3	3
Setophaga ruticilla	American Redstart	M	--	1	1
Setophaga petechia	Yellow Warbler	BR,M, P	46	1	47
Setophaga striata	Blackpoll Warbler	P	--	1	1
Setophaga caerulescens	Black-throated Blue Warbler	M	--	2	2
Setophaga palmarum	Palm Warbler	M	--	9	9
Coereba flaveola	Bananaquit	BR	6	4	10
Tiaris olivaceus	Yellow-faced Grassquit	BR	68	3	71
Tiaris bicolor	Black-faced Grassquit	BR	2	--	2
Loxigilla violacea	Greater Antillean Bullfinch	BR	7	2	9
Phaenicophilus palmarum	Black-crowned Palm-Tanager	BR	15	2	17
Ammodramus savannarum	Grasshopper Sparrow	BR	11	2	13
Quiscalus niger	Greater Antillean Grackle	BR	22	--	22
Molothrus bonariensis	Shiny Cowbird	BR	15	280	295
Passer domesticus	House Sparrow	BR	2	4	6
Ploceus cucullatus	Village Weaver	BR	440	230	670
Lonchura punctulata	Scaly-breasted Munia	BR	2	--	2
Lonchura malacca	Tricolored Munia	BR	1	--	1
Total spp.			**72**	**72**	**95**
Total individuals					**6411**

Appendix 8. Relative abundance of birds in each of the major habitat types surveyed in 3BNP. Uncommon, few records (+); common, several records (++); abundant, multiple records (+++). MF – Mudflats; MG – Mangroves; IL – Interior Lagoons; SP – Salt Ponds; SV – Savannas; RI – Ripparian; PA – Pastures; AG – Agroforestry.

Scientific Name	English Name	Relative Abundance by habitat							
		MF	MG	IL	SP	SV	RI	PA	AF
Anas discors	Blue-winged Teal		++	++					
Anas bahamensis	White-cheeked Pintail			++					
Aythya affinis	Lesser Scaup		++	++					
Numida meleagris	Helmeted Guineafowl		+	+	+	++		+	+
Tachybaptus dominicus	Least Grebe	+	+	+					
Podilymbus podiceps	Pied-billed Grebe	+	+	+					
Phoenicopterus ruber	American Flamingo		+	+					
Fregata magnificens	Magnificent Frigatebird			+					
Pelecanus occidentalis	Brown Pelican			+					
Ardea herodias	Great Blue Heron	+	+	++					
Ardea alba	Great Egret	+	++	+++	++				
Egretta thula	Snowy Egret	+	+	++	+				
Egretta caerulea	Little Blue Heron	+	+	++	+				
Egretta tricolor	Tricolored Heron	+	+	++	+				
Bubulcus ibis	Cattle Egret	+	+	++	++	+	+	+	+
Butorides virescens	Green Heron	+	++	++	++		+		
Nycticorax nycticorax	Black-crowned Night-Heron		+	+					
Nyctanassa violacea	Yellow-crowned Night-Heron	+	+	+	+				
Eudocimus albus	White Ibis				+				
Plegadis falcinellus	Glossy Ibis	+	++	+	++				
Platalea ajaja	Roseate Spoonbill		+	+	++		+		
Pandion haliaetus	Osprey		+	+					
Rallus crepitans	Clapper Rail	+	+	+	+				
Gallinula galeata	Common Gallinule		++	++	+		+		
Fulica caribaea	Caribbean Coot	+	+	++	+		+		
Himantopus mexicanus	Black-necked Stilt	+++	++	++	+++				
Pluvialis squatarola	Black-bellied Plover	++		++	+				
Charadrius nivosus	Snowy Plover	++							
Charadrius wilsonia	Wilson's Plover	+++	+	+	+				
Sternula antillarum	Least Tern	+	+	++	++				
Charadrius semipalmatus	Semipalmated Plover	++	+	+	+				
Charadrius vociferus	Killdeer	+++	+	++	+	+		++	
Actitis macularius	Spotted Sandpiper	++	+	+	++				
Tringa melanoleuca	Greater Yellowlegs	++		++	+				
Tringa semipalmata	Willet	+		+	+				

Scientific Name	English Name	Relative Abundance by habitat							
		MF	MG	IL	SP	SV	RI	PA	AF
Tringa flavipes	Lesser Yellowlegs	++		+	++				
Numenius phaeopus	Whimbrel	+		+					
Arenaria interpres	Ruddy Turnstone	+	+	++	+				
Calidris minutilla	Least Sandpiper	+++	+	+++	++				
Limnodromus griseus	Short-billed Dowitcher			+					
Gallinago delicata	Wilson's Snipe		+	+					
Leucophaeus atricilla	Laughing Gull		+	++	+				
Gelochelidon nilotica	Gull-billed Tern		+	+					
Thalasseus maximus	Royal Tern	+	+	++					
Thalasseus sandvicensis	Sandwich Tern	+	+	++	+				
Columba livia	Rock Pigeon					+		+	+
Patagioenas leucocephala	White-crowned Pigeon	+	++	+	+	+	+		
Patagioenas inornata	Plain Pigeon		+	+	+	+	++	+	++
Columbina passerina	Common Ground-Dove	++	+	+	+	+++	++	+++	++
Zenaida asiatica	White-winged Dove		++	+	+	++	+	++	++
Zenaida aurita	Zenaida Dove	+	+	+		+	+	++	+
Zenaida macroura	Mourning Dove	+	+	+	+	++	+	++	+
Coccyzus minor	Mangrove Cuckoo		+						
Coccyzus longirostris	Hispaniolan Lizard-Cuckoo			+		+	+++		++
Crotophaga ani	Smooth-billed Ani		+	+		++	++	++	++
Chordeiles gundlachii	Antillean Nighthawk			++		+++	+	+++	++
Cypseloides niger	Black Swift			+	+			+	+
Mellisuga minima	Vervain Hummingbird	+	+			+	+		++
Anthracothorax dominicus	Antillean Mango		+			+	++		++
Chlorostilbon swainsonii	Hispaniolan Emerald	+					+	+	+
Todus subulatus	Broad-billed Tody			+		+++	++	+	+++
Megaceryle alcyon	Belted Kingfisher			+					
Melanerpes striatus	Hispaniolan Woodpecker			+			+	+	+
Falco sparverius	American Kestrel		+	+		++	+	+	+
Amazona ventralis	Hispaniolan Parrot						+		
Elaenia fallax	Greater Antillean Elaenia					+			
Myiarchus stolidus	Stolid Flycatcher					+	+		
Tyrannus dominicensis	Gray Kingbird		++	+		+++	++	++	++
Tyrannus caudifasciatus	Loggerhead Kingbird					+			
Vireo flavifrons	Yellow-throated Vireo		+						
Vireo altiloquus	Black-whiskered	+	+						
Corvus palmarum	Palm Crow	+					+	+	+
Corvus leucognaphalus	White-necked Crow				+	+	++	++	+++
Petrochelidon fulva	Cave Swallow	+++	+	+++	+	+++	+	+++	+
Mimus polyglottos	Northern Mockingbird	+	+	+	+	+++	++	++	++
Dulus dominicus	Palmchat	+					++	+	+++

Scientific Name	English Name	Relative Abundance by habitat							
		MF	MG	IL	SP	SV	RI	PA	AF
Parkesia noveboracensis	Northern Waterthrush		+				+		
Geothlypis trichas	Common Yellowthroat		+	+	+				
Setophaga ruticilla	American Redstart					+	+		+
Setophaga petechia	Yellow Warbler	+	+		++	+	+		
Setophaga striata	Blackpoll Warbler					+			
Setophaga caerulescens	Black-throated Blue Warbler			+		+			
Setophaga palmarum	Palm Warbler		+	+	+	+			
Coereba flaveola	Bananaquit			+			+		++
Tiaris olivaceus	Yellow-faced Grassquit			+		+		+	++
Tiaris bicolor	Black-faced Grassquit			+		+	+	+	
Loxigilla violacea	Greater Antillean Bullfinch	+				+			
Phaenicophilus palmarum	Black-crowned Palm-Tanager		+			++	+	+	+
Ammodramus savannarum	Grasshopper Sparrow			+				++	
Quiscalus niger	Greater Antillean Grackle		+	++	+		+	+	+
Molothrus bonariensis	Shiny Cowbird	+	+	+++		+		++	+
Passer domesticus	House Sparrow							+	+
Ploceus cucullatus	Village Weaver		+	++		+++	++	+	+++
Lonchura punctulata	Scaly-breasted Munia	+				+	+	+	+
Lonchura malacca	Tricolored Munia			+		+		+	

Appendix 9. List of amphibians and reptiles recorded in 3BNP.

Scientific name	English name	Redlist status	Distribution
Rhinella marina	Cane Toad	LC	Introduced
Bufo guentheri	Southern Crested Toad	VU	Native
Osteopilus dominicensis	Hispaniolan Common Tree Frog	LC	Native
Lithobates catesbeianus	Bull Frog	LC	Introduced*
Reptiles			
Anolis chlorocyanus	Hispaniolan Green Anole	Not listed	Native
Anolis cybotes	Large-headed Anole	NT	Native**
Anolis distichus	Bark Anole	Not listed	Native
Leiocephalus schreibersii	Curly-tailed Lizard	LC	Native
Leiocephalus personatus	Hispaniolan Masked curly-tailed Lizard	Not listed	Native
Ameiva chrysolaema	Common Ameiva	LC	Native
Chilabothrus fordii	Haitian Ground Boa	Not listed	Native
Chilabothrus striatus	Hispaniolan Boa	Not listed	Native
Uromacer catesbyi	Catesbyi Pointed Snake	Not listed	Native
Uromacer oxyrhynchus	Pointed Snake	Not listed	Native
Hemidactylus mabouia	Tropical House Gecko	Not listed	Introduced

*According to IUCN.org, this species was introduced to Hispaniola, but only confirmed in northern and eastern Dominican Republic, not in Haiti

**According to IUCN.org, this species is only known to occur in southern Haiti and southwest Dominican Republic (3BNP is in the northeast of Haiti).

Appendix 10. Coordinates for sampling sites of freshwater fauna species in 3BNP.

Site	Latitude	Longitude
TdN A	N19° 34' 44.22"	W71° 59' 37.02"
TdN 1	N19° 39' 14.11"	W72° 0' 24.90"
TdN 2	N19° 39' 41.87"	W72° 0' 34.74"
TdN 3	N19° 40' 20.39"	W72° 0' 17.82"
TdN 4	N19° 41' 4.49"	W72° 0' 26.22"
TdN 5	N19° 41' 30.23"	W72° 0' 17.10"
TdN 6	N19° 41' 55.21"	W72° 0' 55.60"
FtL#1	N19° 38' 25.91"	W71° 51' 36.97"
Mal 1	N19° 38' 21.05"	W71° 50' 41.21"
Mal 2	N19° 38' 45.20"	W71° 50' 35.10"
Mal 3	N19° 38' 22.81"	W71° 50' 18.67"
GdN 1	N19° 42' 4.031"	W72° 8' 32.64"
GdN 2	N19° 42' 57.96"	W72° 8' 12.12"
GdN 3	N19° 45' 4.86"	W72° 8' 2.11"
LaB 1	N19° 39' 59.04"	W71° 47' 44.23"
LaB 2	N19° 39' 47.34"	W71° 47' 21.30"
LaB 3	N19° 39' 36.54"	W71° 47' 10.14"
LaB 4	N19° 39' 28.26"	W71° 47' 1.75"
LaB 5	N19° 39' 40.93"	W71° 46' 54.84"
LaB 6	N19° 41' 4.56"	W71° 47' 24.61"

Appendix 11. Complete freshwater fauna list organized by sampling date and site in 3BNP. An "x" indicates collected at that site on the indicated date.

