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Climate Change Resilience and Socioeconomic Impacts of MPAs and MPA Networks in the Caribbean - Case Study: Evaluation of the Effectiveness of the Management of MPAs and Coastal Zones in the Dominican Republic

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CLIMATE CHANGE RESILIENCE AND SOCIOECONOMIC IMPACTS OF MPAS AND MPA NETWORKS IN THE CARIBBEAN

CASE STUDY: EVALUATION OF THE EFFECTIVENESS OF THE MANAGEMENT OF MPAS AND COASTAL ZONES IN THE DOMINICAN REPUBLIC

By

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Abstract

Many Caribbean nations have established MPAs to preserve marine biodiversity and maintain their economically important marine resources. In some Caribbean nations, in particular the Dominican Republic, most MPAs have failed in these respects and have remained “paper parks” due to being modeled along traditional conservation lines without careful consideration of socioeconomic factors, good management practices or increasingly important climate change factors. Successful Caribbean MPAs and MPA networks effectively function as refuges, attractions, sources of socioeconomic development and ecosystem-based climate change resilience mechanisms. The latter is of utmost importance to Small Island Developing States (SIDS) and other larger island developing states in the region because of their vulnerability to climate change. This multidimensional vision of MPAs has not been developed or applied in the Dominican Republic, and the reasons behind this issue are presented in this paper. Existing Dominican MPAs are analyzed as two individual case studies; National Park del Este and Montecristi National Park. Proposals for their improved management are outlined and a comparison is made with two successful Caribbean MPAs: La Soufrière Marine Management Area and the Bonaire Marine Park. The role of Dominican and international NGOs, coastal community involvement and MPA stakeholders such as dive operators and donors is investigated in defining these broad-based MPA objectives. Finally, alternative approaches for reaching the goals of preserving marine biodiversity, integrating socioeconomic impacts and building climate change resilience are proposed. The improvement of national MPAs and integration with regional MPA networks are the best long-term win-win marine conservation solutions for the Dominican Republic and the Caribbean.

ACRONYMS AND ABBREVIATIONS

AGRRA	Atlantic and Gulf Rapid Reef Assessment (Caribbean-wide study of coral reef health)
BNMP	Bonaire National Marine Park
CaMPAM	Caribbean Marine Protected Areas Management
CANARI	Caribbean Natural Resources Institute
CARIPOL	Marine Pollution Monitoring Program in the Caribbean
CCI	Caribbean Challenge Initiative
CEBSE	Center for the Conservation and Eco- development of Samaná Bay and its Surroundings
CEP (UNEP-CEP)	Caribbean Environment Program
CIBIMA	Centro de Investigaciones en Biología Marina
CICAR	Cooperative Institute for Climate Applications and Research
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLME	Caribbean Large Marine Ecosystem
CNCCMDL	Dominican National Council on Climate Change and Mechanisms for Clean Development
CZMT	Coastal Zone Management
DCNA	Dutch Caribbean Nature Alliance
DNP	National Park Board
EEZ	Exclusive Economic Zone
ENCORE	European Network for Conservation-Restoration Education
ENSO	El Niño-Southern Oscillation
FUNDEMAR	Dominican Foundation for Marine Studies
GCFI	Gulf and Caribbean Fisheries Institute
GEF	Global Environment Facility
GLOSS	Regional Sea Level Observing System and Network
GO	Government Organization
ICRAN	International Coral Reef Action Network
IOCARIBE	IOC Sub-Commission for the Caribbean and Adjacent Regions
IPCC	Intergovernmental Panel on Climate Change
IUCN	World Conservation Union (formerly International Union for the Conservation of Nature and Natural Resources)
LBS	Land-based Sources
MARPOL	International Convention for the Prevention of Pollution from Ships
MINA	Central Government Department of Nature and the Environment
MPA	Marine Protected Area
MR	Marine Reserves
NOAA	National Oceanic and Atmospheric Association
PIP	Parks in Peril

PNE	National Park of the East (Parque Nacional del Este)
POP	Persistent Organic Pollutant
PRONATURA	Pro Nature Fund
RAMSAR	Convention on Wetlands of International Importance especially as Waterfowl Habitat
REA	Rapid Ecological Assessment
SEMARENA	Dominican Ministry of the Environment and Natural Resources
SIDS	Small Island Developing States
SINAP	Dominican National System of Protected Areas
SMMA	Soufrière Marine Management Area
SPAW	Specially Protected Areas and Wildlife – Annex of the Cartagena Convention
STINAPA	Stichting Nationale Parken Nederlandse Antillean
TCB	Tourism Corporation Bonaire
TNC	The Nature Conservancy
USAID	United States Agency for International Development
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
WCPA	World Commission on Protected Areas
WCR	Wider Caribbean Region
WRI	World Resources Institute
WWF	World Wide Fund for Nature

Section 1: Introduction: The Issue of Concern

About 285 MPAs were identified in 35 countries and territories of the Lesser Antillean and Central Caribbean biographic zones, plus Belize and the Turks and Caicos (CANARI, 2001). The Caribbean Basin is comprised of nine sub-regions and each has its own environmental legislation which governs their MPA management within their geographical area or within a network. Within the classification of MPAs important physical parameters include salinity, currents, tides, tides at sea bottom, water temperature and wave action. The marine ecosystems (which include MPAs) in the Caribbean are; estuaries, sea grass beds, wetlands, mangrove forests, and coral reefs (near shore and off-shore). MPAs and their networks in the Caribbean are extremely varied; when examining coral reefs alone one can observe barrier reef systems (like the Belize MPA network), fringing reefs and patch reefs. Reef ecosystems of various types can be found in about 80% of the region's MPAs and they are described as extensive and diverse. They are also often economically important recreational dive sites. (CANARI, 2001).

Historically, there has not been a consistent and coordinated approach to Coastal Zone Management and the Management of MPAs in the Caribbean. Caribbean Islands operate under different Dutch, English, American, French and Spanish political systems that have been expanded upon since colonial rule and hence have differing legislation. Agenda 21, a global environmental plan of action on sustainable development put forth by the United Nations, was adopted following the Rio Declaration on Environment and Development by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 (UNEP, 2003). Following Agenda 21, a number of states in the wider Caribbean Region made commitments to manage and implement coastal zone management programs and MPAs in their regions. However, since this plan of action is non-binding and voluntary there is no uniformity in its implementation nor in ensuing environmental legislation across MPAs in the Caribbean. As a result, more than half of the region's MPAs have a low level of management and approximately 25% have no management at all (CANARI, 2001). In the Dominican Republic effective multidimensional MPA management is non-existent on a national level and existing governmental environmental legislation is not practiced nor enforced, with the exception of a few isolated MPAs that do include funding and supervision by international and national NGOs (Geraldes, 2001). This paper will explore the background behind these shortcomings and illustrate why effective management of MPAs and MPA networks with an emphasis on an integrated multidimensional style (including conservation, socioeconomic and ecosystem based climate resilience factors) is of critical importance in the Dominican Republic and the associated wider Caribbean. It will also include a section describing suggested mechanisms that could help improve the management of MPAs and MPA networks.

Section 2. Literature Review

2. 1 Overview and State of MPAs and CZMT in the Caribbean

Marine Protected Areas, (MPAs) are defined by the IUCN as "any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part of or all of the enclosed environment"(IUCN, 2008). A marine protected area is an area of the ocean where some or all activities are limited or prohibited in order to protect natural, socioeconomic and cultural resources (Guarderas, 2008). The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, the Cartagena Convention (also known as the Caribbean Action Plan), was adopted and signed in 1983 in Cartagena, Columbia and ratified in 1986 (Montero, 2002) . Within the Convention, the Convention Area is meant to be the "Greater Caribbean" and refers to the marine environment of the Gulf of Mexico, the Atlantic Ocean and the adjacent Caribbean Sea south of 30° north latitude and within 200 nautical miles of the Atlantic coasts of the United States (Montero, 2002) and this is the area I will be referring to throughout this paper (Figure 1 & Table 1).

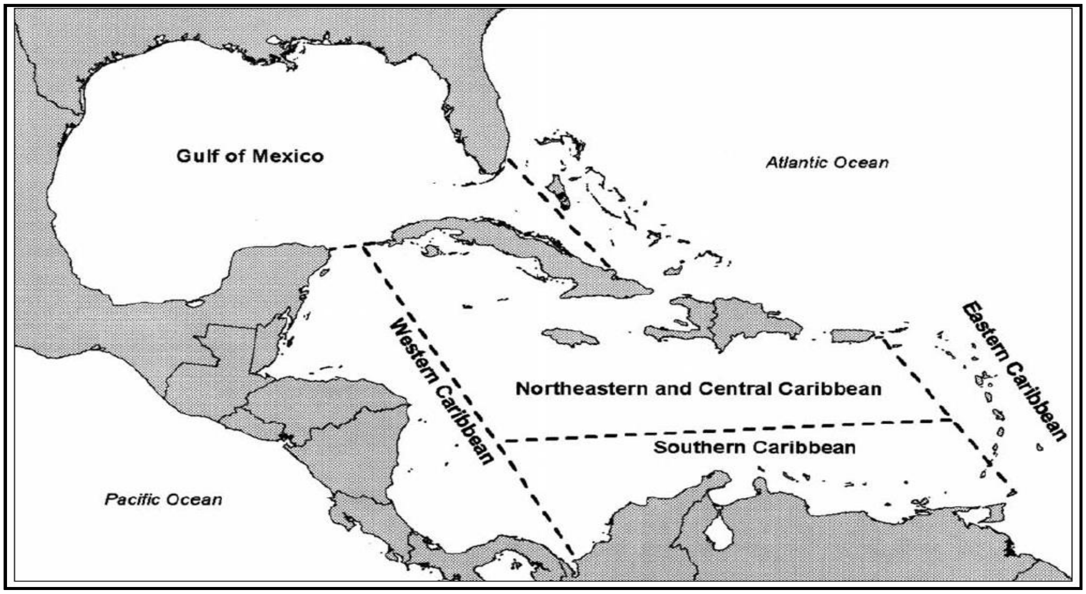

Figure 1: The "Greater Caribbean" (Chiappone, 2001 (Part 2)

Table 1: Countries by zone in the "Greater Caribbean" (Chiappone, 2000)

Zone	Countries
Gulf of México	Cuba, México, United States
Western Caribbean	Belize, Costa Rica, Guatemala, Honduras, México, Nicaragua, Panamá
Northeastern and Central Caribbean	Bahamas, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Turks and Caicos Islands
Eastern Caribbean	Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands. Dominica, Grenada, Guadeloupe, Martinique, Montserrat, St. Lucia, St. Maarten, St. Kitts and Nevis, St. Vincent and the Grenadines, U.S. Virgin Islands
Southern Caribbean	Aruba, Bonaire, Colombia, Curação, Tobago, Trinidad, Venezuela

The Cartagena Convention serves as the only comprehensive treaty for the whole region and three protocols have been implemented since 1986 to address issues in marine environmental management that directly affect MPA management: the Concerning Cooperation in Combating Oil Spills (OILSPILL), SPAW (uses an ecosystem conservation approach) and the Protocol Concerning Land-based Sources (LBS) of Marine Pollution Wildlife (Anderson et al., 2002). The Regional Program for Specially Protected Areas and Wildlife was designed to implement the provisions and requirements of the SPAW Protocol (the largest treaty of its kind) which was adopted in 1990 by members of Caribbean Environmental Program (CEP) (Anderson et al., 2002). The CEP in Kingston is administered and supervised by the United Nations Environmental Program Caribbean Coordinating Unit (UNEP-CAR/RCU) and SPAW also acts as a tool for the wider implementation of the Convention on Biological Diversity (CBD 1993 created at the Earth Summit in Rio de Janeiro) and the Convention on the Prevention of Marine Pollution from Ships (MARPOL 1978) for the region (Anderson et al., 2002). The Stockholm Convention has also been adopted by the Greater Caribbean and allows for the reduction and mitigation of contamination from the "dirty dozen" Persistent Organic Pollutants (POPs) that can be grouped in three categories (Pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, Industrial Chemicals: hexachlorobenzene, polychlorinated biphenyls (PCBs); and By-products: hexachlorobenzene; polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) and PCBs) (Van Lavieren et al., 2011). The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of UNCED to monitor and report on implementation of the agreements at the local, national, regional and international levels (Anderson et al., 2002).

Most Caribbean MPA data can be found in the publicly available World Database on Protected Areas as well as the Nature Conservancy, NOAA, the U.S. Geological Survey and the US Department of the Interior (Selig et al., 2012). The Greater Caribbean or the tropical western Atlantic is considered one of the most endangered tropical bio-geographic provinces (Chiappone, 2000). At the present time it has been estimated that more than 700 MPAs have been established (or are in the process of being established) which cover about 1.5% of shelf and coastal waters and cover more than 300,000 square kms in the Caribbean (Guarderas, 2008). Many Caribbean nations have established protected areas to preserve marine biodiversity while trying to help maintain their marine resources which are economically important to them. As a result of Caribbean MPAs being so different and complex, it is difficult to compile data to evaluate them effectively. Figure 2 is a general map of MPAs in the Caribbean. The largest MPAs on the map are in the Greater Antilles; in particular the Dominican Republic and Cuba.

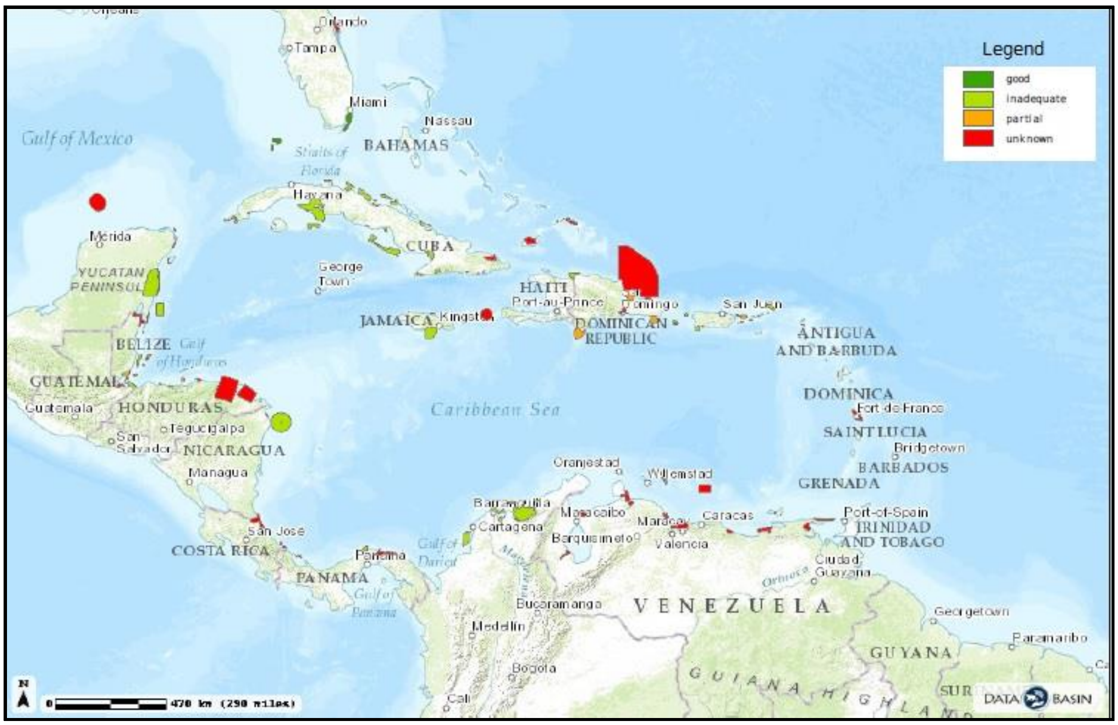

Figure 2: MPAs in the Caribbean (not including the Western Caribbean)
Legend (State of MPAs): green-good, light green-adequate, orange-partial, red-unknown
Courtesy of Databasin Map Sevices -www.databasin.org

The main marine ecosystems (which include MPAs) in the Caribbean are; estuaries, sea grass beds, wetlands, mangrove forests, dunes and beaches and coral reefs (near shore and off-shore). The largest MPAs are SeaFlower Biosphere Reserve in

Colombia (60,000 km^2) and the Banco de la Plata Whale Sanctuary in the Dominican Republic (25,000 km^2) (Guarderas, 2008). Countries that do not have MPAs in the Caribbean Basin are Anguillla, Haiti (many proposed, like Les Trois Baies, but not yet officially established), Montserrat and Puerto Rico (CANARI, 1998). Despite the impulse of marine conservation and its prioritization in Latin America and the Caribbean, a comprehensive detailed survey of the MPAs and MRs in the region does not exist (studies are either outdated, too habitat-specific or pertain to only certain regions in the Caribbean) (Guarderas, 2008). Progress has been made in developing nations in the establishment of MPAs but the creation and implementation of MPA management is lacking. Despite promoting ecologically sustainable development and involving local communities and stakeholders in MPAs, very few tropical developing countries have incorporated MPA management plans and those that have been incorporated are deemed to be of limited success by area managers (Alder et al., 2010).

Regional MPAs cover a majority of Greater Caribbean reefs. The Caribbean has a total reef area of about 20,000 km^2 (9% of the world's mapped reefs) and about two-thirds are 'at risk,' and one-third are classified as highly threatened (USAid, 2014). As a result, the status of the region's reefs is a good indicator of the status of regional MPAs. There has been a rapid decrease in coral cover (important indicator of coral reef "health" as many reef taxa are dependent on its structure) of 80% in the last 4 decades in the Caribbean (Aronson & Precht, 2006). This began in the late 1970s with a widespread die off of complex corals due to disease and was exacerbated in the following years primarily due to overfishing, sedimentation and uncontrolled pollution (UN Framework Convention on Climate Change, 2006). The mass mortality of the herbivore echinoid *Diadema antillarum* (1983-1984), increases in coastal development and mass bleaching events (a total of 6 in 1998 and 1999 tied in with a strong ENSO) also played pivotal roles in the drastic reduction of coral cover (Alvarez et al., 2011, Selig at al., 2012, Aronson & Precht 2006). Bleaching is predicted to become an annual event in the

Caribbean by 2100 if greenhouse gas emissions are not curtailed (Wilkinson & Souter, 2005).