					June 2015								August 2015						
Order	**Family**	**Scientific Name**	**Common Name(s)**	**Distrib-ution**	**TdNA**	**TdN1**	**TdN2**	**TdN3**	**TdN4**	**TdN5**	**TdN6**	**TdN1**	**FtL1**	**Mal1**	**Mal3**	**GdN1**	**GdN2**	**GdN3**	**LaB1-5**
Fish																			
Anguilliformes	Anguillidae	*Anguilla rostrata*	American eel	Native	x	x										x			x
Beloniformes	Hemiramphidae	*Hemiramphus balao*	balao halfbeak	Native							x								
Cyprinodontiformes	Poeciliidae	*Gambusia hispaniolae*	Hispaniolan gambusia	Native			x	x	x	x		x	x	x					
Cyprinodontiformes	Poeciliidae	*Gambusia nicaraguensis*	Nicaraguan gambusia	Native											x				
Cyprinodontiformes	Poeciliidae	*Limia tridens*	trident limia	Native	x	x													
Cyprinodontiformes	Poeciliidae	*Limia pauciradiata*	few-rayed limia	Endemic		x													
Mugiliformes	Mugilidae	*Mugil* sp.	mullet	Native							x					x			X
Perciformes	unidentified Gobiidae		goby	Native							x								
Perciformes	Eleotridae	*Dormitator maculatus*	fat sleeper	Native		x			x	x				x					X
Perciformes	Eleotridae	*Eleotris amblyopsis*	largescaled spinycheek sleeper	Native											x				
Perciformes	Eleotridae	*Eleotris perniger*	smallscaled spinycheek sleeper	Native	x	x	x		x			x		x	x		x	x	X
Perciformes	Gerreidae	*Eucinostomus* sp.	mojarra	Native							x								
Perciformes	Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	Invasive				x				x		x					X
Perciformes	Gobiidae	*Awaous banana*	goby	Native												x			
Perciformes	Centropomidae	*Centropomus* sp.	snook	Native															X
Perciformes	Scaridae	*Sparisoma* sp.	parrot fish	Native							x								
Perciformes	Centropomidae	*Centropomus* sp.	snook	Native							x								
Perciformes	unidentified Gerreidae		mojarras	Native							x								
Perciformes	Sparidae	*Archosargus rhomboidalis*	western Atlantic	Native							x								

					June 2015								August 2015						
Order	**Family**	**Scientific Name**	**Common Name(s)**	**Distrib-ution**	**TdNA**	**TdN1**	**TdN2**	**TdN3**	**TdN4**	**TdN5**	**TdN6**	**TdN1**	**FtL1**	**Mal1**	**Mal3**	**GdN1**	**GdN2**	**GdN3**	**LaB1-5**
			seabream																
Perciformes	unidentified Carangidae		jack	Native							x								
Pleuronectiformes	unidentified Bothidae		lefteye flounder	Native							x								
Tetraodontiformes	Tetraodontidae	*Sphoeroides testudineus*	checkered puffer fish	Native							x								
Crab																			
Decapoda	Gecarcinidae	*Gecarcinus* sp.	land crab	Native						x									
Decapoda	Sesarmidae	*Aratus pisonii*	mangrove crab	Native							x								
Decapoda	Sesarmidae	*Sesarma* ?		Native					x										
Decapoda	Ocypodidae	*Uca* sp.	fiddler crab	Native							x								X
Decapoda	Ocypodidae	*Ocypode* sp.	ghost crab	Native							x								
Decapoda	Coenobitidae	*Coenobita clypeatus*	Carribean hermit crab	Native							x								
Decapoda	Portunidae	*Callinectes* sp.	swimming crab	Native							x								
Shrimp																			
Decapoda	Palaemonidae	*Macrobrachium crenulatum*	river prawn	Native	x	x	x	x	x	x		x							
Decapoda	Palaemonidae	*Macrobrachium faustinum*	river prawn	Native	x											x	x	x	
Decapoda	Palaemonidae	*Macrobrachium acanthurus*	river prawn	Native											x				x
Decapoda	Palaemonidae	*Palaemonetes* sp.	grass or glass shrimp	Native						x									
Decapoda	Palaemonidae	*Palaemon pandaliformis*		Native											x			x	
Decapoda	Xiphocarididae	*Xiphocaris elongata*	yellow rhino shrimp	Native		x	x	x	x							x	x	x	x
Decapoda	Penaeidae	*Penaeus* sp.	penaeid shrimp	Native							x								x
Decapoda	Alyidae	*Jonga serrei*		Native												x		x	
Decapoda	Atyidae	*Potimirim* sp.		Native													x		
Decapoda	Atyidae	*Micratya poeyi*		Native													x		
Decapoda	Atyidae	*Potimirim mexicana*		Native						x			x						

					June 2015								August 2015						
Order	**Family**	**Scientific Name**	**Common Name(s)**	**Distrib-ution**	**TdNA**	**TdN1**	**TdN2**	**TdN3**	**TdN4**	**TdN5**	**TdN6**	**TdN1**	**FtL1**	**Mal1**	**Mal3**	**GdN1**	**GdN2**	**GdN3**	**LaB1-5**
Gastropod																			
Hygrophila	Planorbidae	*Biomphalaria* sp. *(was Planorbella)*	marsh ram horn	Native						x									
Mesogastropoda	Ampullariidae	*Pomacea* sp.	apple snail	Native									x	x					x
Neogastropoda	Thaididae	*Thais rustica*	dog winkel	Native							x								
Neotaenioglossa	Thiaridae	*Melanoides tuberculata*	red-rimmed melania	Invasive									x	x					
Neotaenioglossa	Thiaridae	*Melanoides turricula*	fawn melania	Invasive											x				x
Neotaenioglossa	Thiaridae	*Tarebia granifera*	quilted melania	Invasive	x	x	x	x	x			x	x	x	x	x			x
Neritopsina	Neritidae	Neritidae sp. A	nerite	Native						x									
Archaeogastropoda	Cerithiidae	*Cerithium* sp.	cerith snail	Native							x								
Neritopsina	Neritidae	Neritidae sp. B	nerite	Native							x								
Bivalve																			
Lucinoida	Lucinidae	*Lucina pectinata*	thick lucine	Native							x								
Ostreoida	Ostreidae	*Crassostrea rhizophorae*	mangrove oyster	Native							x								
Pterioida	Pteriidae	*Pinctada* sp.	pearl oyster	Native							x								
Veneroida	Veneridae	*Chione cancellata*	cross-barred venus	Native							x								
Insect																			
Coleoptera	Gyrinidae	*Dineutus* sp.	whirligig beetle	Native				x									x		
Heteroptera	Belostomatidae	*Abedus herberti*	giant water bug	Native	x				x										
Heteroptera	Belostomatidae	*Lethocerus indicus*	giant water bug	Native		x				x									
Odonata	Libellulidae	*Tramea* ?	dragonfly nymph	Native						x									
Odonata	Libellulidae	*Libellulidae* sp. A	dragonfly nymph	Native										x					
Annelid																			
Sabellida	Serpulidae	*Spirorbis* sp.		Native															x

Appendix 12. Freshwater fauna collected from each of the four habitat types, and ranked by number of sites from which each was collected in 3BNP. Note: all Permanent Brackish sites (LaB) were consolidated into one sample so no ranking was possible.

Permanent River	# sites	Seasonal Stream	# sites	Permanent Brackish	Estuarine	# sites
Macrobrachium crenulatum	7	*Tarebia granifera*	3	*Anguilla rostrata*	*Sparisoma* sp.	1
Xiphocaris elongata	6	*Eleotris perniger*	2	*Centropomus* sp.	*Hemiramphus balao*	1
Eleotris perniger	6	*Gambusia hispaniolae*	2	*Oreochromis mossambicus*	*Centropomus* sp.	1
Pleurocera sp. (now *Goniobasis*)	5	*Pomacea* sp.	2	*Dormitator maculatus*	unidentified Gerreidae	1
Gambusia hispaniolae	5	*Melanoides tuberculata*	2	*Eleotris perniger*	*Mugil* sp.	1
Macrobrachium faustinum	3	*Oreochromis mossambicus*	1	*Mugil* sp.	*Archosargus rhomboidalis*	1
Anguilla rostrata	3	*Dormitator maculatus*	1	*Uca* sp.	unidentified Carangidae	1
Dormitator maculatus	3	*Eleotris amblyopsis*	1	*Macrobrachium acanthurus*	unidentified Bothidae	1
Oreochromis mossambicus	2	*Gambusia nicaraguensis*	1	*Penaeus* sp.	unidentified Gobiidae	1
Limia tridens	2	*Potimirim mexicana*	1	*Xiphocaris elongata*	*Eleotris perniger*	1
Tarebia granifera	2	*Macrobrachium acanthurus*	1	*Pomacea* sp.	unidentified Gerreidae	1
Abedus herberti	2	*Palaemon pandaliformis*	1	*Melanoides turricula*	*Sphoeroides testudineus*	1
Lethocerus indicus	2	*Melanoides turricula*	1	*Tarebia granifera*	*Coenobita clypeatus*	1
Dineutus sp.	2	unident. Libellulidae	1	*Spirorbis* sp.	*Uca* sp.	1
Eleotris amblyopsis	1			*Eupera* sp.	*Ocypode* sp.	1
Awaous banana	1				*Callinectes* sp.	1
Mugil sp.	1				*Aratus pisonii*	1
Limia pauciradiata	1				*Jonga serrei*	1
Gecarcinus sp.	1				*Macrobrachium faustinum*	1
Sesarma ?	1				*Penaeus* sp.	1
Jonga serrei	1				*Palaemon pandaliformis*	1
Potimirim sp.	1				*Palaemon pandaliformis*	1
Micratya poeyi	1				*Xiphocaris elongata*	1
Potimirim mexicana	1				*Neritidae* sp. B	1

Permanent River	# sites	Seasonal Stream	# sites	Permanent Brackish	Estuarine	# sites
Palaemonetes sp.	1				*Thais rustica*	1
Neritidae sp. A	1				*Lucina pectinata*	1
Unidentified Planorbidae	1				*Crassostrea rhizophorae*	1
Tramea ?	1				*Pinctada* sp.	1
					Chione cancellata	1

Appendix 13. Sampling design of the freshwater surveys (including site number, location, sampling date, substrate and coordinates surveyed in 3BNP).

Location	Site	Date	Substrate	Latitude	Longitude
Caracol	CAR-02	8-Jun 31-Aug	Reef crest Deep forereef	19.75797	-72.02730
	CAR-03	9-Jun 9-Jun 31-Aug	Seagrass Mangrove Seagrass	19.70281	-72.04036
	CAR-04	9-Jun	Mangrove	19.70532	-72.06774
	CAR-05	9-Jun 31-Aug	Seagrass	19.73099	-72.05966
	CAR-06	10-Jun 10-Jun 1-Sep	Seagrass Reef crest Deep forereef	19.73430	-71.98589
	CAR-07	10-Jun 30-Aug	Back reef Deep forereef	19.73447	-71.95261
	CAR-08	10-Jun 10-Jun 1-Sep	Seagrass Mangrove Deep forereef	19.70508	-71.98928
	CAR-27	30-Aug	Deep forereef	19.74771	-71.96522
	CAR-28	31-Aug	Deep forereef	19.76800	-72.04786
	CAR-29	1-Sep	Deep forereef	19.73587	-71.95717
	CAR-30	1-Sep	Back reef	19.75291	-71.99451
	CAR-32	3-Sep	Wall	19.74955	-72.01480
Fort Liberté	FL-09	11-Jun 11-Jun	Seagrass Mangrove	19.67405	-71.81802
	FL-10	11-Jun 11-Jun 29-Aug	Mangrove Seagrass Deep patch reef	19.69168	-71.85808
	FL-11	11-Jun	Seagrass	19.67585	-71.84247
	FL-12	12-Jun 28-Aug	Reef crest Deep forereef	19.71582	-71.83204
	FL-13	12-Jun 27-Aug	Hardground Wall	19.71123	-71.84519
	FL-14	12-Jun 28-Aug	Hardground Deep forereef	19.70508	-71.84326
	FL-15	12-Jun 12-Jun 29-Aug	Seagrass Mangrove Deep patch reef	19.69831	-71.84266
	FL-19	25-Aug	Deep forereef	19.71896	-71.85563
	FL-20	26-Aug	Deep forereef	19.70882	-71.77298
	FL-21	26-Aug	Deep forereef	19.71220	-71.80173

Location	Site	Date	Substrate	Latitude	Longitude
	FL-22	26-Aug	Deep forereef	19.76793	-72.04778
	FL-23	27-Aug	Deep forereef	19.73249	-71.92929
	FL-24	27-Aug	Deep forereef	19.73587	-71.95444
	FL-25	28-Aug	Deep forereef	19.75291	-71.99451
	FL-26	29-Aug	Deep forereef	19.72742	-71.90593
Limonade	L-16	13-Jun 2-Sep	Reef crest Deep forereef	19.77607	-72.09149
	L-17	13-Jun 3-Sep	Patch reef	19.76311	-72.10127
	L-18	13-Jun 2-Sep	Patch reef	19.75213	-72.12226
	L-31	2-Sep	Deep forereef	19.77646	-72.10715
	L-33	3-Sep	Deep patch reef	19.74944	-72.04940

Appendix 14. Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Caracol within 3BNP.

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
Anemone															
	Pale	*Aiptasia tagetes*		x											
	Corkscrew	*Bartholomea annulata*		x			x			x	x	x	x	x	x
	Upside down	*Cassiopea frondosa*		x											
	Giant	*Condylactis gigantea*	x			x	x	x		x	x	x	x	x	x
	Red beaded	*Phymanthis crucifer*	x				x	x		x	x	x	x	x	x
	Hidden	*Lebrunia coralligens*						x			x	x	x		x
	Branching	*Lebrunia danae*	x				x	x		x	x	x	x		x
	Sun	*Stichodactyla helianthus*	x			x	x	x						x	
	Cup-Tipped	*Telmatactis americana*	x												
	Turtle Grass	*Viatrix globulifera*		x					x						
Bryozoan															
		Bugula minima			x										
Coral															
	Staghorn	*Acropora cervicornis*										x			
	Elkhorn	*Acropora palmata*	x				x	x				x	x	x	
	Lettuce	*Agaricia agaricites*	x				x	x		x	x	x	x		x
	Fragile Saucer	*Agaricia fragilis*	x				x			x			x		
	Lowrelief Lettuce	*Agaricia humilis*	x				x								
	Lamarck's Sheet	*Agaricia lamarcki*								x	x		x		x
	Thin Leaf Lettuce	*Agaricia tenufolia*	x				x	x			x	x	x		
	Cauliflower	*Cladopsammia sp.*								x	x		x		x
	Boulder Brain	*Colpophyllia natans*								x	x	x	x		x
	Pillar	*Dendrogyra cylindrus*					x	x		x	x	x	x		x
	Elliptical Star	*Dichocoenia stokesi*												x	x
	Knobby Brain	*Diploria clivosa*	x				x						x		
	Smooth Flower	*Eusmilia fastigiata*								x	x	x	x		x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
	Golfball	*Favia fragum*	x				x	x							
	Rough Star	*Isophyllia rigida*											x		
	Sinuous Cactus	*Isophyllia sinuosa*						x			x	x			
	Sunray Lettuce	*Helioseris cucullata*								x	x	x	x		x
	Yellow Pencil	*Madracis aurentenra*						x		x	x	x	x		x
	Ten-Ray Star	*Madracis decactis*						x	x	x	x	x	x		x
	Eight-Ray Finger	*Madracis formosa*													x
	Star	*Madracis pharensis*								x		x	x		x
	Rose	*Manicina areolata*						x		x	x	x			
		Meandrina jacksoni								x	x	x	x		x
	Maze	*Meandrina meandrites*						x		x	x	x	x		x
	Branching Fire	*Millepora alcicornis*	x				x			x	x	x	x		x
	Blade Fire	*Millepora complanata*	x				x	x			x	x	x	x	
	Great Star	*Montastraea cavernosa*	x				x	x		x		x	x		x
	Spiny Flower	*Mussa angulosa*								x	x	x	x		x
	Knobby Cactus	*Mycetophyllia alcicae*								x	x	x	x		x
	Rough Cactus	*Mycetophyllia ferox*								x					
	Rigged Cactus	*Mycetophyllia lamarckiana*								x	x				
	Boulder Star	*Orbicella annularis*	x				x	x		x	x	x	x	x	x
	Boulder Star	*Orbicella faveolata*	x					x		x	x	x	x		x
	Boulder Star	*Orbicella franksi*									x	x			x
	Mustard Hill	*Porites astreoides*	x			x	x	x		x	x	x	x		x
	Thin Finger	*Porites divaricata*	x			x	x	x		x		x		x	x
	Branched Finger	*Porites. furcata*	x			x	x	x		x	x	x	x	x	x
	Finger	*Porites porites*	x				x			x	x	x	x		x
	Grooved Brain	*Pseudodiploria labyrinthiformis*						x		x	x	x	x		x
	Symmetrical Brain	*Pseudodiploria strigosa*	x				x	x		x	x	x	x	x	x
	Artichoke	*Scolymia cubensis*								x					x
	Lesser Starlet	*Siderastrea radians*	x			x	x							x	x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
	Massive Starlet	*Siderastrea siderea*	x			x	x	x		x	x	x	x	x	x
	Blushing	*Stephanocoenia intersepta*				x		x		x	x	x	x		x
	Lace	*Stylaster sp.*	x				x	x		x	x	x	x		x
	Orange Cup	*Tubastraea coccinea*	x				x						x		x
Corallimorph															
	Forked	*Discosoma carlgreni*									x		x		x
	Warty	*Rhodactis osculifera*	x				x	x		x	x	x			
	Florida	*Ricordea florida*	x					x		x	x	x	x		x
Echinoderm															
	Furry Sea Cucumber	*Astichopus multifidus*					x		x						
	Golden Crinoid	*Davidaster rubiginosa*								x	x	x	x		x
	Long-Spined Urchin	*Diadema antillarum*	x				x			x	x	x		x	x
	Rock-Boring Urchin	*Echinometra lucunter*	x				x	x	x						
	Reef Urchin	*Echinometra viridis*	x			x	x			x	x	x			
	Slate-Pencil Urchin	*Eucidaris tribuloides*	x			x	x	x				x	x	x	
	Donkey Dong Sea Cucumber	*Holothuria mexicana*		x		x	x		x					x	
	Three-Rowed Sea Cucumber	*Isostichopus badionotus*				x						x			
	Common Comet Star	*Linckia guildingii*				x									
	Variegated Urchin	*Lyechitnus variegatus*		x		x		x						x	
	Red-Heart Urchin	*Meoma ventricosa*	x					x						x	
	Cushion Star	*Oreaster reticulatus*		x		x									
	West Indian Sea Egg	*Tripneustes ventricosus*				x		x		x				x	
Hydrioid															
	Feathered	*Halocordyle disticha*			x										
	Branching	*Sertularella speciosa*		x											
		Tall hydroid				x									
Octocoral															
		Allogorgia acerosa										x			x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
		Allogorgia americana						x		x	x	x			
		Allogorgia rigida						x							x
		Briareum asbestinum					x	x			x	x			x
		Ellisella barbadensis									x		x		
		Erythropodium caribaeorum	x				x				x	x	x		x
		Eunicea colombiana										x			x
		Eunicea flexuosa	x				x	x			x	x	x		x
		Eunicea laciniata									x				
		Eunicea laxispica										x			x
		Eunicea sp.										x			x
		Eunicea tournefort					x	x					x		x
		Gorgonia mariae	x									x			x
		Gorgonia ventalina	x				x	x		x	x	x	x		x
		Muricea atlantica											x		
		Muricea laxa										x			
		Muricea muricata								x		x			x
		Muricea pinnata										x			
		Plexaura homomalla					x	x				x			
		Plexaura kuekenthali													
		Plexaurella fusifera	x				x	x				x			x
		Plexaurella nutans					x								
		Pseudoplexaura flagellosa & wagenarii										x	x	x	x
		Pterogorgia citrina													x
Sponge															
		Aaptos brown sp.					x								
		Aaptos pernucleata		x											
		Agelas sp.								x					
		Agelas citrina					x			x	x	x	x		x
		Agelas clathrodes													x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
		Agelas conifera	x												x
		Agelas dilatata								x					
		Agelas dispar									x	x	x		x
		Agelas schmidti						x		x	x	x	x		x
		Agelas tubulata								x	x	x	x		x
		Agelas wiedenmayeri	x							x		x	x		x
		Aiolochoria crassa						x		x	x	x	x		x
		Aiolochoria sp.									x	x	x		x
		Amphimedon compressa sp.								x	x		x		
		Amphemidon compressa		x						x	x	x	x		x
		Amphemidon compressa black					x								
		Amphemidon compressa green				x									
		Amphemidon compressa orange				x						x	x		
		Amphemidon compressa yellow				x									
		Amphemidon viridis		x		x		x			x				
		Aplysina archeri													x
		Aplysina cauliformis								x	x	x	x		x
		Aplysina fistularis				x				x	x	x	x		x
		Aplysina fulva		x		x						x	x		x
		Aplysina lacunosa								x	x	x			x
		Callyspongia armigera													x
		Callyspongia fallax								x	x	x	x		x
		Callyspongia pallida		x		x			x						
		Callyspongia plicifera										x			x
		Chalinula molitba		x											
		C. pseudomolitba		x											
		Chondrilla caribensis				x	x	x				x	x		x
		Chondrosia reniformis											x	x	x
		Chondrosiakuekenthali	x							x	x	x	x		x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
		Clathria curacaoensis		x		x	x		x						
		Clathria echinata											x		x
		Clathria faviformis	x												
		Clathria minuta								x	x	x			
		Clathria sp. yellow		x											
		Clathria sp. (Thalysias)									x				
		Clathria sp. turquoise		x											
		Clathria virgultosa		x			x								
		Cliona aprica								x					
		Cliona caribbaea	x				x	x				x	x	x	x
		Cliona delitrix								x	x	x	x		x
		Cliona laticavicola					x			x	x		x		x
		Cliona peponaca	x								x	x	x	x	x
		Cliona tenuis	x				x	x		x	x	x			
		Cliona varians					x								
		Cream unknown sp.		x											
		Desmapsamma anchorata													x
		Dictyonella funicularis				x									
		Dysidea etheria		x		x			x						
		Ectyoplasia ferox								x	x	x	x		x
		Erylus formosus								x		x	x		
		Geodia neptuni								x	x	x	x		
		Geodia papyracea				x									
		Haliclona tubifera		x											
		Hyrtios cavernosus				x									
		Hyrtios violaceus					x								
		Iotrochota arenosa		x		x	x						x		x
		Iotrochota birotulata						x		x		x			x
		Ircinia black sp.				x	x						x		x
		Ircinia brown sp.					x	x				x	x		x