Coral reef disturbances can be divided into two categories; biological (bleaching and disease) and physical disturbances like tropical storms and hurricanes that have local impacts (Alvarez et al., 2011). Over-exploitation and unsustainable coastal development are the two main threats to MPAs and their coral reefs (Chiappone, 2001 (Part 3)). Over 500 million people live within 100 km of coral reefs and 60% of worldwide reefs are threatened by anthropogenic activities (Chiappone, 2001 (Part 3)). The human demographic expansion and associated increases in nutrient loading, fishing, ocean warming as well as environmental variables have been used to explain the degradation of MPAs (especially the coral reefs) in the Caribbean (Mora, 2008). Coastal development which results in intensive tourism, pollution, poor land use planning, ineffective environmental management, overfishing and increasing cultural, social and economic demands from population growth threatens about 80% of Caribbean reefs (Burke et al., Maidens, 2004). The coastal zone of the Greater Caribbean has about 80 million residents and receives about 20 million visitors yearly (Mora, 2008). The Dominican Republic receives more than 3.5 million tourists per year (Geraldes et al., 2003). The government now has a goal to attain 10 million. Development and tourism impacts MPAs in three main adverse ways; excessive use of renewable and non- renewable resources, emission of pollutants (solid waste, waste water, garbage, etc.) and physical impacts on MPAs (construction close by, coastal erosion, filling of wetlands, dredging and sand mining) (USAid, 2014). The majority of reefs at risk in the Caribbean are part of MPAs and are impacted in the same ways (Figure 3).

The architectural complexity of Caribbean MPAs and their associated reefs has declined rapidly due to a mix of natural and anthropogenic causes; mostly hurricanes, land clearing for agriculture and development, coastal construction, bleaching (losing their zooxanthellae), pollution and contamination (domestic and industrial) and

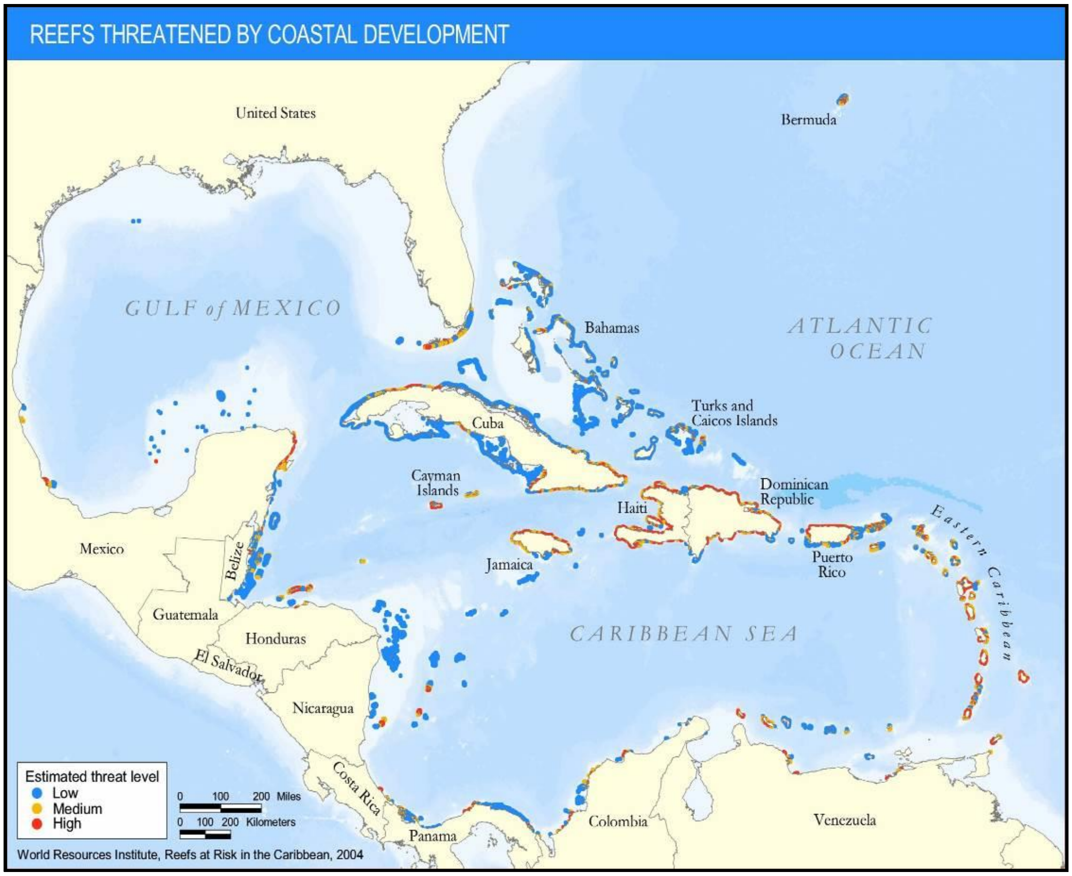

Figure 3: Reefs at Risk in the Caribbean (WRI, 2010)

overfishing (Alvarez et al., 2011, Selig et al., 2012). Caribbean MPAs tend to predominate in areas of poverty and high population growth rates making them especially susceptible to human activities. It has been agreed upon in literature covered for this capstone that most MPAs in the Caribbean have suffered from: 1) modifications in the quality and quantity of run-offs into the sea from drainage basins causing nitrification, pollution and contamination, 2) damage from dredging, anchoring and other recreational and fishing activities and 3) overfishing of target species like snapper, grouper, spiny lobster, conch which affects spawning stock (Chiappone, 2000).

The Caribbean Natural Resources Institute (CANARI) conducted a survey of the MPAs in the Caribbean and found that most marine resources were under stress (Bacci, 1998). Stressors ranged from natural events such as hurricanes and coral diseases to human activities such as unplanned development, over-fishing and recreational boating (Bacci, 1998). The World Resources Institute (WRI) uses four criteria to try and assess MPA effectiveness: existence of management activity, existence of a management plan, availability of resources, and extent of enforcement (CANARI, 2001). It was found that of the 285 active MPAs researched in the Caribbean, only 6% were effectively managed and 13% were partially effectively managed. As mentioned, nearly half were of MPAs were inadequately managed and the other third had too little data to be able to be evaluated (Figure 4).

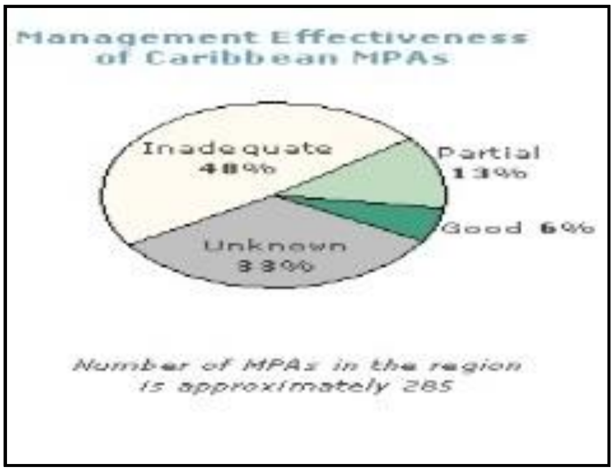

Figure 4: Evaluation of active MPA Management (WRI, 2010; CANARI, 2001)

The marine ecosystems of the Caribbean and Latin America are going through a significant and rapid detrimental transformation (Guarderas, 2008). In general terms, MPAS can be categorized into 3 broad categories; 1) limited-take MPAs, 2) no-take MPAs and 3) mixed MPAs (a combination of 1) and 2)). Limited-take MPAs are by far the most common in the region (76%) compared to no-take (17%) and mixed-use (7%) (Guarderas, 2008). Many Caribbean nations have not been successful with MPA management because it requires financial resources, political will and multidimensional collaborations with governments, institutions and organizations. Three common reasons across the Caribbean for MPA failures are lack of support from the local community (which can be traced back to a lack of participatory procedures and local involvement in planning), lack of political will and lack of long-term financial support (CANARI, 2001). MPAs that have high to moderate levels of management are in territories of the UK, Netherlands, France and the US and can depend on more consistent financial support. (CANARI, 2001). Sustainable financing for MPAs in independent Caribbean nations must be developed if they are to function well in the long term (some parks directly generate income) and financial resources come from three sources; user and visitor fees, donor assistance and allocations from governments (CANARI, 1998). The Bonaire National Marine Park (BNMP) actually charges a fee of 10 $US as a diver fee and this helps raise about 60% of the BNMP budget. Saba Marine Park raises 70% of its income through 10 $US diving fees as well.

MPAs and coastal systems of high biodiversity and marine productivity are the main building blocks of Caribbean economies that allow for fishing and sea and sun-type tourism. The vast majority of tourists come to the Caribbean because of the "quality of the sandy beaches (25%)" and the "tropical weather (37%)" (Beekhuis, 1981). In the last decades, beaches in the Dominican Republic and other Caribbean destinations have experienced accelerated beach erosion and this long-term loss of beaches is different to the natural cycles of sand deposition and erosion. Beach quality is a determining factor in the selection of the Dominican Republic as a vacation destination (Mercado & Lassoie, 2002). In order to maintain the quality of beaches that tourists travel for, beach enhancement projects have been executed all over the region. In particular, on the North Coast of the Dominican Republic (Puerto Plata, Cabarete and Rio San Juan), artificial structures have been strategically placed in shallow waters to mitigate wave impact and sand has been deposited from other intact underwater banks onto severely eroded and damaged beaches (UNEP/GPA, 2003). The solution for the erosion of beaches which has caused changes to sand quality (a concern of tourists) and impacts on wildlife (e.g. sea turtles) in the Dominican Republic depends on the policies implemented by the local government and regional cooperation in order to protect the coastal ecosystems and

MPAs. However, beach enhancements have been an example of poor CZMT in the Dominican Republic because over US$20 million was invested in beach enhancements over the last decade by the Dominican government without studying the total coastal currents and sand movement dynamics and little research was carried out on the root causes of beach erosion (Heredia, 2009).

Increasingly dense Caribbean coastal settlements (large cities like Santo Domingo with a population of almost 5 million) grow exponentially without adequate infrastructure or environmental legislation (due to fragmented urbanization trends) leading to decentralized systems and threats to the viability of coastal systems including MPAs (USAid, 2006). A common idea is that proximity of people leads to the faster degradation of MPAs. This is not the case in the remotest areas of the Caribbean where corals have been shown to die of WBD (white band disease) close or far away from anthropogenic influences (Aronson & Precht 2006). This is due, in part, to the fact that Caribbean MPAs are affected by the passage of cruise ships. On average, cruise ships generate 2,228 gallons of oily bilge and 278.5 gallons of garbage daily and their anchors can collectively ruin up to 200 km^2 of ocean floor (Burke et al., 2004). In the last 20 years, cruise ship tourism has quadrupled with 58% of cruise ship business occupying the Caribbean (Burke and Maidens, 2004).

The ecological balance of coral reefs in the Caribbean has been altered by overfishing resulting in decreased coral cover (decreased sand production for beaches from coral reefs) and increased algal growth due to the removal of herbivores (Burke et al., 2004; Aronson & Precht 2006). In much of the documentation it has been suggested that declines in coral reefs and resulting MPA degradation (higher algal cover, lower coral cover and greater incidences of disease) can be attributed to region-wide pollution (Hallock et al., 1993). It has been observed that many reef ecosystems (within MPAs also) have shifted from coral to algal dominance (Herrera-Moreno et al., 2011). Contrary to much of the literature reviewed, microalgal overgrowth cannot be solely held accountable for coral mortality, but warming, alterations in ocean chemistry (ocean acidification), increase in hurricane intensity (all stemming from greenhouse gas emissions) and infectious marine diseases are causing it. Microalgae can also act as reservoirs for infectious marine diseases leading to a positive feedback loop where coral mortality is present (Aronson & Precht 2006). Fish largely depend on the coral reef matrix and hence they can be threatened long-term due to the uncontrolled threats affecting coral reefs inside MPAs (Mora, 2008).

Studies show that there are a wide variety of chemical pollutants and contaminants affecting MPAs in low concentrations throughout the Wider Caribbean Region (WCR) and, in particular, Persistent Organic Pollutants (POPs). There is little capacity to monitor the effects of POPs in Caribbean wildlife and fish, the abiotic environment and in humans in spite of the Stockholm Convention (Van Lavieren et al. 2011). Sources of POPs that adversely affect Caribbean MPAs have been identified as coming from hydrocarbon extraction, wastes from the industrial sector, pesticide usage and local sewage inputs (USAid, 2014). POPs "biomagnify" within the food chains and cause adverse health effects in humans and severe impacts in the marine and coastal environments; changes in reef communities and structures (due to increases in algae or sponges and decreases in live coral cover), extensive damage to sea grass beds (which are critical for juvenile fish), mortality in fish mass and even the thinning of bird egg shells over time (Van Lavieren et al., 2011). Sedimentation has increased on Caribbean reefs by 20% since the 1960s and this indicates uncontrolled changes in infrastructure development and land use which has greatly damaged MPAs (Torres et al., 2001). The effect of sedimentation is an increase in turbidity causing a reduction in light which leads to a change in growth rates, growth forms, species diversity, coverage, mortality and dominance patterns of corals in MPAs (Torres et al., 2001). Additionally, the influx of POPs into the Greater Caribbean comes from regional inputs; large continental rivers such as the Orinoco in the southeast as mentioned and also the three major rivers that enter the Gulf of Honduras in the southwest (Van Lavieren et al., 2011). Sedimentation and pollution events can be recorded in coral reef systems in MPAs. The flooding of the Orinoco River during the

1980s is recorded in many skeletons of corals that are downstream in areas as far away as Tobago (Risk et al., 1992).

The contamination by hydrocarbons (grease and petroleum) from shipping routes, industrial and domestic sources is a threat to tropical coastal ecosystems. This threat is real in the WCR because the tropical western Atlantic is one of the largest oil producers with 97 refineries (50% in USA) and areas of production located in Venezuela, Mexico, Colombia, the US Gulf Coast and Trinidad and Tobago (Chiappone, 2001 (part2)). We can see the main shipping routes in red and a list of the main oil spills in black (dots on the map) of the last decade until 1997 (Figure 5). This map does not include the major Deepwater Horizon oil spill of 2010, where there is no reliable data on how Caribbean MPAs have been affected (short term and long term).

No.	Year	Source and spill zone	Millions of litres (type of oil)
1	1971	Sain Augusta, St. Croix, U.S. Virgin Islands	13 (crude)
2	1973	Zoe Colocotronis, Cabo Rojo, Puerto Rico	5 (crude)
3	1975	Garbis, Florida Keys, United States	24-25 (crude)
4	1976	Ruptures pipeline in Corpus Christi, Puerto Rico	1 (crude)
5	1977	Unidentified ship, Guaanilla Bay, Puerto Rico	2 (crude)
6	1978	Howard Star, Tampa, Florida, United States	15-20% crude, 80% bunker
7	1979	Burhah Agate, Texas United States	5–41
8	1979	Atlantic Empress, off the coast of Trinidad and Tobago	158
9	1979-1980	Itox I, marine platform explosion, Campeche Mexico	528-1626 (crude)
10	1984	Alvenus, Louisiana, United States	25
11	1985	Ranger, marine platform explosion, Texas United States	24-52
12	1986	Las Minas Refinery, Panama	8 (crude)
13	1991	Vista Bella Barge, of Saint Kitts and Nevis	2(bunker C)
14	1994	Berman, San Juan, Puerto Rico	375 (gasoil No. 6)
15	1997	Nisos Amorgos, tanker, Gulf of Venezuela	3.2

Figure 5: Major oil routes and oil spills in the Wider Caribbean region (The International Tanker Owners Pollution Federation Limited ITOPF, http://www.itopf.com/index.html)

There have been a variety of stressors/ impacts (applied stimuli) affecting the degradation of Caribbean MPAs and these result from natural and anthropogenic causes (Rapport et al., 1985). The Caribbean MPA stressors/ impacts are divided into water quality impacts, coastal nutrification, mechanical impacts, vessel groundings and harvesting/ fishing impacts (Table 2).

Table 2: Examples of sources, stressors and biological responses (symptoms) (Chiappone, 2001 (part2))

Sources	Stressors	Examples Biological Responses/ Symptoms
Water Quality Impacts Alteration in hydrology (water diversion, construction)	decreased tidal flow increased salinity	decreased productivity of mangroves, declines in secondary production (water diversion, construction) · mortality of sea grasses if hypersaline conditions persist · loss of habitat to higher trophic levels · numerous secondary effects possible
Coastal nutrification	increased levels of water column nutrients	increased epiphyte loads on sea grasses, (excess nutrient input) water column nutrients · decreased productivity of sea grasses, weakening of root-rhizome system · shift from benthic to water column productivity in some cases · change in food web structure · hypoxia resulting from decomposition of organic matter
Mechanical Impacts Diving and snorkeling	touching or in some way affecting the bottom disturbance to fish and other epifauna	fragmentation, decreased reproductive success, decreased growth, mortality affecting the bottom · alteration in behavior of fishes, may affect grazing and predation
Vessel groundings	mechanical impact to the bottom increased sedimentation	partial and complete mortality, decreased growth, reduced recruitment bottom · decreased species diversity, abundance, and biomass of epifauna · increased sedimentation
Harvesting/Fishing Impacts	removal of organisms from their environment injury to organisms from fishing methods	increase in mortality and bioerosion their environment decrease in diversity, abundance, size, reproductive output injury to organisms from · change in species composition and growth fishing methods

The most impacted coastal waters in the WCR are Havana Bay (Cuba), Cartagena Bay (Colombia), Kingston Harbour (Jamaica) and Santo Domingo (Dominican Republic) but degradation of MPAs and coastal areas occur whenever there are large coastal populations with inadequate buffer zones or infrastructure in coastal environments (Marszalek, 1987). It was predicted that the coastal population of the WCR would be over 55 million people by the early 21st century and this would be exacerbated by projected increases in tourism (UNEP, 1994). This prediction was greatly surpassed as USAID recently documented that most of the WCR's 200 million people live on or near the coast (USAID, 2013). The types of contaminants and pollutants posing the most significant threats in these areas and the WCR are sewage (primary source of pollution in Santo Domingo and other tropical coastal ecosystems), oil, pesticides, toxic waste, sediments and plastics (Marszalek, 1987). Only about 10% of the sewage generated in WCR is properly treated (secondary treatment) and only about 25% of hotels and resort complexes in the area have sufficient treatment plant operating conditions (UNEP, 1994). Open access fishing is also a serious problem in the WCR, where entry into a fishery is open to all at no extra cost other than having your fishing gear and even this is often subsidized by local governments (purchase of fishing equipment, outboard engines and boats) (Aiken and Haughton, 1985). The WCR is the most threatened large marine ecosystem in the world due to its complexity; from unregulated coastal development and overfishing to the highest coastal population density and number of different political units in the Western Hemisphere (Richards & Bohnsack., 1990).

2.1.1 Overview and State of MPAs and CZMT in the Dominican Republic

The Dominican Republic has 1,570 km of coastline (824 km of Atlantic Coast and 752 km of Caribbean Coast) of which 1,473 km corresponds to the big island and 97 km to cays and small islands (Herrera-Moreno & Betancourt, 2001). There are 19.3 km (12 mi) of contiguous zone, 321.9 km (200 mi) of EEZ and 38.6 km (24 mi) of territorial seas that are established by law 186 from 1967 (Heredia, 2009). The total marine area under the jurisdiction of the Dominican Republic is about 138,000 km^2 including the Exclusive Economic Zone (Herrera-Moreno & Betancourt, 2001). The general locations of the 6 main MPAs in the Dominican Republic can be seen below (Figure 6).

Many of the Dominican Republic's coral reefs, sea grass beds and mangrove forests are in established MPAs or other protected areas which cover about 22% of the coastline (Geraldes et al., 2003). In the Dominican Republic, MPAs are covered by Law 202-04 in the Dominican Constitution. There are 86 protected areas (including terrestrial

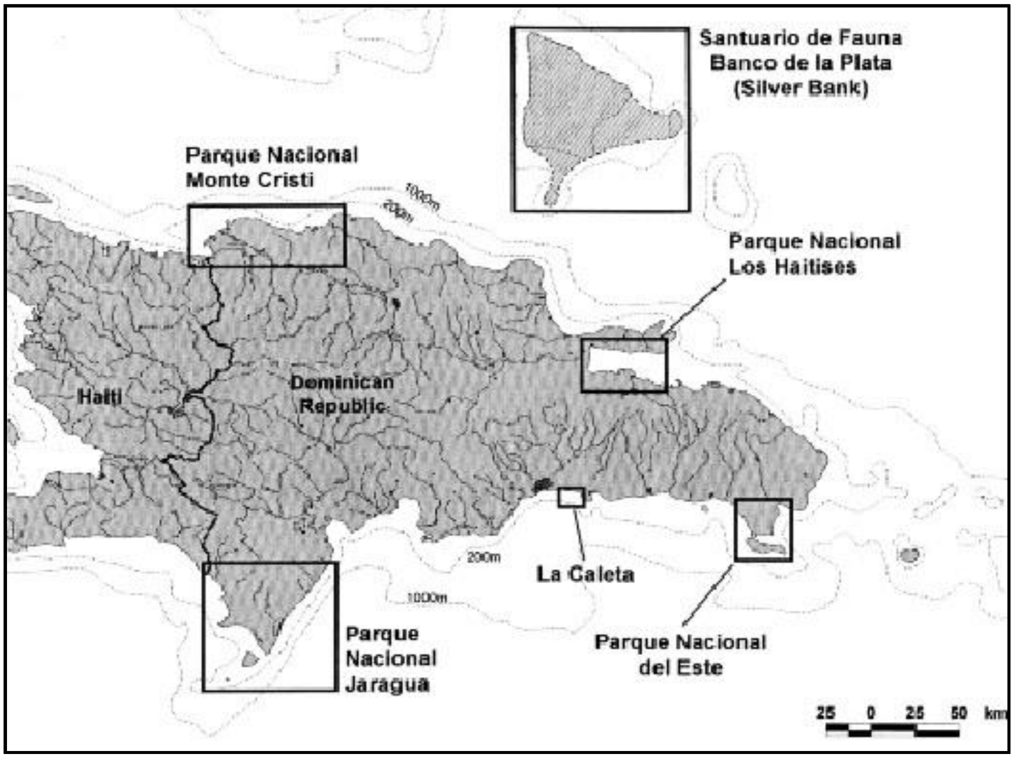

Figure 6: General locations of MPAs in the Dominican Republic (Chiappone, 2001)

areas) which equate to about 25% of the National Territory, but only 34 have any environmental administration (Brioso, 2008). The diverse and seismically active spectacular topography of Hispaniola (last major earthquake with accompanying tsunami was in 1953 in the vicinity of Nagua and caused over 3,000 casualties) is accentuated by three extensive valleys and four mountain chains that run northwest to southeast with the two highest mountain peaks in the Northern Caribbean (Pico Duarte at 3,175 m and La Pelona at 3,087 m) (Lewis et al., 1990). The Dominican Republic has a National System of Protected Areas (SINAP) that is governed largely by the Protected Areas Sector Act which was put into place in 2004 (law 202-04) under the General Law of the Environment and Natural Resources of the year 2000 (law 64-00) (Reynoso, 2004). The Ministry of the Environment and Natural Resources (SEMARENA) is responsible for monitoring and control of terrestrial and marine ecosystems and the management of security measures (Reynoso, 2004). However, there are no governmental politics that enforce MPAs or CZMT and NGOs that get involved only follow guidelines without real government-backed execution plans (Heredia, 2009).

The National System of Protected Areas consists of 123 protected areas including 33 declared through the presidential decree No.571 from 2009 (Reynoso, 2004). 46,669 km^2 of coastal marine area are covered through this decree and it includes 33 marine areas with an estimated 1,955 coastal and marine species in the Dominican Republic (Geraldes et al., 2003, Heredia, 2009). Three coastal provinces have the largest extensions of mangrove forest; Samana, Montecristi and Altagracia have a total of 70% of the mangroves of the Dominican Coast (Herrera-Moreno & Betancourt, 2001). About 17.8% of the Dominican coastline are beaches (mostly in the provinces of Altagracia, Puerto Plata and Samana) (Herrera-Moreno & Betancourt, 2001). An over-capitalization of fisheries on a global scale (open-access and subsidy-driven) has led to an urgent and major crisis in fisheries (Pauly et al., 1998). The issue with marine resources, particularly fisheries in the Dominican Republic and the WCR, can be seen as a “tragedy of the commons” —when the marine resource does not have ownership or regulations imposed there is no responsibility for maintaining the resource and every person will have a tendency to over-use the resource (Wallace et al., 1994). Below are some of the resource characteristics of marine areas of the Dominican Republic (Table 3).

Of the 600 km of coastline in the Dominican Republic approximately 11% is protected by coral reefs (Reynoso, 2004). There are also two offshore banks; Silver Banks and Navidad Shoals which consists of two barrier reefs and several fringing reefs. Among active MPAs and other protected areas listed in Table 3 above, only the "Santuario de Mamiferos Marinos" has a seasonally prohibited (no take) fisheries management policy (CANARI, 2001). This area of Dominican territorial waters mainly on the Silver Banks (80 nautical miles north of Puerto Plata) is the largest breeding ground for humpback whales in the world (Geraldes et al., 2003) (Figure 7).

Table 3: Resource Characteristics of MPAs and other protected areas in the Dominican Republic (CANARI, 2001)

MPA or Other Protected Area	Reefs	Mangroves	Sea grass Beds	Terrestrial Component	Solely Marine	Endangered Species	Active Manage-ment
Area Nacional de Recreo Cayo Levantado				X		Nesting seabirds	No
Area Nacional de Recreo Boca Chica	X		X	X			No
Monumento Natural Isla Catalina	X	X	X	Offshore Island			No
Parque Nacional Cabo Cabron				X			No
Parque Nacional del Este		X	X	X		Turtles, Manatees	Yes
Parque Nacional Jaragua	X			X		Turtles, flamingos	Yes
Parque Nacional Los Haitises		X		X		Turtles, seabirds	Yes
Parque Nacional Montecristi	X	X	X	X		Turtles, manatees	No
Parque Nacional Submarino La Caleta	X				X		Yes
Reserva Biologica Gran Estero		X		X			No
Santuario de Mamiferos Marinos	X		X		X	Humpback Whales	Yes

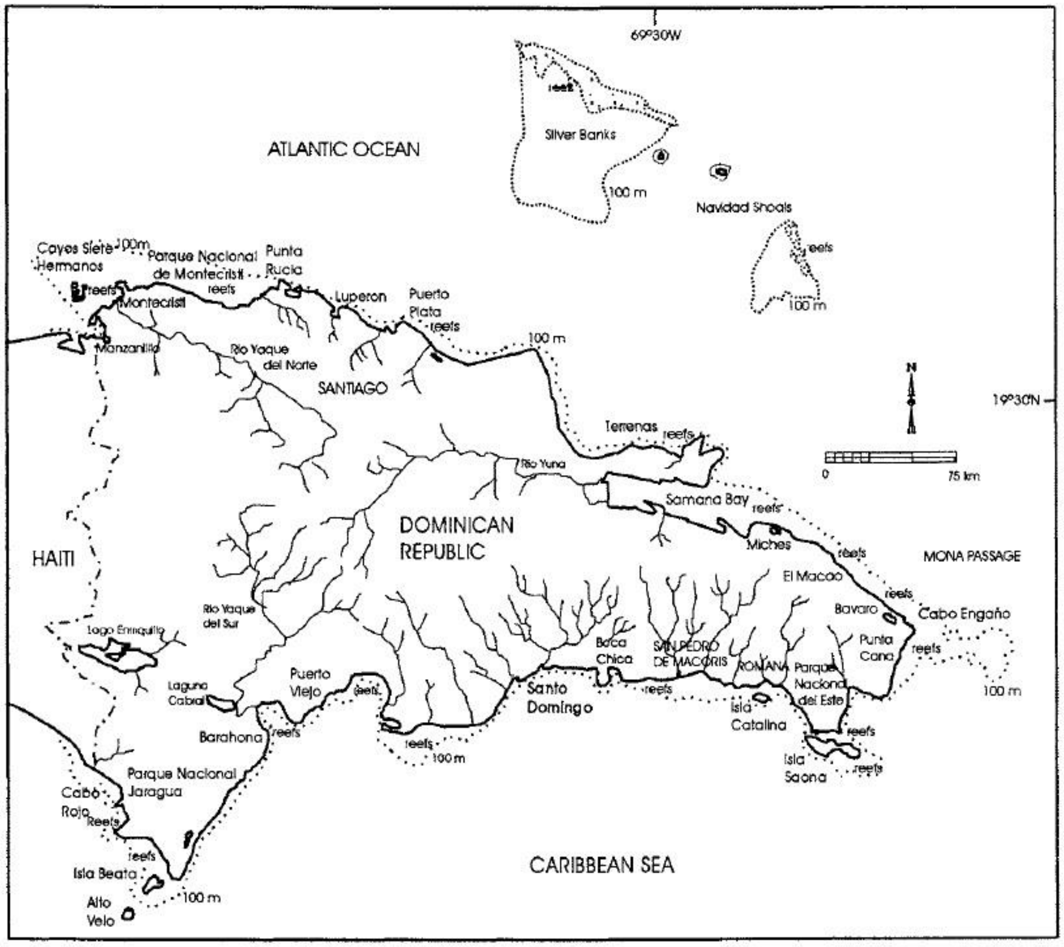

Figure 7: Dominican Republic Coral Reef Localities (Geraldes et al., 2003)

Many coastal and marine areas suffer from "poor vigilance" due to the lack of capacity and equipment to be able to do so (there are only about two dozen coast guard and Dominican Navy boats for the whole country). Enforcement of environmental laws in MPAs is very difficult and MPAs are highly vulnerable and fragmented as a result (especially the ones close to the Haitian Border like Montecristi and Jaragua). MPAs and coastal zones in the Dominican Republic have suffered the same degradation as other areas in the Caribbean evidenced by: 1) increases in algal cover and decreases in coral cover, 2) inability of reef-building flora and fauna to recover from stresses and shocks, 3) loss of mangrove areas and diversity and 4) changes in the distribution, size and frequency of reef fishes (Chiappone, 2000). The management of MPAs and CZMT in the Dominican Republic faces the same problems as many Caribbean islands; it has been handicapped due to a lack of understanding of highly complex coastal ecosystems and there is also a lack of trained expertise in the integration of science issues and coastal management into regional and local policy (Gable et al., 1990).

2.1.2 Environmental Concerns in the Dominican Republic

Biological indicators such as coliform bacteria counts, benthic invasive invertebrates (such as mussels), phytoplankton and viral tracers are used in water quality studies in the WCR and the Dominican Republic to determine the amount of human sewage and the nutrient status (GCFI 2002; Tomascik & Sander, 1985). It was found that the main anthropogenic problems that functional Dominican MPAs face are; very little enforcement of existing MPA legislation, inefficient solid waste control, water pollution (point sources and non-point source), damages from boat anchors and discharges (fishermen and drug trafficking), damages to species caused by visitor impact or take, few MPA infrastructures, no control of charge capacity and a lack of training and pay for environmental or park personnel (Brioso, 2008). There is also a lack of physical and biological baseline data on the present state of Dominican MPAs and coastal resources as well as insufficient resources to fix information gaps (now increasingly done with Rapid Ecological Assessment (REA) technologies) to be able to effectively manage an increasing use of natural resources (Chiappone, 2000). Most people in the WCR and the Dominican Republic recognize indicators of MPA stressors such as low water clarity, algal blooms, changes in coastal environments, sea grass mortality and problematic human activities. However, MPA managers and stakeholders are asked to make decisions and recommendations based on few statistics and little corroborative evidence (Grumbine, 1994). REAs for MPAs include circulation assessments (mega and meso scale) and physical and chemical properties of MPA seawater; indicators on surface water quality, dissolved oxygen, salinity, temperature, sedimentation, turbidity, total nitrogen, total phosphorus, chlorophyll, coral growth and isotopic composition (GCFI 2002; Chiappone, 2001 (part 2)). REAs have been carried out on Parque Nacional del Este and Montecristi MPAs (as opposed to other MPAs where data is more limited) which is why they are being used as case studies in this capstone.

The Dominican Republic deals with an additional stressor to marine and coastal ecosystems in the form of a very large and growing uneducated young population. Almost 5 million Dominicans or 64% of the population lives along the coastline, mostly in the Greater Santo Domingo Area (Herrera-Moreno & Betancourt, 2001). The Dominican Republic population is growing at 1.3% per year and 70% are living in urban areas (looking for economic opportunity from rural areas or increasingly from Haiti since the earthquake in 2010) and this puts tremendous pressure on reduced available land and natural resource bases (USAid, 2006). Historians point out that deforestation and human intervention started to affect the island from the 15th century onwards with large scale sugarcane plantations causing agricultural runoff and sedimentation to the nearby marine areas (Geraldes et al., 2003). Coastal development (including large scale all-inclusive tourism infrastructure) has destroyed mangroves and marshes for landfills and has caused dredging for industrial ports and recreational marinas (Caucedo in Boca Chica and Casa de Campo Marina in La Romana). The erosion of coastal areas due to the illegal mining of sand and construction materials and the harvesting of certain protected coral reefs (black coral, starfishes, reef fishes, sea urchins for the souvenir industry) are also continuing issues of concern. (Geraldes et al., 2003).

The steep topography of the "mega-diverse" Dominican Republic and cultivation in some of the highest areas in the region encourages extreme soil erosion and the movement of POPs to coastal areas including increased sedimentation which directly affect MPAs (Van Lavieren et al., 2011). Cultivation and the mismanagement of agricultural land practices has completely eroded hillsides and mountains in neighboring Haiti causing irreversible damage to marine ecosystems in both countries (through the transportation of pollutants and sediments with regional ocean currents) (Heredia, 2009).

The application of pesticides in agriculture is also increasing in the Caribbean and between 1974 and 1984 pesticide use increased in 7 of 14 countries inspected by UNEP (UNEP, 1994). Pesticide use increased by 68% during the same time period in the Dominican Republic (Simonich & Hites, 1995). Tides in the Dominican Republic are classified as semi-diurnal all around its coastline with a mean spring tidal range of 90 cm and 30 cm on the north coast and the south coast respectively (Molinari et al., 1981). Oceanographic circulation patterns in both northern and southern coastal waters are determined by the Northern Equatorial Current (Molinari et al., 1981). The flow of this current is westward towards the Dominican Republic, splitting into southern and northern forks in the Mona Passage, and resulting in many different regional currents and eddies throughout Hispaniola which can be difficult to assess (Duncan et al., 1977).

Sedimentation has had an impact on the reefs and MPAs of the Dominican Republic through natural and anthropogenic processes. Natural sources of sedimentation are shoreline erosion, the re-suspension of sediments, sediments from river inputs and land run-off after heavy precipitation and sedimentation due to the passing of a tropical storm or a hurricane (Torres et al. 2001). Other anthropogenic activities that accelerate climate change effects by increasing coastal and shore erosion are mineral mining, coral mining and land drainage accompanied by the destruction of mangrove habitats in the Dominican Republic (Gable et al., 1990). Dominican rivers and watersheds suffer from illegal extraction and mismanagement (this impedes their contribution of sediments to the coastlines) and this intensifies coastal erosion (Herrera-Moreno & Betancourt, 2001). Anthropogenic sources of sedimentation in the Dominican Republic are run-off from agriculture (in Haiti as well as mentioned), urbanization, tourist infrastructure, animal husbandry, construction and dredging (Torres et al. 2001). The Dominican Republic is a relatively large landmass in the Caribbean islands and there are three main areas (even if they are relatively dry) that have natural sediment input that restrict reef growth (and is exacerbated by human activities) affecting the reefs in the MPAs in el Morro in

Montecristi, Punta Martin Garcia in Barahona and Punta Salinas in Peravia (Geraldes et al., 2003).