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
		Ircinia campana										x	x		x
		Ircinia felix									x	x	x		x
		Ircinia strobilina				x		x		x	x	x	x		x
		Mycale laevis								x	x	x	x		
		Mycale laxissima								x	x	x	x		
		Mycale microsigmatosa		x				x	x						
		Myrmekioderma gyroderma													x
		Neofibularia nolitangere										x			
		Neopetrosia carbonaria				x								x	
		Neopetrosia proxima										x			
		Neopetrosia rosariensis											x		x
		Niphates erecta				x									
		Oceanapia bartschi													x
		Orange unknown sp.				x	x								
		Petrosia pellasarca								x	x	x	x		
		Phorbas amaranthus													x
		Placospherastra micraster									x				
		Plaktoris angulospiculatus									x				x
		Plaktoris halichondrioides									x				x
		Ptilocaulis walpersii													x
		Scopalina ruetzleri		x			x		x			x	x		
		Siphonodictyon xamaycaense								x	x	x	x		
		Smenospongia aurea						x		x	x				x
		Smenospongia conulosa											x		x
		Spirastrella coccinea	x				x	x		x		x	x		x
		Spirastrella hartmani	x									x			
		Spongia sp.				x									
		Svenzea flava								x					
		Svenzea zeai								x	x	x	x		

Category	Common name	Scientific name	CAR 02	CAR 03	CAR 04	CAR 05	CAR 06	CAR 07	CAR 08	CAR 23	CAR 24	CAR 27	CAR 29	CAR 30	CAR 32
		Tectitethya crypta													x
		Tedania ignis					x		x					x	
		Tedania klausi		x					x						
		Topsentia ophiraphidites													x
		Verongula encrusting									x				
		Verongula gigantea								x		x	x		
		Verongula reiswigi								x	x				
		Verongula rigida					x	x			x	x	x		x
		Xestospongia muta								x		x	x		x
Tunicate															
	Flat	*Botryllloides nigrum*		x	x	x			x						
	Painted	*Clavelina picta*		x	x	x									
	Button	*Distaplia corolla*		x	x										
		Gray tunicate sp.		x											
		Overgrowing tunicates	x												
		Overgrown orange tunicate		x											
	Giant	*Polycarpa spongiabilis*							x				x		
	Overgrowning Mat	*Trididemum solidum*	x				x	x		x	x	x	x		
Zoanthid															
	White encrusting	*Palythoa caribaeorum*	x				x				x	x	x		
	Mat	*Zoanthus pulchellus*	x							x	x	x	x		

Appendix 15. Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Fort Liberté within 3BNP.

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Anemone															
	Pale	*Aiptasia tagetes*		x											
	Corkscrew	*Bartholomea annulata*	x	x		x		x	x					x	x
	Knobby	*Bartholomea lucida*				x									
	Giant	*Condylactis gigantean*		x	x	x	x	x		x	x	x	x	x	x
	Red beaded	*Phymanthis crucifer*		x		x	x	x	x			x	x		x
	Hidden	*Lebrunia coralligens*				x								x	x
	Branching	*Lebrunia danae*				x	x	x		x		x			x
	Sun	*Stichodactyla helianthus*				x	x							x	
		Sponge anemone							x						
Coral															
	Staghorn	*Acropora cervicornis*				x	x				x	x	x	x	x
	Elkhorn	*Acropora palmate*				x								x	
	Fused Staghorn	*Acropora prolifera*				x									
	Lettuce	*Agaricia agaricites*		x	x	x	x	x	x	x	x	x	x	x	x
	Fragile Saucer	*Agaricia fragilis*				x				x	x	x	x	x	
	Lowrelief Lettuce	*Agaricia humilis*				x									
	Lamarck's Sheet	*Agaricia lamarcki*				x	x	x	x					x	x
	Thin Leaf Lettuce	*Agaricia tenufolia*				x				x			x		
	Tube	*Cladocora arbuscula*	x		x				x						
	Cauliflower	*Cladopsammia sp.*				x	x	x							
	Boulder Brain	*Colpophyllia natans*		x		x		x	x	x	x	x	x	x	x
	Pillar	*Dendrogyra cylindrus*				x						x	x	x	x
	Elliptical Star	*Dichocoenia stokes*				x	x	x							
	Knobby Brain	*Diploria clivosa*				x	x	x							
	Smooth Flower	*Eusmilia fastigiata*				x	x	x	x		x	x	x	x	x
	Golfball	*Favia fragum*		x		x			x						

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
	Rough Star	*Isophyllia rigida*				x	x	x				x	x		x
	Sinuous Cactus	*Isophyllia sinuosa*				x	x								x
	Sunray Lettuce	*Helioseris cucullata*		x		x	x		x		x		x	x	x
	Yellow Pencil	*Madracis aurentenra*				x	x			x	x		x	x	x
	Ten-Ray Star	*Madracis decactis*			x	x			x			x	x		x
	Star	*Madracis pharensis*				x		x							x
	Rose	*Manicina areolata*		x	x	x	x	x	x	x	x		x	x	x
		Meandrina jacksoni				x	x	x					x	x	
	Maze	*Meandrina meandrites*				x	x	x	x				x	x	x
	Branching Fire	*Millepora alcicornis*				x	x	x	x		x	x		x	x
	Blade Fire	*Millepora complanata*				x								x	x
	Great Star	*Montastraea cavernosa*				x	x	x	x	x		x		x	x
	Spiny Flower	*Mussa angulosa*				x		x	x	x		x	x		
	Knobby Cactus	*Mycetophyllia alcicae*				x		x	x				x	x	x
	Rough Cactus	*Mycetophyllia ferox*				x							x	x	x
	Rigged Cactus	*Mycetophyllia lamarckiana*				x					x	x	x	x	x
	Boulder Star	*Orbicella annularis*				x	x			x	x	x	x	x	x
	Boulder Star	*Orbicella faveolata*				x	x		x	x		x	x	x	x
	Boulder Star	*Orbicella franksi*				x					x	x			
	Hidden Cup	*Phyllangia americana*			x										
	Mustard Hill	*Porites astreoides*	x	x	x	x	x	x	x	x	x	x	x	x	x
	Thin Finger	*Porites divaricata*	x	x	x			x							
	Branched Finger	*Porites furcata*	x	x	x	x	x			x	x	x	x	x	x
	Finger	*Porites porites*				x	x	x		x	x	x	x	x	x
	Grooved Brain	*Pseudodiploria labyrinthiformis*				x				x	x	x	x	x	x
	Symmetrical Brain	*Pseudodiploria strigosa*				x	x	x		x	x	x	x	x	x
	Artichoke	*Scolymia cubensis*			x			x	x				x	x	x
	Atlantic Mushroom	*Scolymia lacera*	x	x	x				x						
	Lesser Starlet	*Siderastrea radians*		x	x	x	x	x	x						
	Massive Starlet	*Siderastrea siderea*			x	x	x	x	x	x	x	x	x	x	x

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
	Blushing	*Stephanocoenia intersepta*		x	x	x	x	x	x		x	x		x	x
	Lace	*Stylaster sp.*				x						x		x	x
	Orange Cup	*Tubastraea coccinea*				x									
Corallimorph															
	Forked	*Discosoma carlgreni*									x				
	Umbrella	*Discosoma neglecta*					x	x							
	Warty	*Rhodactis osculifera*				x	x	x			x	x	x	x	x
	Florida	*Ricordea florida*			x	x	x	x			x	x	x	x	x
Echinoderm															
	Swimming Crinoid	*Analcidometra armata*										x			
	Five-Toothed Sea Cucumber	*Actinopygia agassizii*						x							
	Furry Sea Cucumber	*Astichopus multifidus*		x											
	Sand Dollar	*Clypeaster subdepressus*					x	x							
		Davidaster rubiginosa			x	x							x	x	x
	Long-Spined Urchin	*Diadema antillarum*			x	x				x	x	x	x	x	x
	Rock-Boring Urchin	*Echinometra lucunter*	x	x	x		x	x							
	Reef Urchin	*Echinometra viridis*	x	x	x	x	x	x	x	x	x	x	x	x	x
	Slate-Pencil Urchin	*Eucidaris tribuloides*		x			x	x	x						
	Donkey Dung Sea Cucumber	*Holothuria mexicana*					x								
	Tiger Tail Sea Cucumber	*Holothuria thomasi*											x		
	Three-Rowed Sea Cucumber	*Isostichopus badionotus*		x											
	Common Comet Star	*Linckia guildingii*					x	x							
		Luidia sp.	x	x	x										
	Variegated Urchin	*Lyechitnus variegatus*	x	x	x			x	x	x		x	x	x	x
	Key Hole Urchin	*Mellita sexiesperforata*					x	x							
	Red-Heart Urchin	*Meoma ventricosa*					x	x							x
	Cushion Star	*Oreaster reticulatus*	x	x	x										
	West Indian Sea Egg	*Tripneustes ventricosus*		x	x	x	x	x			x	x			x

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Octocoral															
		Allogorgia acerosa				x	x	x							
		Allogorgia americana				x	x	x			x	x	x	x	x
		Allotogorgia bipinatta				x	x					x			
		Allogorgia elisabethae					x								
		Allogorgia rigida				x	x								
		Briareum asbestinum				x	x				x	x		x	
		Ellisella barbadensis			x		x								
		Erythropodium caribaeorum		x		x	x	x			x		x		x
		Eunicea calyculata					x								
		Eunicea clavigera												x	
		Eunicea colombiana					x	x							
		Eunicea flexuosa				x	x			x	x	x		x	x
		Eunicea fusca				x									
		Eunicea laciniata				x	x	x				x	x	x	x
		Eunicea laciniata dark					x	x							
		Eunicea laxispica					x					x	x	x	x
		Eunicea mammosa					x								
		Eunicea pallida								x					
		Eunicea sp.													x
		Eunicea succinea				x	x								
		Eunicea tournefort				x	x	x				x		x	x
		Gorgonia mariae				x		x							
		Gorgonia ventalina				x	x	x			x	x	x		x
		Muricea atlantica				x	x								
		Muricea muricata				x	x								
		Muricea pinnata					x								
		Muriceopsis flavida					x					x			
		Plexaura homomalla				x	x	x			x		x	x	x
		Plexaura kuekenthali				x	x	x							

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
		Plexaurella dichotoma				x	x						x		x
		Plexaurella fusifera				x	x	x	x			x	x	x	x
		Plexaurella nutans				x	x							x	
		Plexaurella sp.												x	
		Pseudoplexaura flagellosa & wagenarii				x	x					x	x	x	x
		Pseudoplexaura sp.												x	x
		Pseudoplexaura purosa				x									
		Pterogorgia anceps				x	x								
		Pterogorgia guadalupensis					x								
Sponge															
		Aaptos tuberculate	x	x	x										
		Agelas citrina				x									x
		Agelas clathrodes				x	x						x		
		Agelas conifera						x							
		Agelas dispar				x	x					x	x	x	x
		Agelas schmidti				x									x
		Agelas tubulata													x
		Agelas wiedenmayeri		x	x	x			x					x	x
		Aiolochoria crassa		x		x	x	x		x		x	x	x	x
		Aiolochoria sp.				x	x				x		x	x	
		Amphimedon compressa sp.				x	x						x		x
		Amphimedon compressa		x	x	x	x	x	x			x	x		x
		Amphimedon compressa orange				x						x			
		Amphimedon sp.					x								
		Amphimedon viridis	x	x	x	x	x	x	x						
		Aplysina archeri				x	x								
		Aplysina cauliformis				x	x			x	x	x	x	x	x
		Aplysina fistularis				x	x	x	x	x	x			x	x
		Aplysina fulva		x	x	x	x	x	x	x	x	x			x