MPAs and coastal zones in the Dominican Republic Republic show evidence of mass mortality of reef organisms, increased algae-dominated reef communities within MPAs, increased incidences of coral bleaching and diseases (Shulman & Robertson, 1996), increased bio-erosion (Hallock et al., 1993) and low coral recruitment to replace colonies that are lost throughout the construction and destruction of coral reefs (Dustan & Halas, 1987). Dominican Republic MPAs have been affected by natural disturbances that are exacerbated by human activities; coral bleaching, in particular, in areas that are close to urban settlements and tourism centers (Guayacanes, Juan Dolio, La Caleta, Bavaro, Punta Cana, Sosua, Cabarete, Puerto Plata, Las Terrenas and Macao) and mass mortalities (exacerbated by overfishing and nutrient pollution that have enabled algae to flourish and further erode reefs) (Geraldes et al., 2003). Algal blooms, sea grass mortality, decreases in coastal wetlands, sponge mortality , increases in sea turtle diseases and wading bird disease in coastal wetlands are well known markers of contamination and pollution in MPAs that are well recognized by the Dominican population (Chiappone, 2001 (part3)). All MPAs have been affected by a hurricane or tropical storm as they are very common natural phenomena in the Dominican Republic. In the last 500 years, almost 200 hurricanes and tropical storms have been recorded and most pass over or brush the southern coast as opposed to the north coast (Geraldes et al., 2003). Living coral is directly affected by wave action and storm surges and deposited as debris on top of the reef which serves as a base for future coral growth or is bio-eroded and converted into sand and pebbles. The increased precipitation during these phenomena causes excess water runoff, flooding and deforestation of watersheds which creates a decrease in salinity, excess turbidity and increased water pollution in MPAs. Reefs and MPAs usually become unstable if adjacent watersheds are not managed correctly and some of these issues are visible in the Juan Dolio, Guayacanes, El Portillo, Boca Chica, Playa Dorada and Puerto Viejo reef areas (Geraldes et al., 2003).

2.1.3 Overall Assessment of MPA and CZMT in the Dominican Republic

There are localized efforts within Dominican MPAs in the form of specific partnerships that have had positive results on marine and coastal conservation; the integration of management communities and the conservation of sea turtle nesting beaches in the Jaragua National Park through Grupo Jaragua (also in the Eastern National Park), the training of individuals for regional MPA management through the TNC Caribbean Challenge (CaMPAM, UNEP and SEMARENA), economic alternatives, tourism and sustainable fishing practices for the southern part of the Dominican Republic (Reef Check, CaMPAM, UNEP and SEMARENA) (Reynoso, 2004). The Dominican Republic has signed and ratified international treaties that have assisted with MPA legislation like the Basilea Convention, the Cartagena Convention, MARPOL, the SPAW Protocol, CITES, and the Convention on Biological Diversity and Climate Change (Geraldes et al., 2003). However, there is a lack of short term and middle term policies and established legislation that encourages the preservation of biodiversity conservation and further research in MPAs (Heredia, 2009). There have been many isolated REAs and scientific research in individual MPAs, but there are no "Strategic Plans" or official guidelines for national CZMT or MPA Management and not enough technical and financial efforts are directed towards establishing them (Heredia, 2009). There is also the added inconvenience that every time there is a change of government (every four years) there is a lack of continuity (processes are discontinued or eliminated by the winning party) which further erodes the potential political will for establishing these guidelines. A lot of institutions that work with MPAs and coastal zones are engaged in corruption (very widespread in the Dominican Republic with little transparency), compete with each other, interfere or avoid each other or carry out duplicate work; for e.g. the Consejo Dominicano de Pesca y Acuacultura (CODOPESCA) does not coordinate as much as it should with SEMARENA or the Coast Guard because of its individual financial agenda (Heredia, 2009). Local pilot projects for the evaluation of MPAs and their adjacent coastal areas are sectorial, conjunctural and disconnected when they should be regularized (particulary beneficial to the sustainability of the tourism industy) (Lopez, 2007). Contributions have not been made for research in MPA and CZMT by international organizations like the UNDP and OAS because the monies are not made available for this much-needed research and there are no allocated finances for coastal-marine management on a national and local city hall level (Heredia, 2009).

2.2 Climate Change Effects on Caribbean Small Island Developing States (SIDS)

Worldwide there are 51 SIDS and the majority are found in the relatively small area of the Caribbean Basin.(UN Framework Convention on Climate Change, 2006). The WCR includes 35 nations that have a far greater amount of coastal zone per unit of land than the continental areas in the same region (Gable et al., 1990). The environment, land uses and economies of the Caribbean are largely dictated by a marine influence and will be impacted by climate change (Gable et al., 1990). The Caribbean shorelines and MPAs are characterized by two major episodes in Earth's past; the last interglacial glacial episode that lasted more than 80,000 years and where sea level fell 130 m below the current level (continental shelves were above water and coral reefs were limited to continental slopes or islands) and the start of the growth of reef structures (about 9,000 years ago) (Hallock et al,, 1993). The Caribbean is highly susceptible to rising sea levels, temperature increases, storm patterns and changes in precipitation (Cherian, 2006). These climate characteristics, combined with their particular socioeconomic situations make SIDS (whether they are low-lying or not) some of the most vulnerable countries in the world to climate change. About 50% of the population in the Caribbean SIDS live within 1.5 kilometers of the coast (Henson, 2008). The IPCC Report of 2013 is considered to have the most up to date climate data on the Caribbean Region and states that SIDS are highly vulnerable "frontline states" that will directly face the climate change threat first (USAid, 2013; Cherian, 2006). Caribbean SIDS are among the most vulnerable nations in the world to MPA and coastal degradation due to climate change variables (increase of intensity and frequency of hurricanes, flash flooding, severe drought, sea-level rise and ocean acidification). Additionally, El Niño/ La Niña larger phenomena contribute to Gulf Stream abnormalities and the possible slowing of North Atlantic thermohaline circulation. Improved adaptation and mitigation measures are made possible through increased environmental security. “Environmental security is a condition in which a nation or region, through sound governance, capable management, and sustainable utilization of its natural resources and environment, takes effective steps towards creating social, economic, and political stability and ensuring the welfare of its population “(USAid, 2005). Caribbean SIDS and others will suffer disproportionately from the damaging impacts of climate change compared to other countries (Sem, 2006). In short, they will pay an excessively unfair price and will experience a lack of environmental security because of anthropogenic climate change effects caused by industrialized countries (Sem, 2006).

The IPCC Third Assessment Report (TAR, IPCC, 2001) predicts a projected sea level rise due to anthropogenic factors of 9-88 cm from 1990 to 2100 with a mid-estimate of 48 cm (Nicholls & Lowe, 2004). Several Caribbean Island capitals are near sea level; for example Belize City, St. John's in Antigua and Basse-Terre in Guadeloupe (Gable et al., 1990). A 50 cm rise in sea level could cause 60% of the beaches in Grenada to be lost and it is estimated that 3% of Cuba's mangrove forests will be lost with a 1 meter rise in sea level (UN Framework Convention on Climate Change, 2006). Sea level rises and flooding will have disastrous effects on Caribbean Cities like Santo Domingo in which over a million impoverished people live in informal settlements on the floodplains of the Isabella and Ozama Rivers in Ward 3 in this city (USAid, 2013). Regional sea level rise (like in the Caribbean) depends on the global mean sea level and regional deviations from this mean (Nicholls & Lowe, 2004). It is difficult to accurately predict what sea level rises will be in the Caribbean due to high tectonic activity compared to eustatic sea- level change (worldwide change in sea level in comparison to local land uplift) and so sea level rise will vary greatly from place to place (Gable et al., 1990). There is also an absence of adequate and uninterrupted scientific data (particularly in the Dominican Republic) to be able to properly predict sea level rise and other climate change effects in some areas of the WCR because of discontinuities in meteorological data and a lack of reliable stations (due to a lack of political will, financial resources and maintenance) (USAid, 2013). Sea level rise is very different from other climate change factors because of the physical constraint of the high heat capacity of the ocean meaning that it will continue to rise for hundreds or even thousands of years even after climate change is stabilized (Lawson 2008, Nicholls & Lowe, 2004).

Precipitation has generally become sparser (there are longer periods of drought in the Caribbean) or more intense in localized downpours (USAid, 2013). Due to factors such as topography, geology and water resources (reliance on surface water, groundwater and rainwater), Caribbean SIDS are very vulnerable to changes in precipitation patterns (UN Framework Convention on Climate Change, 2006). Heavy localized downpours cause depletion of soils from leaching and leads to erosion and increased water column turbidity that adversely affects MPAs and their coral reefs (Gable et al., 1990). It is difficult to predict future precipitation patterns in the WCR because there is a heightened climatic variability due to El Niño Southern Oscillation (ENSO) events in the Caribbean Basin (USAid, 2013).

It has been shown through the analysis of data from the late 1950s to 2000 that the number of very warm days and nights is increasing, very cool days and nights are de-creasing and the inter-annual temperature range is decreasing dramatically. (UN Framework Convention on Climate Change, 2006). Atmospheric temperature in the Caribbean is expected to rise by 2-4°C by 2070 (Burke et al., 2004). This means that the pool of water in the Caribbean Basin that remains at 26°C and above (the temperature that is deal for cyclonic activity) will increase in size and duration spurring increased intensity of changing patterns of storm activity (Gable et al., 1990). This manifested itself in 2005 and all records were broken for hurricane activity in the Caribbean with a total of 26 tropical storms and 13 hurricanes causing great damage to reefs and MPAs (including

Hurricane Katrina) because of polluted and muddy freshwater runoff and extreme wave action (Wilkinson & Souter, 2005). Tropical storm intensities could increase from 5 to 10% by 2020 and, combined with the fact that numerous hotel complexes in the Caribbean (70% in Jamaica and almost all in the Dominican Republic) are located within 250 m of the high water mark, places the tourism industry at risk for major structural damage (UN Framework Convention on Climate Change, 2006).

The increase in human population from 6 billion to 9 billion people by the year 2050 and a probable increase in temperature of 1.5-4° C for the same time span suggests that coral reefs within or outside of MPAs will witness a continuing crisis in the next decades (Mora, 2008). As stated before, degradation is taking place in most coastal and marine environments due to increasing urban populations and unsustainable development which exacerbate deforestation, overfishing and mismanagement of MPAs and adjacent coastal areas (Geraldes et al., 2003).

Caribbean SIDS will experience increased water stress due to climate change factors. Areas like Santo Domingo are experiencing severe drought in 2015 and have water rationing plans in place in some urban areas. Shortages of water and the increased danger of vector-borne diseases (such as the Chikungunya epidemic in 2013) will reduce the amount of tourists that visit the Caribbean (UN Framework Convention on Climate Change, 2006). The increased wet and dry cycles associated with ENSO phenomena place a significant stress on island economies and highlights the vulnerability of critical water supplies (which need more effective management with the increase in populations and tourism economies) (UN Framework Convention on Climate Change, 2006).

There are considerable existing efforts in the Caribbean SIDS to investigate and apply climate change adaptation and mitigation plans such as Planning for Climate Change (CPACC), Adapting to Climate Change in the Caribbean (ACCC) and Mainstreaming Adaptation to Climate Change (MACC) (Nicholls & Lowe, 2012, Cherian, 2006). There are too many initiatives to mention in this paper. However, a point worth mentioning is that Caribbean MPA and CZMT management still falls short of effectively integrating climate change factors into MPA design and management frameworks due to a poor understanding of the interconnectedness of conservation, socioeconomic and climate change factors (USAid, 2013).

2.2.1 Climate Change Effects in the Dominican Republic

The Dominican Republic coastal communities of Las Terrenas, Punta Cana, Samaná, Bávaro and Montecristi have reported adverse climate change effects including severely eroded beaches, dying reefs, flooding, pollution, salt water intrusion and shrimp and fishstock depletion (USAid, 2013). The other main issue that negatively influences effective MPA management directly in the Dominican Republic is poverty (exacerbated by climate change and informal coastal settlements). On many of the Caribbean islands (especially the southern and eastern coasts of the Dominican Republic) continuous corridors of coastal development occupy key coastal lands (UN Framework Convention on Climate Change, 2006). This coupled with ineffective municipal land use planning leads to a proliferation of informal settlements in vulnerable areas (along riverbanks, floodplains and low-lying areas). Santo Domingo has had unmonitored waterfront coastal development on reclaimed land coupled with large movements of poor populations settling in vulnerable areas (in particular the Ozama and Isabela floodplains to the east of the city in Ward 3) with an increase in potential storm damage, inland flooding risks and loss of life that are exacerbated by climate change factors (Gable et al., 1990; USAid, 2013). The temporary increases in sea level by storm surges can cause major damages in coastal areas and cause inland flooding and loss of life (in particular in Ward 3 in the city of Santo Domingo where almost 1 million impoverished people are vulnerable to storm surges and flooding along the Ozama and Isabela River Floodplains-Figure 8) (USAid, 2013). In turn, unregulated building practices and beach and river bank mining for construction materials (sand for mixing cement for example) have accelerated coastal degradation and the destruction of coral reefs in these areas exacerbating climate change effects (UN Framework Convention on Climate Change, 2006). Storm surges could

Figure 8: Residents of " La Barquita" along the Ozama River in Santo Domingo after rains from Hurricane Sandy (CRIS Program, USAid, 2014)

coincide with extreme localized precipitation events (similar to a domino effect) making the situation even worse (Herrera-Moreno & Betancourt, 2001).

The main climate change effects in the WCR are also affecting the Dominican Republic; extreme temperatures, changes in precipitation patterns, ocean acidification and projected sea level rise and increases in tropical storm activity (USAid, 2013). The Dominican Republic is regularly ranked as one of the 10 most vulnerable and exposed areas in the world in relation to climate change effects (mostly due to socio-economic factors, lack of urban planning and lack of drinking water) (USAid, 2013). The IPCC defines exposure as “the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected” (IPCC, 2001). According to Germanwatch, the Dominican Republic is ranked 8th in the world with regards to vulnerability to climate change (Table 4) using their long-term climate risk index and 5 of the 11 most vulnerable countries are in the WCR (Figure 9) (Soenke et al.,2013, Kleft & Eckstein, 2013).

It is projected that there will be three times as many days with temperatures over 90° F (32.2° C) and more consecutive days over that temperature by 2070 in the

Table 4: Long-term Climate Risk Index Results (CRI): Results in specific indicators of 11 countries most affected between 1993 and 2012 (Soehnke et al., 2013)

CRI 1993–2012 (1992–2011)	Country	CRI score	Death toll	Deaths per 100,000 inhabitants	Total losses in million US$ PPP	Losses per unit GDP in %	Number of Events (total 1993–2012)
1 (1)	Honduras	10.17	329.80	4.86	667.26	2.62	65
2 (2)	Myanmar	11.83	7135.90	13.51	617.79	1.20	38
3 (5)	Haiti	16.83	307.50	3.45	212.01	1.73	60
4 (3)	Nicaragua	17.17	160.45	2.81	224.61	1.74	44
5 (4)	Bangladesh	19.67	816.35	0.56	1832.70	1.16	242
6 (6)	Vietnam	24.00	419.70	0.52	1637.50	0.91	213
7 (14)	Philippines	31.17	643.35	0.79	736.31	0.29	311
8 (10)	Dominican Republic	31.33	212.00	2.43	182.01	0.32	54
8 (12)	Mongolia	31.33	12.85	0.52	327.38	3.68	25
10 (9)	Thailand	31.50	160.35	0.26	5410.06	1.29	193
10 (11)	Guatemala	31.50	82.35	0.69	312.23	0.58	72

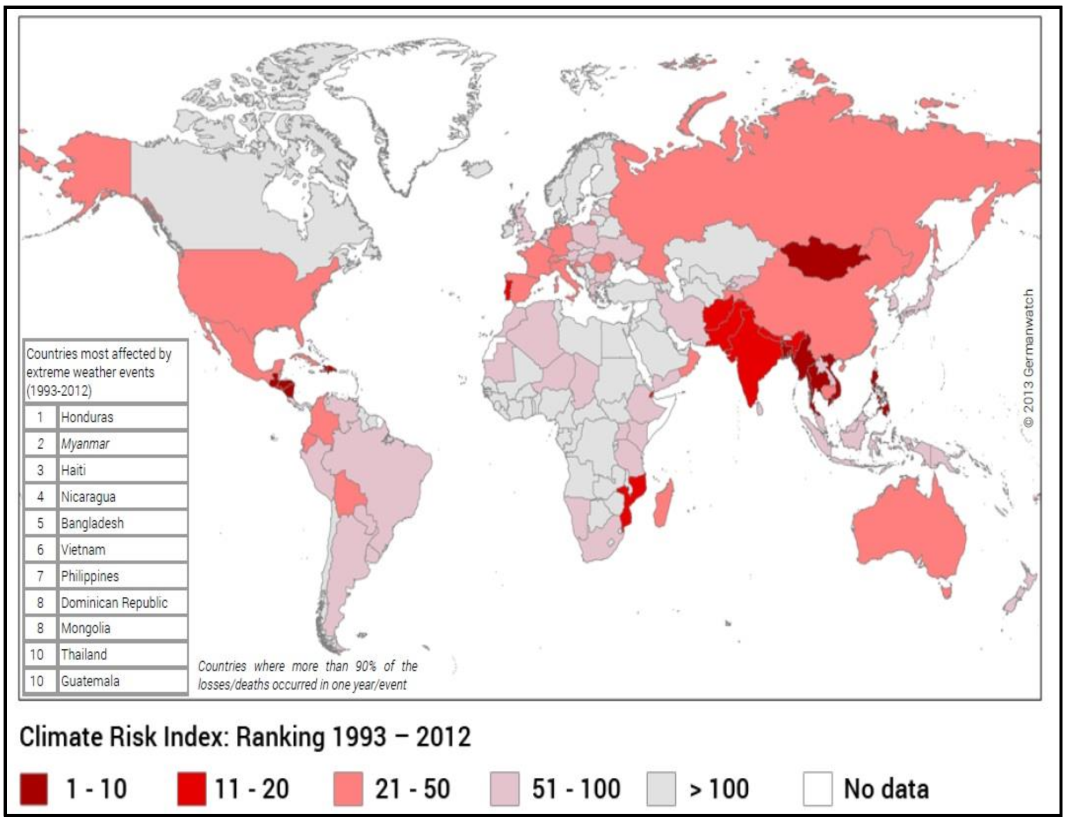

Figure 9: World Map of the Climate Risk Index 1993-2012 (Soehnke et al., 2013)

Dominican Republic (CRIS Program, USAid 2014). Changing thermodynamics is a result of increased atmospheric temperature which leads to rainfall events that are more intense (USAid, 2013). The climate of the Dominican Republic is classified as tropical marine dry (Sealey, 1992). This classification will most likely have to be reconsidered as precipitation patterns are changing due to climate change with wetter wet seasons and drier dry seasons (Table 5) (CRIS Program, USAid 2014).

Table 5: Monthly Participation Patterns in the Dominican Republic 1960-2009 (USAid, 2014)

Monthly Precipitation– Dominican Republic				
	1960 - 1990	**1990-2009**	**Difference**	**%**
February	59.7	56.5	-3.2	-5%
March	56.4	51.5	-4.9	-9%
April	97.4	114.4	17	17%
May	196.1	197.4	1.3	1%
June	130.6	115.9	-14.7	-11%
July	117.4	115.6	-1.8	-2%
August	125.7	115.8	-9.9	-8%
September	152.4	159.2	6.8	4%
October	165.5	212.9	47.4	29%
November	132.7	162.9	30.2	23%
December	89.3	106	16.7	19%
January	70.9	82.5	11.6	16%

In table 5 we can see that there are differences (variability) in precipitation. Many climate change effects are linked and lead to multiple effects. Increased levels of intense localized precipitation will cause sporadic flooding by freshwater and can cause increased coral reef mortality because corals cannot tolerate wide fluctuations in short time spans in salinity levels within or outside MPAs (Longhurst & Pauly, 1987). There is a problem with hydrological meteorological station coverage in the Dominican Republic as data has not been recorded in a systematic manner in the last 50 years (due to maintenance and financing issues) and so it is hard to accurately predict climate change models based on precipitation for the country (Herrera-Moreno & Betancourt, 2001). However, it is clear that excessive wave and storm action in conjunction with freshwater flooding increases the mortality rate of corals in Montecristi, Santo Domingo and Samana Bay (USAid, 2013).

Ocean acidification will place a strain on MPAs in the Dominican Republic, particularly coral reefs and surrounding food chains, because calciferous organisms will not be able to maintain their structures and will not be able to supply sand or prevent beach erosion through the reduction of wave energy (Weilgus et al., 2010). This, in turn, will cause populations adjacent to MPAs to become more vulnerable to climate change effects like sea level rise and storms causing a loss of coastal vegetation (key in anchoring sand substrates), which, in turn, will cause more coastal erosion. Sea level rise, in turn, activates the same two important mechanisms which cause sand loss; irreversible beach erosion and flooding (Herrera-Moreno & Betancourt, 2001). It has been estimated that sea level could increase between 0.5 and 1.1 meters by 2070 in the Dominican Republic (CRIS Program, USAid 2014). The increased sea-level rise and the intensification of repeated storms will handicap the ability of beaches to recuperate in between disturbances before the next storm hits and they erode even more (USAid, 2013). Other factors such as infrastructure development and intensive tourism activities also hamper their ability to recuperate. For the North Coast of the Dominican Republic the beach loss is forecasted to be between 340,000 m^2 and 670,000 m^2 by 2100 for a 10 km stretch of continuous beach (Herrera-Moreno & Betancourt, 2001). In Bavaro (the all-inclusive mecca in the Eastern Dominican Republic) coastline loss is estimated to reach about 1,793,000 m^2 or the equivalent of 99% of local beaches by 2050 dealing a major blow to the tourism industry (Herrera-Moreno & Betancourt, 2001). Sea level rise will also have an effect on fisheries with an increase in turbidity associated with coastal erosion. The increase in turbidity could have a negative impact in fisheries where the early life cycles of some species develops close to the coast (estuarine species could be especially vulnerable to changes in salinity) (Herrera-Moreno & Betancourt, 2001). Most of the fisheries in the Dominican

Republic are artisanal (not commercial) and are very vulnerable to climate change effects (USAid, 2013).

There are three scenarios for sea level rise for the Dominican Republic identified by IPCC; IS92c (optimistic) , IS92a (moderate) and IS92f (pessimistic) (Table 6):

Table 6: Sea Level Rise for the Dominican Republic according to three emissions scenarios. (Herrera-Moreno & Betancourt, 2001)

Scenarios	**2010**	**2030**	**2050**	**2100**
IS92c	1.47 cm	3.77 cm	6.53 cm	12.71 cm
IS92a	4.73 cm	12.33 cm	22.75 cm	55.19 cm
IS92f	13.55 cm	26.73 cm	47.27 cm	105.67 cm

Global warming has caused an increase in sea surface temperatures and widespread bleaching events. The warm water anomaly caused by climate change in the Caribbean in 2005 affected the Dominican Republic severely with corals suffering up to 38% mortality (Wilkinson & Souter, 2005). For each 2 to 4 degree increase in sea surface temperature, wind velocity in hurricanes increase anywhere from 10 to 22% (Herrera-Moreno & Betancourt, 2001). Hurricanes will form at higher latitudes (which means that the Dominican Republic is more frequently on their path) causing an increase in frequency of storms and recession of the shoreline. (Gable et al., 1990). There has been an increase in incidences of hurricanes affecting the Dominican Republic in the last 50 years (Table 7).

The most active 5 year period since 1851 is from 2000-2004 when four storms passed over the Dominican Republic (Herrera-Moreno & Betancourt, 2001). The Dominican Republic is already barely visible from all the storm activity tracks since 1851 and it is estimated that about 30- 35% of storms and hurricanes have passed within 60 nautical miles of the Dominican Republic since 1960 (USAid, 2013) (Figure 10).

Table 7: Number of Hurricanes per decade affecting the Dominican Republic (CRIS Program, USAid 2014).

Decade	Number of Hurricanes
1960-1970	4
1970-1980	4
1980-1990	2
1990-2000	4
2000-2010	14

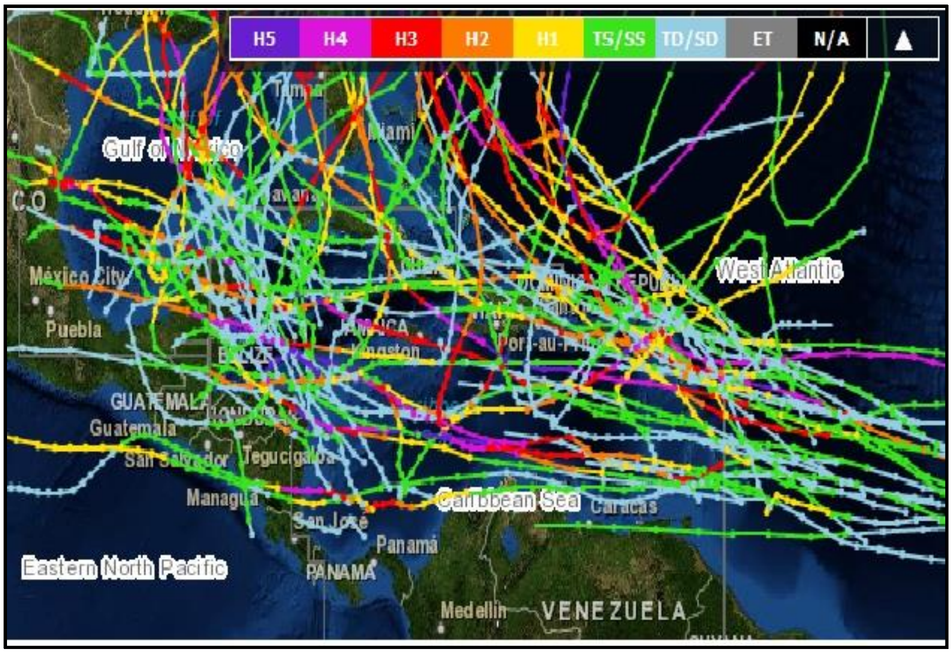

Figure 10: Hurricane and Storm Activity Tracks in the WCR from 1960-2008 (CRIS, USAid, 2014)

Coastal areas in the Dominican Republic have experienced excessive unregulated construction and informal settlements which have exacerbated climate change effects and contributed to MPA degradation and compromised the security of citizens (Cambers, 1999; USAid 2013) (Figure 8).

2.3 How can Caribbean MPAs and MPA networks act as ecosystem-based climate change resilience mechanisms?

An often overlooked and integral part of the effective design of an MPA and/or MPA network management plan is that when followed through it actually creates climate change resilience for SIDS. Estuarine, mangrove and soft-bottom habitats within and outside MPAs and MPA networks occupy key roles as regulators of water regimes, buffers against wave action, protectors of coastal zones and/or nurturers of marine life when left to their natural courses (Herrera-Moreno & Betancourt, 2001; USAid 2013). However, when disrupting their natural dynamic, they are particularly vulnerable to flooding and erosion from climate change and can no longer protect adjacent coastlines (USAid, 2013). Estuarine, mangrove and soft-bottom habitats within and outside MPAs and MPA networks continue to be modified for tourism infrastructure, agricultural and aquaculture projects without regard to their climate change resilient roles (USAid, 2013). Caribbean SIDS need to improve adaptation and mitigation measures through better environmental security and improved MPAs and MPA networks because they are compromising resilience to climate change by not doing so. MPAs have been proposed as a tool to increase ecosystem resilience and resistance (in particular for coral reefs) against the negative effects of climate change by being able to promote conditions that are necessary for recovery from them (Selig et al.,2012).

Caribbean SIDS are notorious for a high degree of endemism and biological diversity (Cherian, 2006). Caribbean SIDS are home to a significant proportion of the world's biodiversity (in particular the Dominican Republic with the highest in the Caribbean) because of their isolation leading to the occurrence of many endemic species (UN Framework Convention on Climate Change, 2006). If biodiversity is lost, the adaptive capacities of SIDS' marine ecosystems are compromised causing an increased vulnerability to climate change stressors and natural disasters (Cherian, 2006). MPAs have been largely recognized as a useful tool for the protection of biodiversity through the mitigation of stressors; reducing or prohibiting of unsustainable fishing practices, decreasing land-based sediments, reducing inputs from nutrients and promoting inter-connectivity of degraded populations (Selig et al., 2012, Alvarez et al., 2011). The latter can be promoted through MPA networks that act as marine corridors.

Over the long-term, MPAs and MPA networks have caused a reduction of physiological stresses on corals which allow them to become more resilient (and hence the MPA and accompanying coastline) to climate change (Selig et al., 2012). MPAs result in an increase in biomass, an increase in size and diversity of fishes and invertebrates within their designated areas compared to other areas nearby (Guarderas, 2008). As a result of MPAs being successful in restoring trophic structure and fisheries in coral reefs, they are also useful in mitigating stresses caused by climate change (Selig et al., 2012). Coral reefs in MPAs and MPA networks supply sand to coastlines and also control coastal erosion rates by reducing wave energy (Weilgus et al., 2010). An estimated 21% of the Caribbean shorelines are protected by reefs associated with MPAs acting as an extra buffer by dissipating waves, reducing storm energy and hampering sea level rise projected to be at 3 cm to 10 cm per decade for the WCR (Burke et al., 2004). It is beneficial and important for Caribbean MPAs (especially the Dominican Republic with virtually no effective MPA management) to be integrated into regional MPA networks as they offer additional regional legislative leverage with regards to regional biodiversity conservation, socio-economic factors, financial mechanisms and climate change resilience (Hererra-Moreno, 2001).

Worldwide, 2005 and 1998 were the worst years on record when it came to damage to corals and included the hottest recorded sea surface temperatures since 1880 (Wilkinson & Souter, 2005). Sea surface temperature anomalies that contribute to climate change effects in the WCR are usually small (Selig et al., 2012). Seventy percent of overall sea surface temperature anomalies were found to be less than 75 km^2 in size while a few (larger ENSO phenomena) are over 100,000 km^2 in size in the Eastern Pacific (IUCN 2010, Selig et al., 2012). To our advantage, it has been documented that MPAs are able to decrease the variability in size, frequencies and patterns of smaller sea surface temperature anomalies in the WCR thereby increasing resilience to climate change and ENSO phenomena (Selig et al., 2012). Surprisingly, it has been found that the architectural complexity of reefs in MPAs did not decline severely on reefs that had been affected by a hurricane in the last 10 years (Alvarez et al., 2011). MPAs and MPA networks can recuperate from physical disturbances and become more climate change resilient even though their coral cover becomes less structurally complex (decline in coral species that are less resistant to hurricanes; e.g. branching elkhorn coral species) (Chiappone, 2001 (part 3)). This is why some Caribbean MPAs have experienced an increase in biodiversity, biomass, average size of corals, abundance and diversity of invertebrates and fish but large-scale declines in coral species can happen within their limits (Alvarez et al., 2011).

MPAs and MPA networks address many concerns about ecosystem damage from climate change; preserving mangroves and coral reefs that serve as natural buffers for adjacent vulnerable coastal zones, restoring and conserving local ecosystems, managing habitats for endangered or rare species and protecting and enhancing services provided by ecosystems (Cherian, 2006). MPAs help protect wetlands and mangroves (very important to ecology and economy of coastal areas) because they dissipate wave energy, protect coastlines in bays, lagoons and estuaries (Gable et al., 1990). Mangroves act as coastal erosion and shoreline inhibitors and provide support for fisheries (both artisanal and commercial) in the form of being nurseries for many species of juvenile fish (Cherian, 2006).

MPAs and MPA networks that are effectively designed have been shown to be able to spread out the risk of climate change effects by protecting key source populations and making them more resilient to climate change impacts (Selig et al., 2012). Shoreline structures (jetties, groins, embankments and sea walls) can be short-term solutions against climate change effects but many times they make shoreline loss worse while protecting structures that are inland (IUCN 2008, Gable et al., 1990). MPAs and MPA networks offer a level of integral protection to coasts that does not require as many man-made shoreline structures for climate change resilience (Figure 11).

Land and fresh water influence MANGROVES	Lagoonal system SEAGRASS BEDS	Open sea interface FRINGING CORAL REEFS
▪ Trap fine land sediments ▪ Consume and accumulate organic matter and nutrients ▪ Buffer changes in salinity ▪ Stabilise sediments ▪ Reduce wave action ▪ Export particles of organic matter	▪ Stabilise and bind sediments ▪ Accumulate, consume and export organic matter and nutrients ▪ Poor at withstanding wave action	▪ Accrete Calcium Carbonate, ▪ Accumulate organic matter and sediment ▪ Recycle nutrients and organic matter ▪ Consume suspended organic matter ▪ Produce sediment e.g. parrotfish droppings ▪ Slow or divert water currents ▪ Protect from storm damage by reducing wave energy

Figure 11: Functions and ecosystem-based resilience of MPAs and MPA networks (STINAPA, 2006)

Climate change effects (natural and anthropogenic) occur at different rates on Caribbean SIDS and can vary greatly. So, it is important to analyze climate change effects and adaptation efforts individually wherever possible in order to design appropriate MPAs and MPA networks for a given area. Even though the WCR is a relatively small area, there are many factors that influence climate change resilience. For example, shoreline erosion on the south and west coasts of Barbados (very tourist-oriented) has been up to 6 meters in the past 30 years (Gable et al., 1990). Mangrove growth towards the ocean (an important buffer against coastal climate change effects) has been halted by tourism development in the Bavaro Region of the Dominican Republic for the past 20 years (USAid, 2013). Grande Anse Beach on the island of Grenada eroded at 0.7 m/ per year between 1970 and 1982 because of sea level rise and local sand mining (Gable et. al., 1990). Offshore sand extraction in the Dominican Republic (dredging of shoals off Playa Grande and Sabaneta on the North Coast to fill in the eroded tourist beaches of Cabarete and Puerto Plata) has ironically accelerated erosion because of lack of research and comprehension about the total coastal dyamics (Geraldes, 2001; Herrera-Moreno & Betancourt, 2001). Other Caribbean coasts are rapidly eroding in Mexico, Panama and

Cuba at different rates due to a variety of reasons and this is also exacerbated by sea-level rise (Gable et al., 1990). Ecosystem-based climate resilience of MPAs is effective when coastal and marine areas are examined on a case by case basis (even though they are in close proximity) and steps are taken to establish a tailored MPA management plan.