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
		Aplysina lacunosa		x		x	x	x	x		x	x		x	x
		Biemna caribea					x			x					x
		Black unknown sp.	x												
		Black unknown sp.2			x										
		Blue unknown sp.			x				x						
		Callyspongia armigera		x			x	x							
		Callyspongia fallax	x			x	x	x	x			x	x	x	x
		Callyspongia pallida		x			x	x	x						
		Callyspongia plicifera				x	x								x
		Callyspongia strongylophora						x							
		Callyspongia tenerrima						x							
		Callyspongia vaginalis					x	x							
		Chondrilla caribensis		x		x	x	x	x			x	x		x
		Chondrosia collectrix		x			x	x						x	
		Cinachyrella apion			x										
		Cinachyrella kuekenthali				x	x	x	x		x		x		
		Clathria curacaoensis			x	x		x	x						
		Clathria echinata		x		x	x		x						
		Clathria minuta				x			x			x			
		Clathria sp. (Thalysias)				x						x			
		Clathria virgultosa						x	x						
		Cliona aprica			x	x							x		
		Cliona caribbaea				x	x		x					x	x
		Cliona delitrix		x		x	x	x	x				x		x
		Cliona laticavicola	x			x	x	x		x			x	x	
		Cliona peponaca				x	x	x			x	x		x	
		Cliona tenuis		x	x	x	x	x	x			x		x	x
		Cliona varians	x	x	x		x								
		Cream unknown sp.							x						
		Desmapsamma anchorata	x	x	x	x	x	x	x						

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
		Dictyonella funicularis		x											
		Dysidea etheria		x				x	x						
		Dysidea janiae							x						
		Ectyoplasia ferox		x	x	x	x	x	x		x	x	x		x
		Erylus formosus				x	x			x		x	x	x	
		Gray unknown sp.2					x								
		Geodia neptuni				x	x	x			x		x	x	x
		Green unkown sp.				x									
		Haliclona ruetzleri		x											
		Halisarca caerulea					x								
		Hyrtios violaceus			x										
		Iotrochota arenosa		x											x
		Iotrochota birotulata				x	x	x			x	x	x	x	x
		Ircinia black sp.				x	x		x						
		Ircinia brown sp.		x		x	x	x	x			x		x	x
		Ircinia campana		x		x		x	x				x		
		Ircinia felix		x	x	x	x	x	x		x	x	x		x
		Ircinia strobilina		x		x	x	x	x						x
		Maroon unkown sp.	x												
		Monanchora arbuscula				x								x	
		Mycale laevis		x		x	x	x	x		x		x		
		Mycale laxissima		x		x		x	x						
		Mycale microsigmatosa	x	x	x	x		x	x						
		Myrmekioderma gyroderma				x	x		x						x
		Myrmekioderma rea	x	x	x		x								
		Neofibularia nolitangere		x		x	x	x	x						x
		Neopetrosia carbonaria					x	x							
		Neopetrosia proxima		x			x	x	x						x
		Neopetrosia rosariensis		x		x	x	x	x		x	x	x	x	x
		Niphates digitalis					x	x	x						

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
		Niphates erecta					x	x							
		Niphates recondita		x											
		Oceanapia bartschi		x		x									
		Orange unknown sp.2	x	x											
		Orange unknown sp.3							x						
		Pandaros acanthifolium					x	x							
		Petrosia pellasarca				x	x						x	x	x
		Petrosia sp.						x							
		Phorbas amaranthus					x					x		x	
		Pink unknown sp.					x								
		Placospherastra micraster					x	x							
		Plakinastrella onkodes							x						
		Plaktoris angulospiculatus		x											
		Plaktoris sp.									x				
		Pleraplysilla sp.			x			x							
		Ptilocaulis walpersii						x	x						
		Scopalina ruetzleri				x	x	x	x						x
		Siphonodictyon xamaycaense		x									x		
		Smenospongia aurea				x	x	x			x		x	x	x
		Smenospongia conulosa						x					x		
		Spheciospongia vesparium					x	x							
		Spirastrella coccinea				x	x	x	x			x			
		Spirastrella hartmani	x	x	x	x	x	x	x						x
		Spongia obscura			x										
		Spongia tubulifera					x		x						
		Stelletta kallitetilla		x											
		Svenzea flava										x			
		Svenzea zeai				x	x				x	x		x	x
		Tectitethya crypta		x		x	x	x	x				x		
		Tedania ignis		x	x			x	x						

Category	Common name	Scientific name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
		Tedania klausi		x			x	x	x						
		Topsentia ophiraphidites			x	x	x			x	x		x		
		Verongula encrusting					x				x		x		x
		Verongula gigantea		x		x	x					x	x	x	x
		Verongula reiswigi				x	x	x			x		x	x	
		Verongula rigida		x		x	x	x		x			x		x
		Xestospongia muta			x	x	x	x	x		x	x	x		x
		Yellow unknown sp.													x
Tunicate															
	Green Tube	*Ascidia sydneiensis*		x											
		Pink tunicate sp.	x	x	x										
	Flat	*Botryllloides nigrum*	x	x				x							
	Row Encrusting	*Botrylloides* sp.				x									
	Row Encrusting	*Botrylloides* sp.2	x												
	Mottled Social	*Polyandrocarpa tumida*	x	x											
	Giant	*Polycarpa spongiabilis*	x	x	x	x		x	x						
	Reef	*Rhopalaea abdominalis*	x	x	x	x	x	x							
	Encrusting Social	*Symplegma viride*	x	x	x										
	Overgrowing Mat	*Tridemum solidum*	x	x			x		x						x
Zoanthid															
	White encrusting	*Palythoa caribaeorum*				x	x	x		x		x		x	x
	Mat	*Zoanthus pulchellus*			x	x						x	x		x
	Sponge	*Parazoanthus parasiticus*				x									

Appendix 16. Species list of the marine sessile- and motile-benthic organisms identified at the different sites surveyed in Limonade within 3BNP.

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
Anemone								
	Elegant	*Actinoporus elegans*		x				
	Corkscrew	*Bartholomea annulata*		x		x	x	X
	Knobby	*Bartholomea lucida*	x	x				
	Giant	*Condylactis gigantea*	x	x	x	x	x	X
	Red beaded	*Phymanthis crucifer*	x	x	x	x	x	X
	Hidden	*Lebrunia coralligens*				x	x	X
	Branching	*Lebrunia danae*	x	x	x		x	X
	Sun	*Stichodactyla helianthus*	x	x	x	x		
Coral								
	Staghorn	*Acropora cervicornis*					x	
	Elkhorn	*Acropora palmata*	x	x	x			
	Fused Staghorn	*Acropora prolifera*		x				
	Lettuce	*Agaricia agaricites*	x	x	x	x	x	X
	Fragile Saucer	*Agaricia fragilis*		x				X
	Lowrelief Lettuce	*Agaricia humilis*		x				
	Lamarck's Sheet	*Agaricia lamarcki*		x	x	x		X
	Thin Leaf Lettuce	*Agaricia tenufolia*				x	x	
	Cauliflower	*Cladopsammia sp.*						X
	Boulder Brain	*Colpophyllia natans*			x	x	x	X
	Pillar	*Dendrogyra cylindrus*	x			x	x	
	Elliptical Star	*Dichocoenia stokesi*					x	
	Knobby Brain	*Diploria clivosa*	x	x	x			
	Smooth Flower	*Eusmilia fastigiata*			x	x	x	
	Golfball	*Favia fragum*	x	x	x			
	Rough Star	*Isophyllia rigida*			x		x	
	Sinuous Cactus	*Isophyllia sinuosa*			x	x	x	
	Sunray Lettuce	*Helioseris cucullata*			x	x	x	X
	Yellow Pencil	*Madracis aurentenra*				x	x	
	Ten-Ray Star	*Madracis decactis*			x	x	x	X
	Star	*Madracis pharensis*				x		
	Rose	*Manicina areolata*		x				
		Meandrina jacksoni	x			x	x	
	Maze	*Meandrina meandrites*			x		x	X
	Branching Fire	*Millepora alcicornis*	x	x	x	x	x	X
	Blade Fire	*Millepora complanata*	x	x	x	x		
	Great Star	*Montastraea cavernosa*	x	x	x	x	x	X
	Rigged Cactus	*Mycetophyllia lamarckiana*					x	
	Boulder Star	*Orbicella annularis*	x	x	x	x	x	X

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
	Boulder Star	*Orbicella faveolata*		x	x	x	x	X
	Boulder Star	*Orbicella franksi*						X
	Hidden Cup	*Phyllangia americana*	x					
	Mustard Hill	*Porites astreoides*	x	x	x	x	x	X
	Thin Finger	*Porites divaricata*	x	x		x	x	X
	Branched Finger	*Porites furcata*	x	x	x	x	x	X
	Finger	*Porites porites*	x	x	x	x	x	X
	Grooved Brain	*Pseudodiploria labyrinthiformis*				x	x	
	Symmetrical Brain	*Pseudodiploria strigosa*	x	x	x	x	x	
	Artichoke	*Scolymia cubensis*			x			
	Lesser Starlet	*Siderastrea radians*	x	x	x		x	
	Massive Starlet	*Siderastrea siderea*	x	x	x	x	x	X
	Blushing	*Stephanocoenia intersepta*	x	x	x	x	x	X
	Lace	*Stylaster sp.*	x	x	x	x	x	
	Orange Cup	*Tubastraea coccinea*	x	x	x	x		
Corallimorph								
	Forked	*Discosoma carlgreni*		x	x	x	x	X
	Umbrella	*Discosoma neglecta*		x				
	Warty	*Rhodactis osculifera*		x	x			
	Florida	*Ricordea florida*	x	x	x	x	x	X
Echinoderm								
	Five-Toothed Sea Cucumber	*Actinopygia agassizii*		x				
	Golden Crinoid	*Davidaster rubiginosa*				x		
	Long-Spined sea urchin	*Diadema antillarum*				x	x	
	Rock-Boring Urchin	*Echinometra lucunter*	x	x				
	Reef Urchin	*Echinometra viridis*	x	x		x	x	
	Donkey Dung Sea Cucumber	*Holothuria mexicana*						X
	Common Comet Star	*Linckia guildingii*	x	x				
	Red-Heart Urchin	*Meoma ventricosa*		x		x	x	
	Variegated Urchin	*Tripneustes ventricosus*	x	x				
Hydrioid								
	Unbranched	*Cnidoscyphus marginatus*			x			
	Feathered	*Halocordyle disticha*		x				
Octocoral								
		Allogorgia acerosa			x	x	x	
		Allogorgia americana	x	x	x	x		
		Allotogorgia bipinatta				x	x	
		Briareum asbestinum		x	x	x	x	
		Ellisella barbadensis						X
		Erythropodium caribaeorum		x	x	x	x	
		Eunicea asperula		x	x		x	

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
		Eunicea calyculata			x		x	
		Eunicea clavigera						X
		Eunicea colombiana			x			X
		Eunicea flexuosa	x	x	x	x	x	
		Eunicea laciniata		x	x		x	
		Eunicea laxispica				x		
		Eunicea mammosa	x	x	x			X
		Eunicea pallida	x	x				X
		Eunicea sp.		x			x	
		Eunicea succinea		x	x			X
		Eunicea tournefort	x	x	x	x	x	
		Gorgonia mariae	x	x				x
		Gorgonia ventalina	x	x	x	x	x	
		Muricea atlantica	x		x		x	
		Muricea muricata	x	x	x	x	x	
		Muricea pinnata					x	
		Muriceopsis bayeriana	x					
		Muriceopsis flavida		x	x			x
		Plexaura homomalla	x	x	x	x	x	
		Plexaura kuekenthali		x				
		Plexaurella dichotoma		x	x	x	x	x
		Plexaurella fusifera		x		x	x	
		Plexaurella nutans			x		x	
		Plexaurella sp.						x
		Pseudoplexaura flagellosa & wagenarii	x	x	x	x	x	
		Pterogorgia citrina	x	x				
Sponge								
		Agelas sp.				x		
		Agelas citrina	x			x		
		Agelas clathrodes	x					
		Agelas conifera						x
		Agelas dilatata					x	x
		Agelas dispar	x			x	x	x
		Agelas schmidti				x		x
		Agelas tubulata					x	x
		Agelas wiedenmayeri	x			x		x
		Aiolochoria crassa	x			x	x	x
		Aiolochoria sp.	x			x	x	
		Amphemidon compressa sp.						x
		Amphemidon compressa	x		x		x	
		Amphemidon viridis			x			
		Aplysina archeri						x

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
		Aplysina cauliformis		x	x	x	x	x
		Aplysina fistularis	x	x	x	x	x	x
		Aplysina fulva	x	x	x		x	
		Aplysina insularis	x					x
		Batzella rubra					x	
		Biemna caribea				x	x	
		Blue unknown sp.						x
		Callyspongia armigera					x	x
		Callyspongia fallax				x	x	
		Callyspongia pallida			x		x	x
		Callyspongia plicifera				x	x	
		Callyspongia tenerrima						x
		Callyspongia vaginalis					x	
		C. pseudomolitba						x
		Chondrilla caribensis	x	x	x	x	x	
		Chondrosia collectrix	x	x	x			
		Cinachyrella apion						x
		Chondrosiakuekenthali		x	x	x	x	
		Clathria curacaoensis			x			x
		Clathria echinata			x		x	
		Clathria sp. black					x	
		Clathria sp. (Thalysias)						x
		Clathria virgultosa	x					x
		Cliona aprica	x			x		
		Cliona caribbaea	x	x		x	x	
		Cliona delitrix			x	x		
		Cliona laticavicola	x	x		x	x	
		Cliona peponaca	x	x	x	x	x	
		Cliona tenuis	x	x	x	x	x	x
		Cream unknown sp.						x
		Dysidea etheria						x
		Dysidea janiae		x				x
		Ectyoplasia ferox				x	x	
		Gray unknown sp.				x		
		Geodia neptuni				x	x	
		Halisarca caerulea	x	x				x
		Haliclona sp.						x
		Hyrtios violaceus						x
		Igernella notabilis						x
		Iotrochota arenosa						x
		Iotrochota birotulata	x	x	x		x	x
		Ircinia black sp.	x		x			x

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
		Ircinia brown sp.	x	x	x		x	x
		Ircinia campana			x	x	x	x
		Ircinia felix			x	x	x	x
		Ircinia strobilina	x			x	x	
		Maroon unkown sp.						x
		Monanchora arbuscula	x	x			x	x
		Mycale laevis	x	x	x	x	x	x
		Mycale laxissima					x	x
		Mycale microsigmatosa						x
		Myrmekioderma gyroderma						x
		Myrmekioderma rea						x
		Neofibularia nolitangere	x		x			x
		Neopetrosia carbonaria						x
		Neopetrosia proxima		x			x	x
		Neopetrosia rosariensis	x	x	x	x	x	
		Niphates digitalis			x			
		Niphates erecta		x	x			
		Niphates purple		x	x			
		Phorbas amaranthus					x	
		Plakinastrella onkodes						x
		Plaktoris angulospiculatus						x
		Pleraplysilla sp.						x
		Ptilocaulis walpersii						x
		Scopalina ruetzleri	x		x	x	x	
		Siphonodictyon xamaycaense			x		x	x
		Smenospongia aurea	x	x		x	x	x
		Smenospongia conulosa	x	x			x	
		Spirastrella coccinea	x	x	x	x	x	x
		Spirastrella hartmani	x	x	x			
		Svenzea zeai				x	x	
		Tectitethya crypta			x		x	
		Tedania ignis	x	x				x
		Tedania klausi			x		x	
		Topsentia ophiraphidites						x
		Verongula encrusting		x				x
		Verongula gigantea				x	x	x
		Verongula reiswigi						x
		Verongula rigida	x	x		x	x	x
		Xestospongia muta				x	x	
Tunicate								
	Button	*Distaplia corolla*			x			
		Gray tunicate sp.						x

Category	Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
		Overgrowing tunicates			x			
	Giant	*Polycarpa spongiabilis*	x		x	x	x	
	Overgrowning Mat	*Tridemum solidum*			x		x	
Zoanthid								
	White encrusting	*Palythoa caribaeorum*	x	x	x		x	
	Sun	*Palythoa grandis*		x				
	Mat	*Zoanthus pulchellus*	x	x	x		x	
	Sponge	*Parazoanthus parasiticus*		x				

Appendix 17. Species list of coral reef fish identified at the different sites surveyed in Caracol within 3BNP.

Common Name	Scienfitic Name	CA R02	CA R03	CA R04	CA R05	CA R06	CA R07	CA R08	CA R23	CA R24	CA R27	CA R29	CA R30	CAR 32
Arrow Blenny	*Lucayablennius zingaro*								x					
Balloonfish	*Diodon holocanthus*		x			x		x	x		x		x	x
Banded Butterflyfish	*Chaetodon striatus*	x					x		x		x	x		x
Bar Jack	*Caranx ruber*	x					x		x			x		x
Barred Cardinalfish	*Apogon binotatus*	x												
Barred Hamlet Caribbean	*Hypoplectrus puella*	x							x	x		x		x
Beaugregory	*Stegastes leucostictus*												x	
Belted Cardinalfish	*Apogon townsendi*	x									x	x		
Bicolor Damselfish	*Stegastes partitus*	x					x		x	x	x	x	x	x
Black Hamlet	*Hypoplectrus nigricans*	x					x		x	x	x	x		x
Blackbar Soldierfish	*Myripristis jacobus*	x					x			x	x	x		x
Blackcap Basslet	*Gramma melacara*											x		x
Blackear Wrasse	*Halichoeres poeyi*	x					x				x	x	x	x
Blue Chromis	*Chromis cyanea*	x					x		x	x	x	x		x
Blue Runner	*Caranx crysos*						x							
Blue Tang	*Acanthurus coeruleus*	x					x		x	x	x	x	x	x
Bluehead	*Thalassoma bifasciatum*	x					x		x	x	x	x	x	x
Bluestriped Lizardfish	*Synodus saurus*											x		
Boga	*Haemulon vittatum*									x				
Bridled Goby Complex	*C. glaucofraenum/C. bol/C. tortugae*								x	x	x	x		x
Broadstripe Goby	*Gobiosoma prochilos*										x	x		x
Brown Chromis	*Chromis multilineata*											x		x
Brown Garden Eel	*Heteroconger longissimus*													x
Bucktooth Parrotfish	*Sparisoma radians*		x		x	x							x	
Butter Hamlet	*Hypoplectrus unicolor*													x
Cardinal Soldierfish	*Plectrypops retrospinis*											x		
Caribbean Puffer	*Sphoeroides greeleyi*					x								

Common Name	Scienfitic Name	CA R02	CA R03	CA R04	CA R05	CA R06	CA R07	CA R08	CA R23	CA R24	CA R27	CA R29	CA R30	CAR 32
Chalk Bass	*Serranus tortugarum*													x
Clown Wrasse	*Halichoeres maculipinna*	x					x		x	x	x	x	x	x
Cocoa Damselfish	*Stegastes variabilis*								x	x	x	x		x
Coney	*Cephalopholis fulva*	x					x		x	x	x	x		x
Creole Wrasse	*Clepticus parrae*	x							x	x	x	x		x
Crested Goby	*Lophogobius cyprinoides*							x						
Doctorfish	*Acanthurus chirurgus*											x		x
Dusky Damselfish	*Stegastes adustus*	x					x		x		x	x		
Dusky Squirrelfish	*Sargocentron vexillarium*	x					x				x	x		x
Fairy Basslet	*Gramma loreto*								x	x	x	x		x
Foureye Butterflyfish	*Chaetodon capistratus*		x						x		x			x
French Grunt	*Haemulon flavolineatum*	x						x		x	x	x		x
Frillfin Goby	*Bathygobius soporator*					x								
Glasseye Snapper	*Heteropriacanthus cruentatus*								x	x	x	x		
Glassy Sweeper	*Pempheris schomburgkii*	x									x			
Goldentail Moray	*Gymnothorax miliaris*								x		x	x		
Goldspot Goby	*Gnatholepis thompsoni*	x							x	x	x	x		x
Gray Snapper	*Lutjanus griseus*				x			x						x
Graysby	*Cephalopholis cruentata*								x	x	x	x		x
Great Barracuda	*Sphyraena barracuda*		x			x								
Greater Soapfish	*Rypticus saponaceus*													x
Green Razorfish	*Xyrichtys splendens*													x
Greenblotch Parrotfish	*Sparisoma atomarium*	x					x		x	x	x	x		x
Hairy Blenny Complex	*Labrisomus nuchipinnis/L. conditus/L.cricota*												x	
Harlequin Bass	*Serranus tigrinus*	x					x		x	x	x	x	x	x
Highhat	*Pareques acuminatus*													x
Honeycomb Cowfish	*Lactophrys polygonius*									x				
Hovering Dartfish (Hovering Goby)	*Ptereleotris helenae*													x
Indigo Hamlet	*Hypoplectrus indigo*	x					x		x	x	x	x		x

Common Name	Scienfitic Name	CA R02	CA R03	CA R04	CA R05	CA R06	CA R07	CA R08	CA R23	CA R24	CA R27	CA R29	CA R30	CAR 32
Jackknife-Fish	*Equetus lanceolatus*													x
Juvenile Hamlet	*Hypoplectrus sp.*								x					
Key Worm Eel	*Ahlia egmontis*				x									
Longfin Damselfish	*Stegastes diencaeus*	x	x		x	x	x	x	x	x	x	x	x	x
Longjaw Squirrelfish	*Neoniphon marianus*	x							x	x	x	x		x
Longsnout Butterflyfish	*Chaetodon aculeatus*										x			
Longspine Squirrelfish	*Holocentrus rufus*								x	x	x	x		x
Mahogany Snapper	*Lutjanus mahogoni*							x						
Masked Goby/Glass Goby	*Coryphopterus personatus/hyalinus*								x	x	x	x		x
Mimic Cardinalfish	*Apogon phenax*													x
Mottled Jawfish	*Opistognathus maxillosus*	x												
Ocean Surgeonfish	*Acanthurus bahianus*	x			x		x		x	x	x	x	x	x
Orangespotted Filefish	*Cantherhines pullus*	x							x		x	x		x
Pallid Goby	*Coryphopterus eidolon*								x	x				
Peacock Flounder	*Bothus lunatus*													x
Peppermint Basslet	*Liopropoma rubre*								x	x				
Peppermint Goby	*Coryphopterus lipernes*								x	x	x			x
Princess Parrotfish	*Scarus taeniopterus*	x					x			x	x	x		x
Puddingwife	*Halichoeres radiatus*	x					x		x	x	x	x		x
Queen Parrotfish	*Scarus vetula*	x							x		x	x		
Rainbow Wrasse	*Halichoeres pictus*								x	x	x	x		
Red Hind	*Epinephelus guttatus*									x				
Red Lionfish (exotic)	*Pterois volitans*								x					x
Red Lizardfish	*Synodus synodus*											x		x
Redband Parrotfish	*Sparisoma aurofrenatum*	x					x		x	x	x	x	x	x
Redlip Blenny	*Ophioblennius atlanticus*	x												
Redspotted Hawkfish	*Amblycirrhitus pinos*	x					x			x	x	x		x
Reef Croaker	*Odontoscion dentex*									x				
Rock Beauty	*Holacanthus tricolor*								x	x	x	x		x