As stated, properly designed and managed Caribbean MPAs and MPA networks have the capacity to become climate change resilient mechanisms and, as a result, render coastlines and their populations more secure and resilient (Chiappone, 2001 (part 3)). Large climate change resilient MPA networks are the key to regional coral reef recovery and normally cascading food- web effects will re-establish with enforced no-take regulations (Aranson et al. 2006). In the short term, MPAs that are not preserved and are already damaged due to stressors (contamination, sedimentation, turbidity, overfishing, massive die-outs, diseases and others mentioned) will provoke negative changes to the hydro dynamic balance of the coastlines which they protect (Herrera-Moreno & Betancourt, 2001). The narrow thermal tolerance of coral reefs (they thrive in temperatures between 23° and 25° C) could increase the extent of bleaching in the Caribbean by 41% with a temperature rise of only 0.1° C and sea surface temperatures are expected to average 30° C in 2100 around the coastal waters of the Dominican Republic (Selig et al., 2012; Herrera-Moreno & Betancourt, 2001). As already mentioned, MPAs and corals will also not recover fast with the slow growth of hard corals due to the acidification of the Caribbean Sea. In summary, MPAs and MPA networks are very efficient climate change resilience mechanisms and we can have faith in nature's ability to adapt in the long term. However, MPAs and MPA networks need to be paired with efforts and policies that aim at reducing anthropogenic activities that compromise climate change resilience globally, regionally and locally (Selig et al., 2012).

2.4 Socioeconomic Implications of MPAs and MPA Networks in the Caribbean

The livelihoods of millions of people in SIDS depend on coastal and oceanic resources. Hence, the effective management of MPAs and MPA Networks in the

Caribbean is of utmost importance to the long term economic and social well-being of the Caribbean SIDS. The coastal zone of the Wider Caribbean, including islands and coastal areas, has about 80 million residents and receives about 20 million visitors that depend on coastal resources (World Resources Institute, 2010). Traditionally, MPAs and their coral reefs were characterized by high species diversity and high rates of primary production (Carpenter, 1986; Gombos et al., 1994; UNEP, 2004). However, in recent decades primary production has been compromised in the WCR through anthropogenic activities. MPAs and MPA networks provide ecological services and economic benefits (attractive reefs and beaches for tourists, fish spawning grounds and fisheries) and are important foundations of subsistence economies, tourism, cultural and community heritage and coastal protection (Maragos et al., 1996). In the Caribbean, tourism is a leading source of income (Gable et al., 1990). Most of the tourism occurs in coastal areas where the main attraction are the beaches and tropical weather. International tourism contributed about 2.1 billion $US to the Caribbean economy in the year 2000 and it accounts for 30% of the GDP in at least 30 countries (Burke et al., 2004). Relatively few of the most intensely developed areas for tourism in the Caribbean (includes the Punta Cana/Bavaro areas in the Dominican Republic) have beaches that are broader than 30 m during high tide and a projected rise in sea level of as little as 30 cm could possibly eliminate many of these income generating tourism beaches within the next two decades (Gable et. al, 1990).

Close to half of all diving tourism in the Caribbean is estimated to occur in MPAs; about 1.2 million divers visited the Caribbean in the year 2000 accounting for about US $4.1 billion in gross expenditures. (Burke et al., 2004). Economic benefits derived from MPAs and MPA networks are often not equally distributed with the largest revenues often going to the tourism industry (educational, community and climate change efforts in MPA management programs are given little importance) (CANARI, 2009). The economic impacts of sea level rise have an effect on amenities, services and consumption of goods. (Gable et al., 1990). Lost benefits from the lack of reef shoreline protection could range from US $140 million to $240 million per year over the next 50 years and net benefits derived from tourism, shoreline protection and fisheries could be reduced as a result of coral degradation by an estimated US $350-870 million per year in the WCR (Burke et al., 2004).

Sustainable MPA and CZMT management practices are difficult to implement when impoverished local populations are too worried about what they are going to eat every day to pay attention to environmental sustainability and to the long-term economic viability of MPAs. They will just take from MPAs to survive and will not realize that they are simultaneously eroding their own long-term socioeconomic benefits and perpetuating their own cycle of poverty. An important step in management practices would be to conduct community outreach programs in the WCR so that underprivileged populations understand the economic viability and socioeconomic importance of MPAs and MPA networks locally whilst promoting alternate sources of income (Geraldes, 2001). The second step is trying to promote a sustainable Green Economy for SIDS in order to effectively curtail poverty issues and effectively manage regional MPAs and MPA networks (Geraldes, 2001).

2.4.1 Socioeconomic Implications of MPAs in the Dominican Republic

The biodiversity of coastal marine ecosystems in the Dominican Republic generates goods and services that help sustain the socioeconomic activities of numerous coastal communities (Reynoso, 2004). Increasingly dense coastal settlements, especially large cities like Santo Domingo with close to 5 million inhabitants, lack adequate infrastructure and environmental legislation (due to exploding and uncontrolled urbanization trends) leading to decentralized systems and threats to the economic viability of their coastal systems (including closeby MPAs) upon which they depend. The main marine ecosystems in the Dominican Republic and the percentage of marine and coastal areas utilized for human activities can be observed in Table 8.

Seventy five percent of industries in the Dominican Republic are located in urban coastal areas (Reynoso, 2004). The Dominican fishing industry produces about 11,000

Table 8: Percentage of marine and coastal ecosystems used for human activities in the Dominican Republic (Geraldes et al., 2001)

Ecosystems	Country Area km^2	Fisheries	Tourism	Urban/ Industries	Rural Agro Development
Mangroves	98.4	75	5	10	10
Sea Grass Bed	186.0	70	20	5	20
Coral Reefs	133.0	90	30	10	20
Beaches	244.2	70	35	10	30
Other Coastal Ecosystems	50,000.0	80	10	8	20

tons/year of fishing product and this corresponds to 0.5% of the gross domestic product with more than 3, 361 boats (98% of them artisanal), 8,399 fishermen and about 46,500 people indirectly employed in activities that have to do with fisheries exerting pressure on regional MPAs (USAid, 2013, Herrera-Moreno et al., 2011). Their gross income has fallen by about 60% in the last 10 years due to overfishing (Reynoso, 2004). Overfishing is a longstanding problem in the Dominican Republic and affects more than 300 species of fish, crustaceans and mollusks that are captured in specific ecosystems of the Dominican Republic; coastline and estuaries, mangroves, grassy beds and coral reefs and the open ocean (Herrera-Moreno et al., 2011). Some fishing resources are especially depleted like conch (*Strombus gigas*) and spiny lobster (*Panulirus argus*) (Herrera-Moreno et al., 2011). We can observe the fishing production, import and export of seafood products in the Dominican Republic (Figure 12).

Ironically, ineffectively managed MPAs and coastal zones are often close to or within tourism zones; one of the main building blocks of the economy of the Dominican Republic and the main reason tourism exists in the first place. I have written about the importance of tourism in previous sections of this paper. It generates about 37% of the total export earnings in the Dominican Republic and it is concentrated in two areas; the Southeast which includes the areas of Punta Cana, Bavaro, Bayahibe and La Romana and

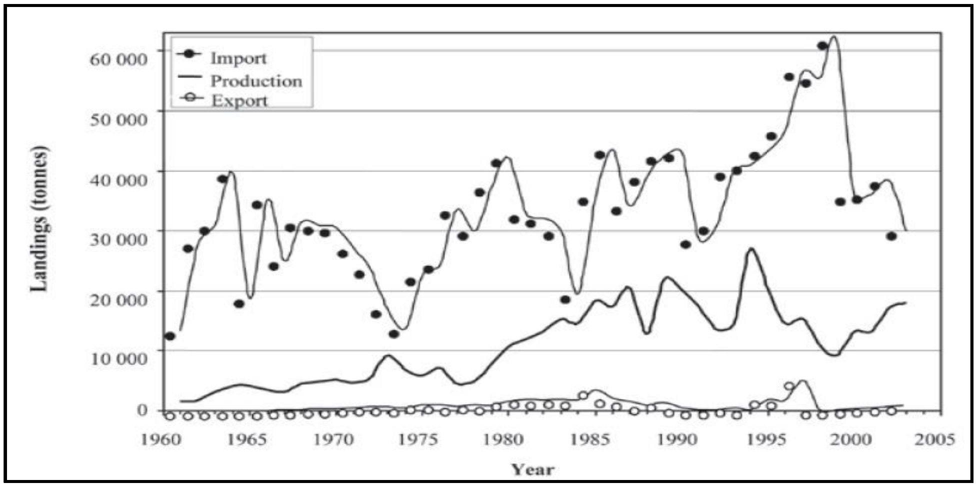

Figure 12: Fishing Production, Import and Export of Seafood Products from 1960 to 2005 (Herrera-Moreno et al., 2011)

in the North which includes the areas of Puerto Plata, Sosua and Cabarete (Reynoso, 2004). In 2005 alone, over 3.6 million people visited the Dominican Republic, and the tourist sector accounted for 7% of national GDP (Barrera et al., 2007). In the year 2000, the Secretary of Tourism of the Dominican Republic already became preoccupied with the degradation of sandy beaches and the practices of dredging sand banks and dumping sand on tourist beaches has accelerated erosion due to the lack of knowledge of the complex interaction of coastal and marine habitats (Herrera-Moreno & Betancourt, 2001). Without MPAs to protect coastlines and serve as climate change resilience mechanisms there will be a loss of environmental quality, infrastructure services and a drastic reduction in the tourism which will result in a severe blow to the Dominican economy. The multiple effects of climate change on tourism can be observed in Table 9.

Sustainable long-term financing for Dominican MPAs should be developed if they are to fulfill their socioeconomic role. It is of critical importance that mechanisms be in place for MPAs to generate income in a sustainable manner and this could be done through tourism. The best socioeconomic MPA models in the Caribbean are self-sustaining MPAs like the Bonaire National Park and the Soufrière Marine Management Area (SMMA) in St. Lucia. They have adequate long term planning, zoning, monitoring and evaluation processes. As previously mentioned, the Bonaire National Marine Park

Table 9: Synopsis of the effects of climate change on the tourism sector (Geraldes et al., 2001)

Impacts of Climate Change	**Consequences**
Changes in Precipitation Patterns	Irrigation and its costs for golf courses increases because of drought and the rate of evapotranspiration
	Free time is reduced for open air activities
	Drinking water volumes are reduced due to drought creating supply issues
	Saline Intrusion can affect drinking water quality. River erosion can cause an increase in turbidity and sedimentation.
	An increase river flow can disrupt the sedimentation balance decreasing sand quality of beaches.
	Tourist infrastructures can be affected by flooding and wave action.
Increase in Temperature	Sun stroke possibilities increase, burns or skin problems with exposure to the sun.
	Diving can lose its quality because of coral bleaching and sedimentation.
	The loss of reefs makes the coast vulnerable and increases coastal erosion.
	The risk of disease caused by ciguatoxins increases in the tourist population
	The changes in climate patterns changes the flux of tourism
	The changes in supply of carbonate materials as a result of damage to reefs can cause a reduction or loss in beaches.
	The increase in frequency and magnitude of meteorological events can cause important losses of infrastructure.
Sea-level rise	Infrastructure in coastal zones will be submerged
	Coastal scenery is changed by erosion, protruding rocks and loss of natural vegetation
	Beaches area reduced and lose their value
	The carrying capacity of beaches (m^2 available/ per tourist) is reduced with a reduction in width because of sea-level rise and erosion
	Beaches change their location and characteristics because of hydrodynamic changes in the spatial and temporal patterns of sediment accumulation

(BNMP) charges a fee of 10 US$ as a diver fee and the SMMA raises 70% of its income through 10 US$ diving fees (SMMA, 2005). These would be good socioeconomic models for MPAs to follow in the Dominican Republic. In fact, in the Parque Nacional del Este (PNE) tourism activities generate $31.79 million US of which about 2.03 million $US are directly invested into adjacent communities (USAid, 2013). Tourism in this area has become a source of stable income (even though the tourist carrying capacity of the MPA is not respected) and has also allowed fishermen and community groups to access funds through organizations and international initiatives in order to improve their quality of life. In the Dominican Republic, fishermen have a particularly low educational level and a high illiteracy rate (24.4%), and no fishermen have university level of education (50% have an elementary educational level) (Herrera-Moreno et al., 2011). This presents a challenge, yet fishermen in the PNE area have been able to regroup into associations for tourism services like ASPLABA and have been able to weather the socioeconomic transition from fishing to tourism in the last 20 years (USAid, 2013). Additionally, a Center for Technical Courses has also been created in order to orient community efforts towards sustainable tourism (with an emphasis on its daily allowed maximum carrying capacity) within the MPA (USAid, 2012).

A socioeconomic challenge in the Dominican Republic is that corruption is a big hurdle in the development of sustainable environmental policies and those in power will not apply sustainable environmental practices (especially not MPAs) and solutions nor inform the public (an ignorant public is more malleable) unless it directly benefits them. The management ineffectiveness of MPAs in the Dominican Republic has often arisen because of the lack of support from the local community due to their lack of awareness and knowledge of the socioeconomic possibilities of MPAs combined with their lack of trust in authorities. Effective MPA management that brings socioeconomic benefits requires transparent multilevel collaborations with governments, institutions, organizations, stakeholders and communities. The Dominican Republic ranked 115 out of

175 countries on the Corruptions Perception Index with national budget openness being ranked as "scant or none" (Transparency International, 2014).

Section 3: Case Studies

3.1 Dominican Republic Case Studies

The Parque Nacional del Este (PNE) and Montecristi MPAs were chosen as Dominican Republic Case Studies because of their contrasting characteristics (Table 10).

Table 10: Contrasting Characteristics of PNE and Montecristi MPAs

PNE MPA	Montecristi MPA
Southeastern portion of the Dominican Republic not bordering Haiti	Northwestern portion of the Dominican Republic bordering Haiti
500,000 + visitors yearly	1, 000 + visitors yearly
Declared a park in 1974	Declared a park in 1986
Patch reefs and deep water fringing reefs	Largest barrier reef system in the DR with a large shelf lagoon
Most developed areas of the DR	Least developed areas of the DR
11% coral cover	40-50% coral cover
Octoral-dominated bottom coral is common	37 species of hard coral
Sedimentation, wave action and infectious diseases (50% or more) affecting coral growth	Sedimentation, wave action and infectious diseases (only 4%) not affecting coral growth
Westward flowing currents that bring contamination from runoff, precipitation, sedimentation and trash from nearby rivers and anthropogenic activities	Westward flowing currents that take away contamination from runoff. precipitation, sedimentation and trash from nearby rivers and anthropogenic activities
Artisanal fishing allowed, no take zones absent, key regional carrying capacity study carried out- model for other MPAs	Artisanal Fishing and commercial fishing allowed, key MPA zoning plan carried out: no take zones present (although they are not enforced)-model for other MPAs
Tourism-dominated economy	Fishing-dominated economy
A few key ecosystems and limited biodiversity	Large variety of ecosystems and biodiversity
Invasive species: over 100 including lionfish	Invasive species: a few including lionfish, sponges and predatory gastropods
Large towns in close vicinity	Mostly adjacent to rural areas
Not part of a larger MPA network	Part of the Caribbean Large Marine Ecosystems Network

PNE is the MPA with the most tourism (over 500,000 visitors yearly) and the most anthropogenic impacts. Data from PNE at 10 m depth at El Peñon CARIMCOMP site showed a decrease in coral cover from 20% in 1996 to only 11% in 2001-the lowest percentage in the Dominican Republic (ICRI, 2002). Montecristi MPA is the most expansive area dedicated to conservation (both coastal and marine) having the largest variety of ecosystems with the least anthropogenic influences while being the most impacted by its closeness to Haiti. The highest coral cover is found in this area of the Dominican Republic (and the Silver and Navidad Banks) at 40-50% coverage (ICRI, 2002).

3.1.1 Parque Nacional del Este Background and Evaluation of MPA Management

This park is located in the southeastern portion of the Dominican Republic and it is the second largest coastal national park (434 km^2 of terrestrial area with an absence of freshwater sources and 120 km^2 of shallow waters generally under 30 meters in depth) that was designated a park by the Dominican government in 1974 (Torres et al. 2001). Below is a map showing the location of PNE in the Dominican Republic (Figure 13).

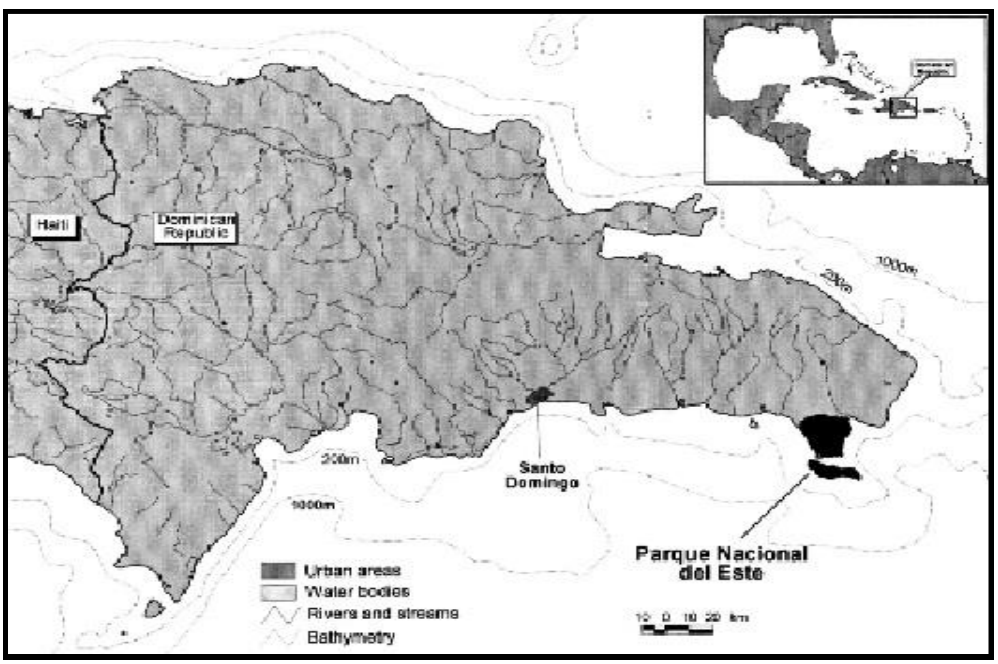

Figure 13: Map of PNE in the southeastern Dominican Republic (Chiappone, 2001 (part1))

Despite the PNE being a national park the Dominican government allows artisanal fishing within its boundaries. It starts at Boca de Yuma and stretches down to Saona Island and the Catuan Passage between the latter and the mainland totaling 32 km and includes Catalina, Catalinita Island and Raton Cay (USAid, 2013). Its characteristics are patch and fringing reefs with large areas of mangrove forests (particularly in the Catuan Passage and eastern parts of Saona Island) and sea grasses (Geraldes et al., 2003). PNE is an important biodiversity refuge and an ideal breeding ground for; lobsters, grunts, snappers, marlin, swordfish, pelagic fishes and conch (Geraldes et al., 2003). Bottlenose dolphins and humpback whales have been observed in the area starting in 2005 (although this has become less frequent now) indicating that they do not exclusively use the waters to the north of the Dominican Republic including the Silver Banks as previously thought (Whaley et al., 2008). PNE has been part of the successful Parks in Peril Program (PIP) funded by the Nature Conservancy and USAID since 1993, which includes 61 sites in 18 countries in Latin America and the Caribbean (Chiappone, 2001(part 1)). Physical transport mechanisms in PNE are mostly influenced by the North Equatorial Current. PNE is very susceptible to hurricanes and tropical storms and between 1945 and 1996 16 passed over PNE causing substantial damage (Torres et al. 2001) (Figure 14).