Common Name	Scienfitic Name	CA R02	CA R03	CA R04	CA R05	CA R06	CA R07	CA R08	CA R23	CA R24	CA R27	CA R29	CA R30	CAR 32
Rosy Blenny	*Malacoctenus macropus*					x							x	
Roughhead Blenny	*Acanthemblemaria aspera*	x							x		x			
Saddled Blenny	*Malacoctenus triangulatus*					x	x							
Sand Diver	*Synodus intermedius*													x
Sand Tilefish	*Malacanthus plumieri*													x
Schoolmaster	*Lutjanus apodus*		x			x		x	x	x	x			x
Sea Bream	*Archosargus rhomboidalis*		x											
Sergeant Major	*Abudefduf saxatilis*	x					x	x	x		x	x	x	x
Sharknose Goby	*Gobiosoma evelynae*	x							x	x	x	x		x
Sharpnose Puffer	*Canthigaster rostrata*						x		x	x	x	x		x
Shy Hamlet	*Hypoplectrus guttavarius*									x				x
Silversides, Herrings, Anchovies			x			x		x						
Slippery Dick	*Halichoeres bivittatus*	x			x		x				x	x	x	x
Smallmouth Grunt	*Haemulon chrysargyreum*								x					
Smooth Trunkfish	*Lactophrys triqueter*										x			
Southern Sennet	*Sphyraena picudilla*									x				
Spanish Hogfish	*Bodianus rufus*	x					x		x	x	x	x		x
Spinyhead Blenny	*Acanthemblemaria spinosa*	x							x	x	x			
Spotted Drum	*Equetus punctatus*	x							x	x				
Spotted Goatfish	*Pseudupeneus maculatus*	x					x				x	x		x
Spotted Moray	*Gymnothorax moringa*											x		x
Spotted Trunkfish	*Lactophrys bicaudalis*									x		x		
Squirrelfish	*Holocentrus adscensionis*											x		
Stoplight Parrotfish	*Sparisoma viride*	x					x		x	x	x	x	x	x
Striped Parrotfish	*Scarus iseri*	x			x	x	x		x	x	x	x	x	x
Sunshinefish	*Chromis insolata*													x
Threespot Damselfish	*Stegastes planifrons*	x					x		x	x	x	x		x
Tobaccofish	*Serranus tabacarius*								x		x			x
Trumpetfish	*Aulostomus maculatus*	x					x		x	x	x	x		x

Common Name	Scienfitic Name	CA R02	CA R03	CA R04	CA R05	CA R06	CA R07	CA R08	CA R23	CA R24	CA R27	CA R29	CA R30	CAR 32
Unidentified Needlefish			x											
White Grunt	*Haemulon plumieri*	x						x	x	x				
Whitestar Cardinalfish	*Apogon lachneri*													x
Yellow Goatfish	*Mulloidichthys martinicus*	x					x		x	x	x	x		x
Yellowfin Mojarra	*Gerres cinereus*		x			x	x	x						
Yellowhead Jawfish	*Opistognathus aurifrons*									x		x		x
Yellowhead Wrasse	*Halichoeres garnoti*	x					x		x	x	x	x		x
Yellowline Goby	*Gobiosoma horsti*	x					x		x	x	x			x
Yellowtail Parrotfish	*Sparisoma rubripinne*	x					x			x	x			
Yellowtail Damselfish	*Microspathodon chrysurus*	x					x		x	x	x	x		x
Yellowtail Snapper	*Ocyurus chrysurus*				x									

Appendix 18. Species list of coral reef fish identified at the different sites surveyed in Fort Liberté within 3BNP.

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Almaco Jack	*Seriola rivoliana*							x						
Atlantic Bumper	*Chloroscombrus chrysurus*			x										
Balloonfish	*Diodon holocanthus*			x	x	x	x						x	
Banded Butterflyfish	*Chaetodon striatus*												x	
Banded Jawfish	*Opistognathus macrognathus*				x									
Bar Jack	*Caranx ruber*		x		x	x		x	x	x	x	x	x	x
Barred Cardinalfish	*Apogon binotatus*		x				x							
Barred Hamlet (Caribbean)	*Hypoplectrus puella*		x	x	x	x	x	x	x	x	x	x	x	x
Beaugregory	*Stegastes leucostictus*		x	x	x	x	x	x	x	x	x	x		
Belted Cardinalfish	*Apogon townsendi*				x								x	
Bicolor Damselfish	*Stegastes partitus*		x		x	x	x	x	x	x	x	x	x	x
Black Hamlet	*Hypoplectrus nigricans*				x	x	x	x	x	x	x	x	x	x
Blackbar Soldierfish	*Myripristis jacobus*				x		x		x	x		x	x	x
Blackear Wrasse	*Halichoeres poeyi*			x	x	x	x				x			x
Blue Chromis	*Chromis cyanea*				x	x	x		x	x	x	x	x	x
Blue Dartfish (Blue Goby)	*Ptereleotris calliurus*						x			x				
Blue Runner	*Caranx crysos*		x		x									
Blue Tang	*Acanthurus coeruleus*		x	x	x	x	x	x	x	x	x	x	x	x
Bluehead	*Thalassoma bifasciatum*			x	x	x	x	x	x	x	x	x	x	x
Bluelip Parrotfish	*Cryptotomus roseus*		x	x			x	x						
Bluestriped Grunt	*Haemulon sciurus*													x
Boga	*Haemulon vittatum*				x	x							x	
Bridled Burrfish	*Cyclichthys antennatus*						x				x			
Bridled Goby Complex	*C. glaucofraenum/C. bol/C. tortugae*		x	x	x	x	x	x	x	x	x	x	x	x
Broadstripe Goby	*Gobiosoma prochilos*				x				x	x		x	x	x
Brown Chromis	*Chromis multilineata*						x				x			
Brown Garden Eel	*Heteroconger longissimus*				x	x								
Bucktooth Parrotfish	*Sparisoma radians*			x		x	x	x						

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Butter Hamlet	*Hypoplectrus unicolor*		x		x		x		x	x	x	x		
Caribbean Puffer	*Sphoeroides greeleyi*						x							
Cero	*Scomberomorus regalis*				x									
Chain Moray	*Echidna catenata*						x							
Chalk Bass	*Serranus tortugarum*					x	x							
Clown Wrasse	*Halichoeres maculipinna*			x	x	x			x	x	x	x	x	x
Cocoa Damselfish	*Stegastes variabilis*			x	x	x	x	x	x	x	x	x	x	x
Colon Goby	*Coryphopterus dicrus*				x		x			x			x	
Coney	*Cephalopholis fulva*				x	x	x			x		x	x	x
Creole Wrasse	*Clepticus parrae*				x	x	x		x	x	x	x	x	x
Doctorfish	*Acanthurus chirurgus*		x	x	x	x	x				x			x
Dusky Cardinalfish	*Phaeoptyx pigmentaria*				x									
Dusky Damselfish	*Stegastes adustus*		x	x	x		x				x	x		x
Dusky Squirrelfish	*Sargocentron vexillarium*				x		x				x		x	
Eyed Flounder	*Bothus ocellatus*													
Fairy Basslet	*Gramma loreto*				x	x	x					x	x	x
Flamefish	*Apogon maculatus*						x							
Foureye Butterflyfish	*Chaetodon capistratus*		x	x	x	x	x	x	x	x	x	x	x	x
French Grunt	*Haemulon flavolineatum*			x	x		x				x	x	x	x
Fringed Filefish	*Monacanthus ciliatus*			x										
Glasseye Snapper	*Heteropriacanthus cruentatus*											x	x	x
Goldentail Moray	*Gymnothorax miliaris*				x									x
Goldspot Goby	*Gnatholepis thompsoni*			x	x	x	x	x	x	x	x	x	x	x
Gray Angelfish	*Pomacanthus arcuatus*		x											
Gray Snapper	*Lutjanus griseus*												x	
Graysby	*Cephalopholis cruentata*				x	x	x		x	x	x	x	x	x
Greater Soapfish	*Rypticus saponaceus*													x
Green Razorfish	*Xyrichtys splendens*					x								
Greenblotch Parrotfish	*Sparisoma atomarium*		x		x	x	x	x	x	x	x	x	x	x
Hairy Blenny Complex	*Labrisomus nuchipinnis/L. conditus/L.cricota*			x										

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Harlequin Bass	*Serranus tigrinus*				x	x	x	x	x	x	x	x	x	x
Harlequin Pipefish	*Micrognathus ensenadae*										x			
Highhat	*Pareques acuminatus*						x					x		
Honeycomb Cowfish	*Lactophrys polygonius*				x									
Hovering Dartfish (Hovering Goby)	*Ptereleotris helenae*						x							
Hybrid Hamlet	*Hypoplectrus (Hybrid)*					x			x					
Indigo Hamlet	*Hypoplectrus indigo*				x	x	x		x	x	x	x	x	x
Jackknife-Fish	*Equetus lanceolatus*													
Juvenile Grunt	*Haemulon sp.*												x	
Juvenile Hamlet	*Hypoplectrus sp.*			x	x		x		x	x	x	x	x	x
Key Worm Eel	*Ahlia egmontis*			x										
Lane Snapper	*Lutjanus synagris*												x	
Lined Sole	*Achirus lineatus*			x										
Longfin Damselfish	*Stegastes diencaeus*				x		x		x		x	x	x	x
Longjaw Squirrelfish	*Neoniphon marianus*				x	x			x	x	x	x	x	x
Longsnout Butterflyfish	*Chaetodon aculeatus*													x
Longspine Squirrelfish	*Holocentrus rufus*				x	x				x	x	x	x	x
Mahogany Snapper	*Lutjanus mahogoni*				x						x			
Masked Goby/Glass Goby	*Coryphopterus personatus/hyalinus*		x	x	x	x	x	x	x	x	x	x	x	x
Mottled Mojarra	*Eucinostomus lefroyi*			x										
Mutton Snapper	*Lutjanus analis*		x											
Night Sergeant	*Abudefduf taurus*			x										
Ocean Surgeonfish	*Acanthurus bahianus*		x	x	x	x	x	x	x	x	x	x	x	x
Orangespotted Filefish	*Cantherhines pullus*				x	x				x			x	x
Orangespotted Goby	*Nes longus*		x	x				x						
Pallid Goby	*Coryphopterus eidolon*				x		x		x	x	x	x	x	
Peppermint Basslet	*Liopropoma rubre*													x
Peppermint Goby	*Coryphopterus lipernes*				x						x	x	x	x
Porkfish	*Anisotremus virginicus*													
Princess Parrotfish	*Scarus taeniopterus*			x	x	x	x	x	x	x	x	x	x	x

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Puddingwife	*Halichoeres radiatus*				x						x			x
Pygmy Seabass	*Serraniculus pumilio*			x										
Queen Angelfish	*Holacanthis ciliaris*						x							
Queen Parrotfish	*Scarus vetula*								x					x
Rainbow Wrasse	*Halichoeres pictus*										x	x	x	x
Red Lionfish (exotic)	*Pterois volitans*		x	x		x		x			x	x	x	x
Red Squirrelfish	*Holocentrus sp.*				x									
Redband Parrotfish	*Sparisoma aurofrenatum*		x	x	x	x	x	x	x	x	x	x	x	x
Redlip Blenny	*Ophioblennius atlanticus*				x									
Redspotted Hawkfish	*Amblycirrhitus pinos*				x		x		x			x		x
Redtail Parrotfish	*Sparisoma chrysopterum*													x
Reef Butterflyfish	*Chaetodon sedentarius*		x			x	x	x		x				
Reef Croaker	*Odontoscion dentex*				x								x	
Reef Squirrelfish	*Holocentrus coruscus*		x	x				x						
Rock Beauty	*Holacanthus tricolor*												x	x
Rosy Blenny	*Malacoctenus macropus*				x									
Rosy Razorfish	*Xyrichtys martinicensis*				x	x								
Roughhead Blenny	*Acanthemblemaria aspera*					x			x	x	x	x		
Saddled Blenny	*Malacoctenus triangulatus*				x		x							x
Sailors Choice	*Haemulon parra*				x									
Sand Diver	*Synodus intermedius*		x		x	x				x		x	x	x
Sand Tilefish	*Malacanthus plumieri*				x									
Saucereye Porgy	*Calamus calamus*											x		
Schoolmaster	*Lutjanus apodus*			x	x	x	x		x		x	x	x	x
Scrawled Filefish	*Aluterus scriptus*										x			
Sergeant Major	*Abudefduf saxatilis*		x		x	x	x	x	x		x	x	x	x
Sharknose Goby	*Gobiosoma evelynae*				x					x	x	x	x	x
Sharpnose Puffer	*Canthigaster rostrata*		x	x	x	x	x	x	x	x	x	x	x	x
Sharptail Eel	*Myrichthys breviceps*											x		
Shortfin Pipefish	*Cosmoccampus elucens*						x							