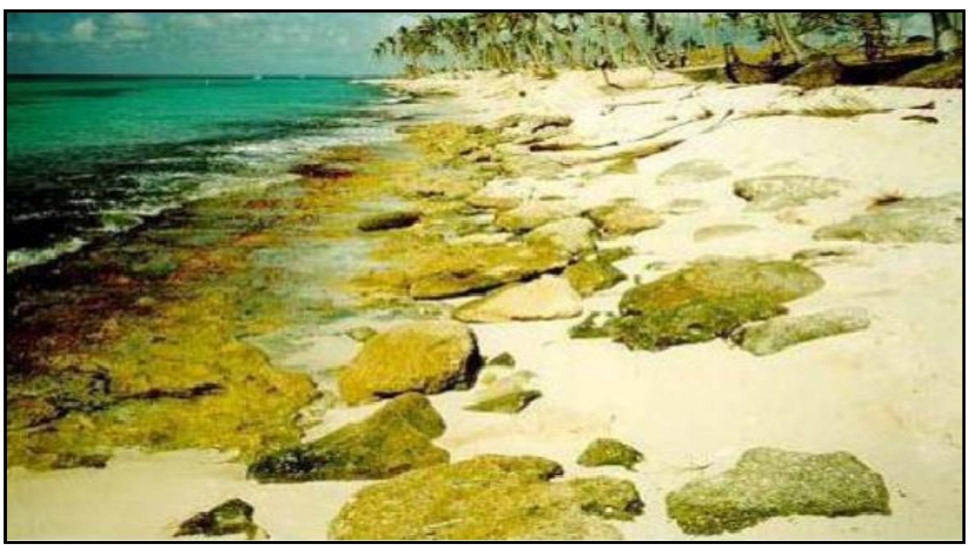

Figure 14: Eroded beach at Dominicus in PNE after the Passage of Hurricane Georges and Mitch in 1998 (USAid, 2013)

Numerous fault lines are present in the park and it is seismically active. The Bayahibe-Valle de la Sabila fault and the Higuey-Chavon, Neiba and Trinchera de los Muertos fault lines influence the terrace-like uplifted reef topography which is riddled with caves and makes PNE susceptible to earthquakes and tsunamis (USAid, 2013). Reef growth is affected by seismic activity and its growth has been shown to be disrupted by uplifting at the offshore reef named Caballo Blanco and along some discontinuous reef crests along the southern shore of Saona Island (Torres et al., 2001). There have been 83 seismic events registered in the area by USGS in Puerto Rico between 2004 and 2010 alone measuring from 2.5 to 5 on the Richter Scale and there have been small tsunamis in the area (USAid, 2012).

There is a prevalence of octocoral-dominated hard-bottom communities in PNE suggesting that sedimentation and wave energy present most likely impede the development of other types of coral to some extent. Corals that are protected by the mainland and the Catuan Channel present more complexity and coral coverage than those in the southern part of Saona Island or the Mona Passage due to wave energy. The reefs in PNE have played a fundamental role; as sand generators contributing sand to beaches, protecting the coast from wave action and erosion as well as providing an important tourist attraction for recreational diving (USAid, 2013). The largest quantity of mangroves can be found in Catuan Channel, Calderon Bay and El Penon. These mangrove areas are a tourist attraction as well as a possible carbon sink of 1,948 tons of carbon per year (assuming a carbon sequestration rate of 1.5 tC/ha/year) and play a pivotal role in the regional climate change adaptation plan (USAid, 2013). Figures 15 and 16 show the approximate location of mangroves and reefs within PNE.

Coral patches and natural sedimentation increase along the western part of Catuan. The coral patches increase in frequency to form deep-water fringing reefs, which are the most common coral structures along the southern coast of the Dominican Republic (Geraldes et al., 2003). PNE reef cover is affected by periodic sedimentation events that are not anthropogenic (Torres et al., 2001). Other sedimentation in the park is determined

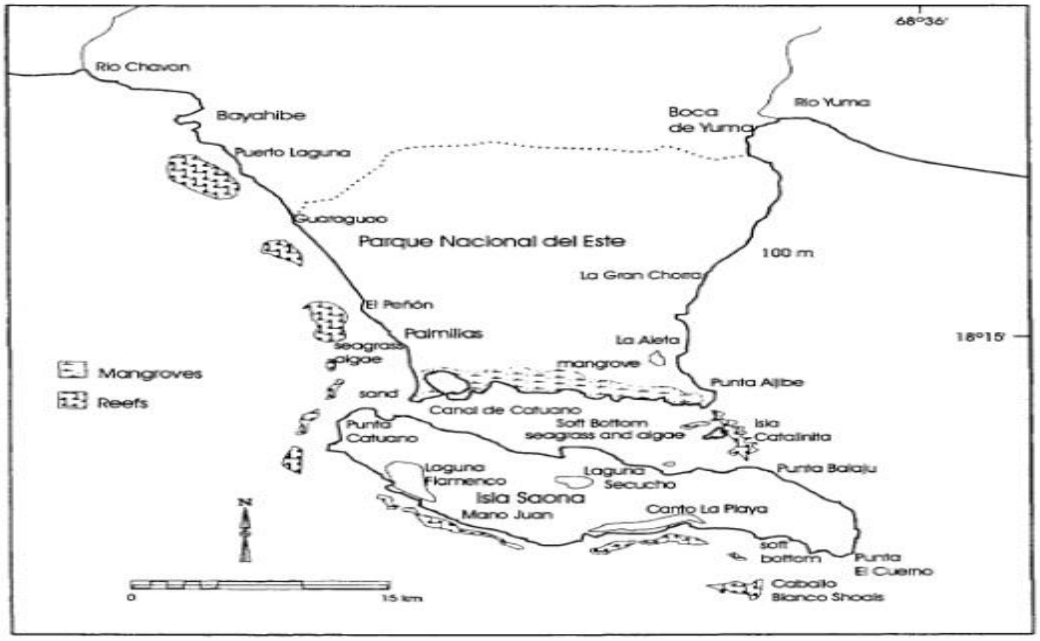

Figure 15: Location of Reefs and Mangroves in PNE (USAid, 2013)

Figure 16: Mangrove habitat, Calderon Bay (USAid, 2013)

by biogenic local production, contribution from beaches towards the eastern end of the park and contributions from the Chavon River at the extreme northwestern end (USAid, 2013). There are three small towns within the park limits (including Mano Juan on the island of Saona) with a total population of just over 2,000 people. Tourism infrastructure is encroaching on the park in the northwestern section and it is estimated that about 85,000 tourists already visited the park in 1993 (Vega et al., 1996). Currently the numbers are well over 500,000 annually (USAid, 2013) (Table 11).

Table 11: Visitors to the PNE between 2004-2012 according to the Eco-tourism Department of SEMARENA (USAid, 2013)

Year	Nationals	Foreigners	Total
2004	179	275, 238	275,987
2005	1,405	324,748	326,153
2006	1,877	356,168	358,045
2007	1,344	365,294	366, 638
2008	85	293,509	293,594
2009	5, 369	308, 861	314,230
2010	15,058	385, 160	400, 218
2011	8, 856	576,647	585, 503
2012	27, 513	557, 256	584,769

Bayahibe was originally a traditional fishing village with small amounts of agriculture, but in a period of 20 years the number of fishermen has been reduced from hundreds to a dozen while hotel rooms went from 0 to about 3,327 making tourism the main economic staple (USAid, 2013). Excursion offers include 10 areas in the MPA and the most popular is the Las Palmillas "Natural Swimming Pool" towards the western end of the MPA (Chiappone, 2001, part 1). PNE has a serious problem with an excessive amount of tourist boats visiting the park (it is not known how far this exceeds daily carrying capacity) and there is considerable harassment of marine life by tourists; picking up of sea urchins, sea stars and conch (USAid, 2012).

PNE has suffered from mismanagement since its designation as an MPA from; organic contamination, increasing trash, the presence of more than 100 invasive species, destruction of sandy beaches in Bayahibe, canalization of run-off to beaches, overfishing and poor boating practices (destruction of reefs and sea grass communities through anchors and tampering with marine life as mentioned) (USAid, 2013). The illegal fishing of lobsters (during the closed season from March to June) in order to offer tourists lobster all year round on excursions is also an issue as it causes the Dominican Republic to not comply with CODEPESCA (regional fishing laws) for the closed season that protect lobster to allow their reproduction in the WCR (USAid, 2013).

Climate change effects will continue to cause a loss of sand from beaches and an increase in storm activity within the park. To predict the exact amount of sand lost from beaches in PNE due to climate change is difficult because there is no exact topographic map of these coastal areas (USAid, 2013). PNE is very vulnerable to climate change and it is projected that sea level rises will be more pronounced in the southern Dominican Republic around the PNE MPA. In Figure 17 illustrates the effect of sea-level rise on the PNE coastline by the year 2100 (USAid, 2013).

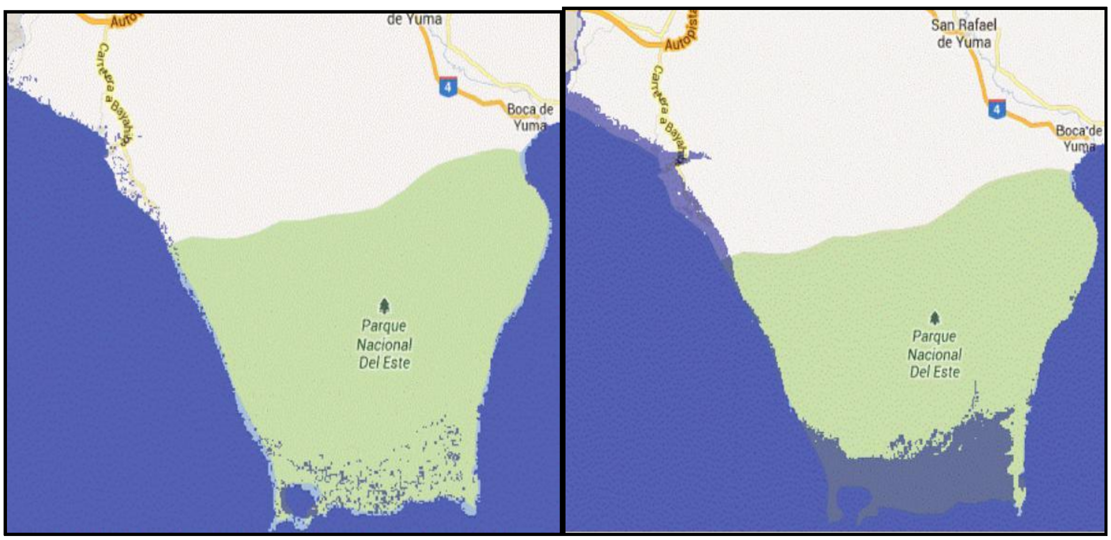

Figure 17: PNE coastline now (left) and with a possible projected 5 meter rise in sea-level (right) under the pessimistic IPCC scenario for 2100 (USAid, 2013)

Reduction of coral cover may be related to the increase in sea level because the vertical growth of the corals may not be able to keep up with the increase in sea level (average growth rate of 0.53 cm/yr), and the suspension of sediments from flooded near shore habitats and lagoons may cause stress (Chiappone, 2001 (part 2)). An additional stressor from climate change is the acidification of the ocean. Oceanic uptake of anthropogenic carbon dioxide results in a decrease in the concentration of the carbonate ion in seawater which leads to a decrease in the saturation state of carbonate minerals which threatens the foundations that corals use for reef building (Manzello, 2010). Warmer sea surface temperatures have caused coral bleaching in the area resulting in the loss of vast areas of coral and caused significant socioeconomic loss (fisheries and tourism). Saltwater intrusion due to sea level rise will cause significant damage to subterranean waters and the hydrological balance in PNE. This would exert water stress on Bayahibe as present and future development is demanding of fresh water (USAid, 2013). Climate change could affect the number of visitors to the MPA as natural resources become damaged and adverse weather conditions could affect nautical excursions.

One of the most anthropogenically impacted areas in the MPA is Bayahibe Beach (sedimentation, turbidity, erosion and organic and inorganic pollution) because of hundreds of boats that embark and disembark tourists on daily nautical excursions and contaminate the adjacent waters with gasoline and trash. The study of the carrying capacites of Bayahibe and the PNE MPA are based on a) infrastructure (there are 3,327 hotel rooms), b) ecological factors (beach quality, reefs, invasive species and quality of trails), c) hydrological resources (availability of groundwater and the risk of salinization, d) management of waste water and e) social and cultural factors (perception of residents, visitors and jobs linked to tourism) (USAid, 2013). It is important to take into account the carrying capacity (land use, ecological, hydrological resources, waste and social) of PNE as not doing this would lead to unsustainable tourism and irreversible damage within the MPA.

In 2005, a workshop was held for fishermen, boat owners, members of the tourism sector and members of the government sector to establish best practices for excursions, including whale watching, in the area (Whaley et al., 2008). A result of this was coming up with trademark ecological excursions under the ECOBAYAHIBE tourism cluster (Figure 18) in conjunction with FUNDEMAR which are still functioning sustainably.

Figure 18. Ecobayahibe Tourism Cluster Logo (USAid, 2013)

PNE is far from exploiting its maximum tourism potential, but it cannot do so sustainably without a proper territorial management plan and CZMT Plan in conjunction with SEMARENA that integrates best management practices. PNE has served as a sort of training ground for other conservation initiatives and non-governmental organizations in the Dominican Republic through its methods for calculating carrying capacities that are being replicated for other MPAs in the Dominican Republic. The PNE carrying capacities are also being used as a baseline for other MPAs (Chiappone, 2001 (part 1); USAid, 2013).

3.1.2 Parque Nacional Montecristi Background and Evaluation of MPA Management

Of the 16 coastal provinces in the Dominican Republic, Montecristi has the largest proportional area dedicated to coastal and marine biodiversity conservation under a formal conservation plan (López & Silva, 2012). The Montecristi Province is adjacent to Haiti and has a variety of protected areas in coastal and marine zones: El Morro National Park, Estero Balsa Mangroves National Park, Siete Hermanos Wildlife Cays, Saladilla Lagoon Wildlife Refuge and Montecristi National Marine Park (López & Silva, 2012). The Montecristi MPA includes the Montecristi National Marine Park with parts of the other protected areas mentioned. The Montecristi MPA enjoys an ideal remote geographic location (lack of urban/coastal development), but the lack of enforced proposed zoning coupled with overfishing have caused the near depletion of reef fish communities and a near collapse of trophic networks (Garza-Perez & Ginsburg, 2007). The total area of the Monticristi MPA is 174 km^2 and coral reefs account for around ~13 km^2 and an additional

~16 km² account for hard bottom communities while the remaining 145 km² is rubble, sandy bottoms and sea grass communities (Geraldes et al., 1997). Figure 19 shows the location of the Montecristi MPA in the northwestern part of the Dominican Republic.

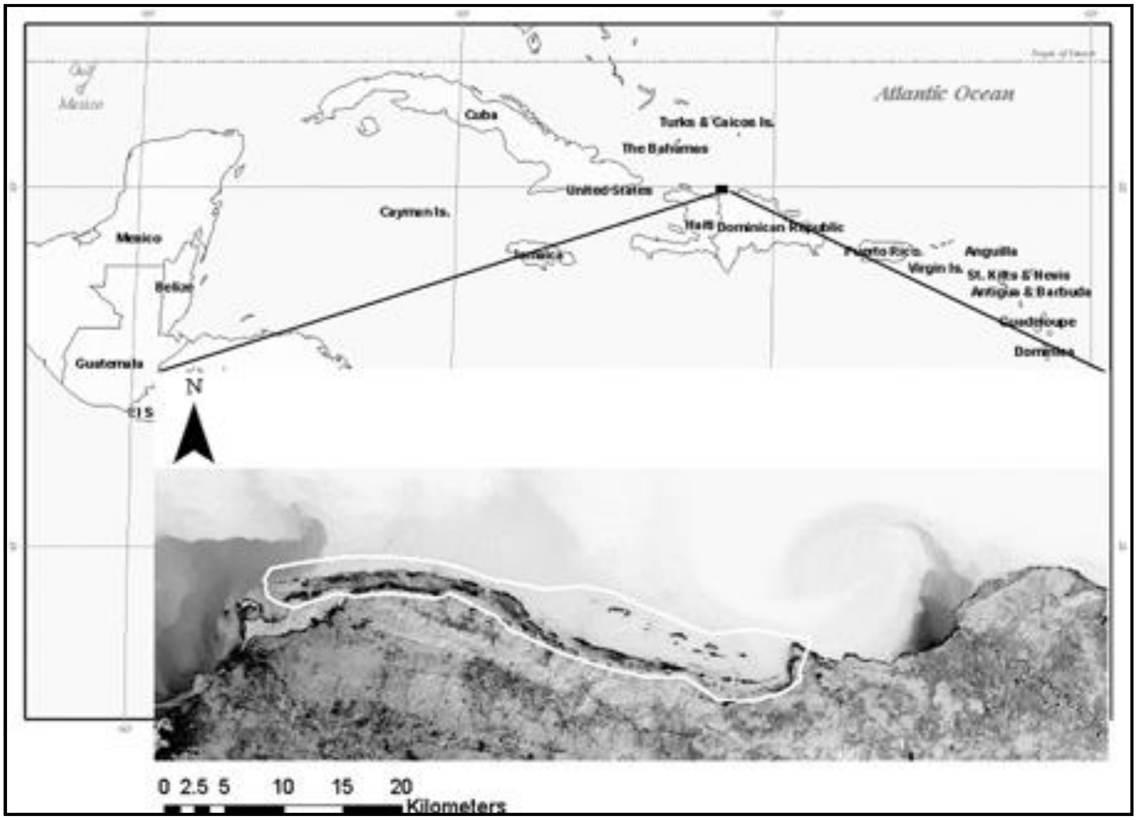

Figure 19: Location of the MonteCristi MPA in the Dominican Republic with the highlighted area representing satellite imagery of the MPA (Garza-Perez & Ginsburg, 2007).