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Shortnose Batfish	*Ogcocephalus nasutus*						x							
Shy Hamlet	*Hypoplectrus guttavarius*				x		x	x	x	x		x	x	
Silver Jenny	*Eucinostomus gula*			x										
Slender Filefish	*Monacanthus tuckeri*			x										
Slender Mojarra	*Eucinostomus jonesii*			x				x						
Slippery Dick	*Halichoeres bivittatus*		x	x	x	x	x	x			x	x		x
Smallmouth Grunt	*Haemulon chrysargyreum*								x			x		x
Smooth Trunkfish	*Lactophrys triqueter*		x						x					
Spanish Hogfish	*Bodianus rufus*				x				x				x	x
Spanish Sardine	*Sardinella aurita*			x				x						
Spinyhead Blenny	*Acanthemblemaria spinosa*				x						x	x		x
Sponge Cardinalfish	*Phaeoptyx xenus*		x											
Spotfin Butterflyfish	*Chaetodon ocellatus*					x								
Spotted Drum	*Equetus punctatus*									x				
Spotted Goatfish	*Pseudupeneus maculatus*			x	x	x	x	x	x	x	x	x		x
Spotted Moray	*Gymnothorax moringa*				x			x						
Spotted Soapfish	*Rypticus subbifrenatus*						x							
Spotted Trunkfish	*Lactophrys bicaudalis*				x								x	x
Squirrelfish	*Holocentrus adscensionis*			x										
Stoplight Parrotfish	*Sparisoma viride*		x	x	x	x	x	x	x	x	x	x	x	x
Striped Parrotfish	*Scarus iseri*		x	x	x	x	x	x	x	x	x	x	x	x
Threespot Damselfish	*Stegastes planifrons*		x	x	x	x	x	x	x	x	x	x	x	x
Tobaccofish	*Serranus tabacarius*		x	x	x		x	x	x	x	x	x	x	x
Tomtate	*Haemulon aurolineatum*				x							x		
Trumpetfish	*Aulostomus maculatus*				x	x	x			x	x	x		x
Twinspot Bass	*Serranus flaviventris*			x				x						
Unidentified Glass Blenny	*Emblemariopsis spp*												x	
White Grunt	*Haemulon plumieri*		x	x	x	x	x				x			
Whitestar Cardinalfish	*Apogon lachneri*												x	
Wrasse Blenny	*Hemiemblemaria simulus*				x									

Common Name	Scienfitic Name	FL09	FL10	FL11	FL12	FL13	FL14	FL15	FL19	FL20	FL21	FL22	FL25	FL26
Yellow Goatfish	*Mulloidichthys martinicus*		x	x		x	x	x	x	x	x	x	x	x
Yellow Jack	*Caranx bartholomaei*										x			
Yellow Stingray	*Urobatis jamaicensis*				x									
Yellowfin Mojarra	*Gerres cinereus*			x				x						
Yellowhead Jawfish	*Opistognathus aurifrons*				x			x	x	x	x	x	x	x
Yellowhead Wrasse	*Halichoeres garnoti*		x	x	x	x	x	x	x	x	x	x	x	x
Yellowline Goby	*Gobiosoma horsti*		x		x	x			x	x	x	x	x	x
Yellowtail Parrotfish	*Sparisoma rubripinne*				x		x			x	x	x		x
Yellowtail Damselfish	*Microspathodon chrysurus*				x						x	x		x
Yellowtail Hamlet	*Hypoplectrus chlorurus*								x		x			
Yellowtail Snapper	*Ocyurus chrysurus*						x			x				

Appendix 19. Species list of coral reef fish identified at the different sites surveyed in Limonade within 3BNP.

Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
Balloonfish	*Diodon holocanthus*	X				x	
Banded Butterflyfish	*Chaetodon striatus*	X					
Banded Jawfish	*Opistognathus macrognathus*			x			
Bar Jack	*Caranx ruber*			x	x		X
Barred Hamlet (Caribbean)	*Hypoplectrus puella*		x	x	x	x	X
Beaugregory	*Stegastes leucostictus*	X		x			X
Belted Cardinalfish	*Apogon townsendi*				x		
Bicolor Damselfish	*Stegastes partitus*	X		x	x	x	X
Black Hamlet	*Hypoplectrus nigricans*	X		x	x	x	
Blackbar Soldierfish	*Myripristis jacobus*			x	x	x	X
Blackear Wrasse	*Halichoeres poeyi*	X		x	x		X
Blue Chromis	*Chromis cyanea*				x	x	
Blue Runner	*Caranx crysos*						X
Blue Tang	*Acanthurus coeruleus*	X	x	x	x	x	X
Bluehead	*Thalassoma bifasciatum*	X	x	x	x	x	X
Bridled Goby Complex	*C. glaucofraenum/C. bol/C. tortugae*		x		x	x	X
Broadstripe Goby	*Gobiosoma prochilos*				x	x	X
Brown Chromis	*Chromis multilineata*	x					
Bucktooth Parrotfish	*Sparisoma radians*	x		x			X
Butter Hamlet	*Hypoplectrus unicolor*	x					
Cardinal Soldierfish	*Plectrypops retrospinis*						X
Cero	*Scomberomorus regalis*				x		X
Chalk Bass	*Serranus tortugarum*						X
Clown Wrasse	*Halichoeres maculipinna*	x		x	x		
Cocoa Damselfish	*Stegastes variabilis*					x	
Colon Goby	*Coryphopterus dicrus*						X
Coney	*Cephalopholis fulva*	x		x	x	x	
Creole Wrasse	*Clepticus parrae*			x	x	x	
Doctorfish	*Acanthurus chirurgus*			x	x		X
Dusky Cardinalfish	*Phaeoptyx pigmentaria*				x		
Dusky Damselfish	*Stegastes adustus*	x	x				
Eyed Flounder	*Bothus ocellatus*						X
Fairy Basslet	*Gramma loreto*				x		
Flagfin Blenny	*Emblemariopsis signifer*				x		
Flamefish	*Apogon maculates*	x					
Foureye Butterflyfish	*Chaetodon capistratus*		x		x		
French Grunt	*Haemulon flavolineatum*		x	x	x		
Glasseye Snapper	*Heteropriacanthus cruentatus*			x			
Glassy Sweeper	*Pempheris schomburgkii*			x			

Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
Goldentail Moray	*Gymnothorax miliaris*			x	x		X
Goldline Blenny	*Malacoctenus aurolineatus*	x					
Goldspot Goby	*Gnatholepis thompsoni*	x	x	x	x	x	x
Graysby	*Cephalopholis cruentata*				x	x	
Greater Soapfish	*Rypticus saponaceus*				x		
Green Razorfish	*Xyrichtys splendens*			x			
Greenblotch Parrotfish	*Sparisoma atomarium*	x		x	x	x	x
Hairy Blenny Complex	*Labrisomus nuchipinnis/L. conditus/L.cricota*		x				
Harlequin Bass	*Serranus tigrinus*			x	x	x	x
Highhat	*Pareques acuminatus*					x	
Honeycomb Cowfish	*Lactophrys polygonius*					x	
Hovering Dartfish (Hovering Goby)	*Ptereleotris helenae*						x
Indigo Hamlet	*Hypoplectrus indigo*	x	x	x	x	x	x
Lane Snapper	*Lutjanus synagris*						x
Lantern Bass	*Serranus baldwini*			x		x	
Longfin Damselfish	*Stegastes diencaeus*	x	x	x	x		x
Longjaw Squirrelfish	*Neoniphon marianus*				x	x	x
Longspine Squirrelfish	*Holocentrus rufus*				x	x	x
Masked Goby/Glass Goby	*Coryphopterus personatus/hyalinus*				x		x
Mottled Jawfish	*Opistognathus maxillosus*						x
Ocean Surgeonfish	*Acanthurus bahianus*	x		x	x	x	x
Orangespotted Filefish	*Cantherhines pullus*			x			x
Orangespotted Goby	*Nes longus*						x
Peacock Flounder	*Bothus lunatus*					x	
Porkfish	*Anisotremus virginicus*				x		
Princess Parrotfish	*Scarus taeniopterus*			x	x		
Puddingwife	*Halichoeres radiates*	x		x	x		
Puffcheek Blenny	*Gobioclinus bucciferus*	x					
Queen Parrotfish	*Scarus vetula*	x			x	x	
Rainbow Wrasse	*Halichoeres pictus*						x
Red Lizardfish	*Synodus synodus*			x			
Redband Parrotfish	*Sparisoma aurofrenatum*	x	x	x	x	x	x
Redlip Blenny	*Ophioblennius atlanticus*	x					
Redspotted Hawkfish	*Amblycirrhitus pinos*	x		x	x	x	
Redtail Parrotfish	*Sparisoma chrysopterum*						x
Reef Croaker	*Odontoscion dentex*		x	x			
Reef Squirrelfish	*Holocentrus coruscus*						x
Rock Beauty	*Holacanthus tricolor*	x		x	x	x	
Roughhead Blenny	*Acanthemblemaria aspera*					x	
Rusty Goby	*Priolepis hipoliti*	x					
Saddled Blenny	*Malacoctenus triangulatus*	x		x			
Sand Diver	*Synodus intermedius*			x	x	x	

Common Name	Scientific Name	L16	L17	L18	L28	L31	L33
Sand Tilefish	*Malacanthus plumieri*					x	
Schoolmaster	*Lutjanus apodus*			x	x	x	
Sergeant Major	*Abudefduf saxatilis*	x		x	x		
Sharknose Goby	*Gobiosoma evelynae*				x	x	x
Sharpnose Puffer	*Canthigaster rostrata*	x		x	x	x	x
Sharptail Eel	*Myrichthys breviceps*	x				x	
Shy Hamlet	*Hypoplectrus guttavarius*					x	
Silversides, Herrings, Anchovies							x
Slender Filefish	*Monacanthus tuckeri*					x	x
Slippery Dick	*Halichoeres bivittatus*	x	x	x		x	x
Smallmouth Grunt	*Haemulon chrysargyreum*	x			x		
Smooth Trunkfish	*Lactophrys triqueter*			x	x	x	
Spanish Hogfish	*Bodianus rufus*		x		x		
Spotted Drum	*Equetus punctatus*	x			x		
Spotted Goatfish	*Pseudupeneus maculatus*			x	x	x	x
Spotted Moray	*Gymnothorax moringa*	x		x			
Squirrelfish	*Holocentrus adscensionis*			x	x		x
Stoplight Parrotfish	*Sparisoma viride*	x	x	x	x	x	x
Striped Parrotfish	*Scarus iseri*	x	x	x	x	x	x
Threespot Damselfish	*Stegastes planifrons*			x	x	x	x
Tobaccofish	*Serranus tabacarius*					x	x
Trumpetfish	*Aulostomus maculatus*			x	x		x
White Grunt	*Haemulon plumier*	x			x	x	x
Yellow Goatfish	*Mulloidichthys martinicus*			x	x		x
Yellow Stingray	*Urobatis jamaicensis*						x
Yellowcheek Wrasse	*Halichoeres cyanocephalus*	x					
Yellowhead Wrasse	*Halichoeres garnoti*	x	x	x	x	x	x
Yellowline Goby	*Gobiosoma horsti*				x	x	x
Yellowtail Parrotfish	*Sparisoma rubripinne*	x			x	x	
Yellowtail Damselfish	*Microspathodon chrysurus*	x		x	x		
Yellowtail Snapper	*Ocyurus chrysurus*			x			