The Montecristi MPA borders with Haiti and its resources of coral reefs and ecosystems are shared by both countries. The pilot project for the management and conservation of fisheries and reef biodiversity in the Montecristi MPA is part of the Caribbean Large Marine Ecosystem Initiative which includes 23 countries and 3 territories in the WCR with the goal of managing joint marine resources in the region. In this sense, the pilot project is developing knowledge on the co-management of resources between nations (López & Silva, 2012). The Montecristi MPA has the largest reef formation (a barrier reef system separated from the mainland by a shelf lagoon up to 2 km wide and 20 m deep) in the Dominican Republic spanning a length of 64.2 km along the

Montecristi Shoals (1,181 km^2) (Geraldes et al., 2003). The western part of the MPA is a shallow platform (less than 150 m deep) which connects the reef system with Siete Hermanos Offshore Cays and Presidente Point (Garza-Perez & Ginsburg, 2007). The Montecristi MPA has an extensive mangrove forest 25.17 km^2 (2,517.37 ha) along with large sea grass beds 12.47 km^2 (1,247.68 ha) along approximately 35 km of coastline (especially around the Gran Mangle Point) within the lagoon (Mumby et al., 2004). There are submerged and exposed cays in the MPA (López & Silva, 2012). The sea grass beds are typical of the Manzanillo, Montecristi and Icaquitos Bays within the MPA and its reef lagoon extends from the latter until Buen Hombre and from the mangroves at Coco Beach to Punta Rusia (Mumby et al., 2004). These coastal environments together with their adjacent coral reefs benefit reef fish communities by acting as habitats for juvenile fish (nurseries), refuges and feeding grounds thereby enhancing biomass (Nagelkerken et al., 2000; Nagelkerken & Van der Velde, 2004). The rocky coasts of the Montecristi MPA are defined as vertical homogenous destructive coast types with active tectonic activity due to the tectonic processes between the North American and Caribbean Plates (López & Silva, 2012). This MPA is in one of the least developed areas in the Dominican Republic. In 1997 about 1,750 people (16.2% of all Dominican fishermen at the time) depended on artisanal fishing (going up to 15 km offshore using long-lines, gill nets, traps and spears) with wooden boats and outboard engines to exploit groupers, snappers, lobster, conch, octopus, grunts, hogfish, jacks and parrotfish (Geraldes et al., 2003). There are 214 active vessels in the area as of 2012 although some of the fishermen also fish the Turks and Caicos (López & Silva, 2012). Another fishing activity in this MPA is the capture of approximately 100 species of invertebrates and fish for the aquarium trade annually (Garza-Perez & Ginsburg, 2007). The overfishing in the area is apparent as the biomass of reef fish indicator species is only 0.49 kg/100 m^2 as opposed to the average of 4.5 kg/100 m^2 from the AGRRA list (Garza-Perez et al., 2007). The different habitats in the MPA are illustrated in Figure 20.

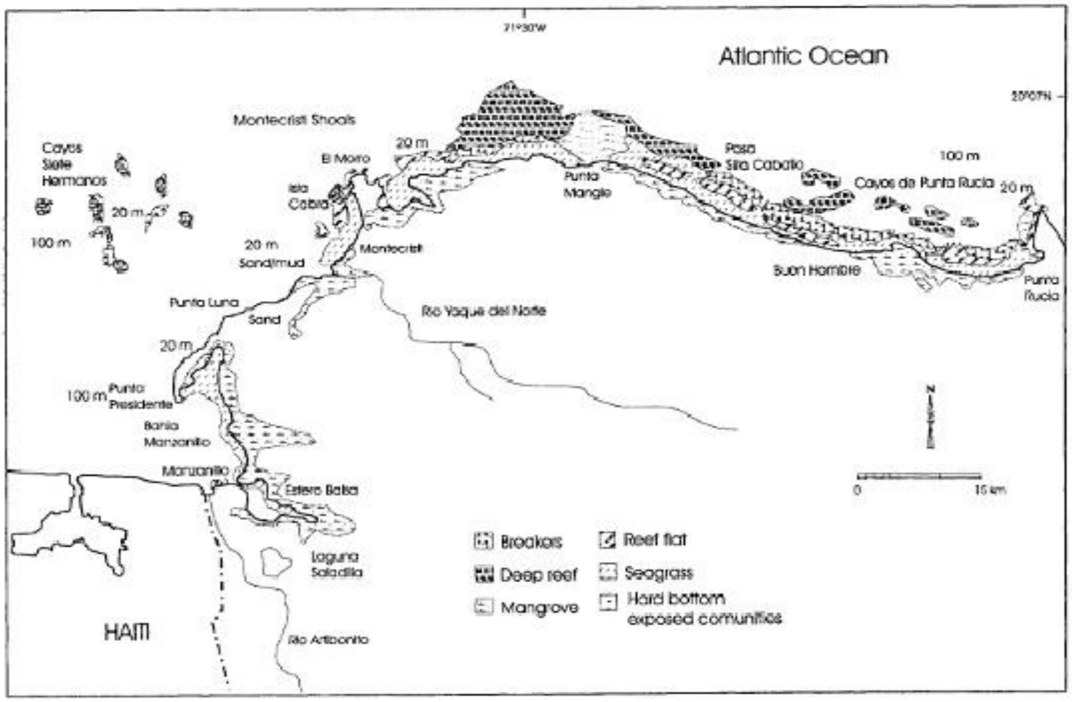

Figure 20: Habitats within the Montecristi MPA (Geraldes et al., 2003).

The overall condition of the Montecristi MPA is defined as susceptible to degradation and at risk as the condition of the coral communities and the complexity of reef assemblages has declined in the same way as most of the MPAs, and their reefs, in the WCR (Lang, 2003; Wilkinson, 2004). The abundance of large predators is often the main indicator of health in these communities and the Montecristi reef fish communities are significantly devoid of high trophic level predators. (Garza-Perez & Ginsburg, 2007). Oceanic waves do not typically get past the Montecristi barrier reef (it has a narrow crest and is traversed by several tidal channels that reduces their force). On the oceanic side of the barrier reef the crest drops abruptly to up to 30 m and coral patches between 10 and 5,000 m^2 in size can be observed (Geraldes et al., 2003). As a result of reduced wave action, the corals are mostly protected and 37 species of hard corals have been inventoried in the MPA and, in general, there was a low occurrence of coral diseases (coral mortality is about 4% of total cover) like white band, black band and yellow blotch (Garza-Perez & Ginsburg, 2007). Brown algae is dominant in most of the reefs with a coral-brown algae ratio of 1:2 even though there is still an extraordinarily high percentage of live coral cover of 40 to 50% (Garza-Perez & Ginsburg, 2007).

The climate around the Montecristi MPA is semi-arid with an average temperature of 26.5° C and an average precipitation of 180 cm.Thus there is a large hydrological deficit in the zone which explains why there are many dry lagoons in the area (López & Silva, 2012) and there is not much contamination in the MPA due to runoff from precipitation or sedimentation. The Yaque del Norte and Masacre Rivers flow into the ocean west ward of the "el Morro" Landmark (Figure 21) bringing pollutants to the Siete Hermanos Cays Region of the MPA with the help of the westward currents (López & Silva, 2012).

Figure 21. El Morro Landmark of Montecristi within the MPA (Yaque del Norte Rivermouth in the background to the west) Courtesy of : http://www.elmorro.com.do

More than 90% of the coastal zone of the Montecristi MPA is preserved with its original flora and fauna (the vegetation is mainly dry tropical forest) due to strong winds and tides and the inaccessibility of some areas (Zapata et al., 2012). Buen Hombre is the most preserved area of the MPA with the most elevated indices in biodiversity and has considerable tourism attraction which is why there is concern that unplanned and uncontrolled tourism development in the region could be a real threat to the stability and conservation of the ecosystem (Zapata et al., 2012). The reefs and large sections of the MPA are already in an ecological imbalance, clearly evidenced by a lack of predatory species (sharks and larger fish) and species that indicate health (Reef Check Manta

Method) due to overfishing in the area. Environmental factors and their causes affecting the Montecristi MPA are listed in Table 12.

Table 12: Overview of Environmental Problems and their Causes in the Montecristi MPA (Zapata et al., 2012)

Overfishing	From the use of artisanal fishing methods with drag nets, gill nets, trawlers and sports diving with tanks which degrade the sea bottom Human consumption of herbivores that upsets the natural balance of the ecosystem (fish, mollusks, conch)
Contamination	Organics from the Yaque del Norte and Masacre Rivers transported by marine currents (even though El Morro blocks most)
Sedimentation	Brought from the Yaque del Norte and Masacre Rivers transported by marine currents (even though El Morro blocks most)
Diseases	Coral diseases caused by bacteria and cyanobacteria (white band, black band and yellow band) and predatory mollusks (*Coralliophilia sp*.)
Invasive Species	From other Caribbean areas; Lionfish

The combination of the above leads to algae dominant reefs where algae compete for space with corals and thereby causes an increase in the population of black sea urchins (*Diadema antillarum)* (Figure 22). Large tracts of coral in certain areas exhibit diseases (Figure 23) and there are invasive species such as lionfish, sponges and predatory gastropods (*Coralliophila sp.*) that feed on the live tissue of coral (López & Silva, 2012).

Areas that need further research within the Montecristi MPA in order to complete the assessment of the MPA are; a reef located between Buren Point and the El Morro Landmark, a sedimentary area between El Morro Landmark and the Yaque del Norte Rivermouth, the Yaque del Norte Rivermouth itself, the section from the Yaque del Norte Rivermouth to Presidente Point and Toruru Cay, the Bay of Manzanillo (with its submarine canyons and sea grass beds) and the Siete Hermanos Cays at the point where the sedimentation plume from the Yaque del Norte Rivermouth stops (López & Silva, 2012). The existing MPA zoning in the area is an older concept and was originally put forth in 1999 by SEMARENA and focused on the fringing coral reef system (a particular

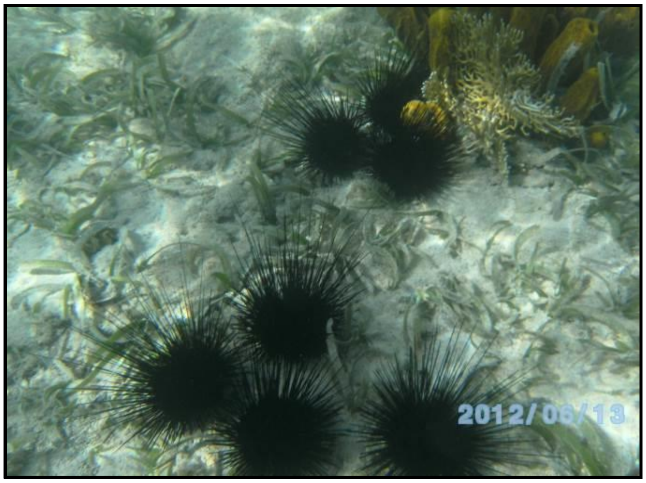

Figure 22. ***Diadema antillarum*** **found in 60% of the MPA (Zapata et al., 2012)**

Figure 23. Black Band Coral Disease on Diploria strigosa found in some areas of the MonteCristi MPA (Zapata et al., 2012)

common reef structure in the Caribbean) and sites in better condition were proposed as no-take zones (Garza-Perez & Ginsburg, 2007). The information gathering for zoning was not complete enough for fisheries planning within the Montecristi MPA but was based on ; the health of the ecosystem., the conservation of species habitats, ecosystems and processes and maritime transport (López & Silva, 2012). The preliminary zoning plan from Punta Rusia to el Morro Landmark was developed through the revision of available literature (most of it from CIBIMA 1998), field trips for verification (although as stated more data is needed in different areas) and the processing and analysis of results (Figure 24) (López & Silva, 2012).

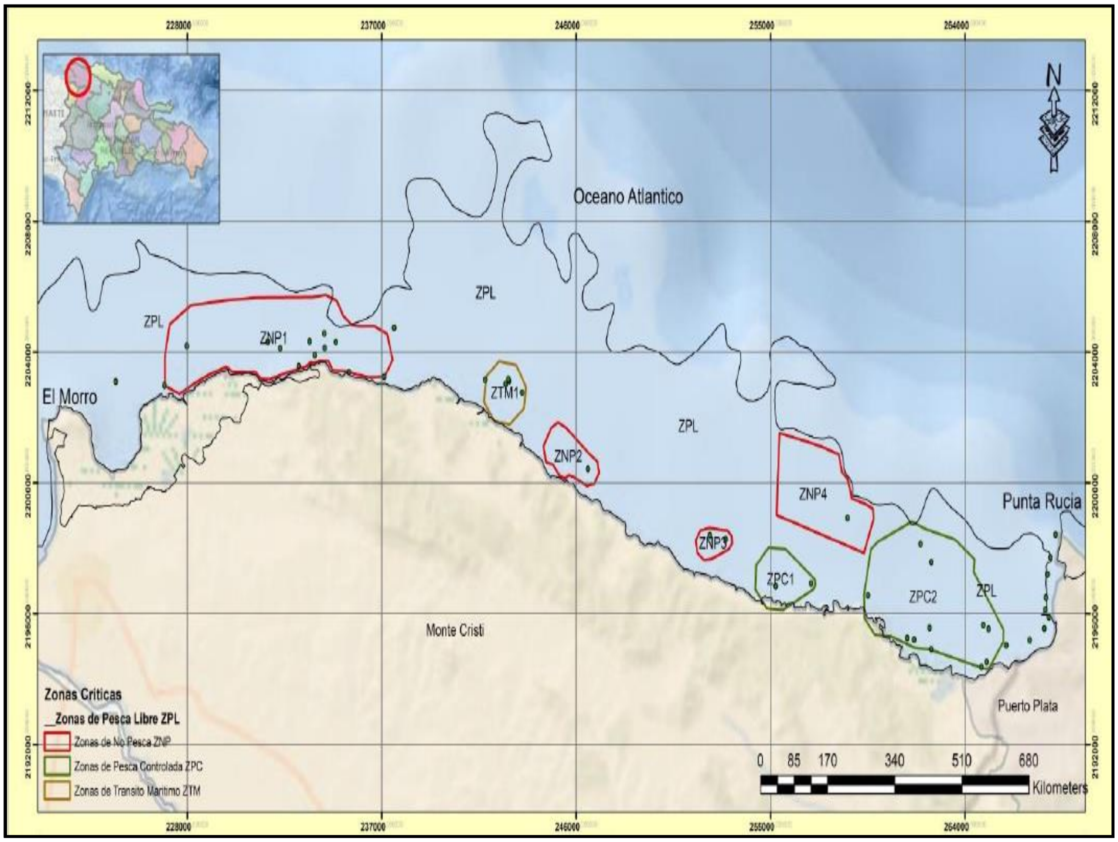

Figure 24: Proposed Fishing Zoning for the Montecristi MPA (red zones or ZNP are no-take areas) (López & Silva, 2012)

The proposed zoning in Figure 16 is divided into Zona de no Pesca (ZNP or No-Take Zone in red), Zona de Transito Maritimo (ZTM or Maritime Transit Zone in orange), Zona de Pesca Controlada (ZPC or Controlled Fishing Zone in green) and Zona de Pesca Libre (ZPL or Open Fishing Zone) and their sub-categories. The no- take zones are proposed to constitute about 10% of the MPA and these are delimited fishing exclusion areas (Garza-Perez & Ginsburg, 2007). No-Take zones work well and it has been proven that the number of individuals, biomass, size ranges and richness in species increase significantly in as little as 2 to 10 years (Burke et al., 2004; Schmidt et al., 2004). The zoning areas have different rules as can be seen in Table 13.

Table 13: Outline of Zoning Regulations in the Montecristi MPA (López & Silva, 2012)

ZNP or No-Take Zone	Fishing activities are prohibited all year Recreational Diving is permitted Anchoring is only permitted in zones with buoys Boat traffic is allowed Scientific activities need SEMARENA approval and are carried out according to regulations
ZTM of Marine Transport Zone	Fishing activities are prohibited all year Selected diving is permitted Anchoring is only permitted in zones with buoys Boat traffic is allowed Scientific activities need SEMARENA approval and are carried out according to regulations
ZPC or Controlled Fishing Zone	Fishing is permitted except during closed season Commercial fishing is allowed except for prohibited species and closed season Boat traffic is allowed Recreational diving is allowed with precautions Anchoring is only permitted in zones with buoys
ZPL or Open Fishing Zone	Commercial fishing is permitted all year Commercial diving is allowed all year using regulated artisanal methods Recreational Diving is permitted all year with precautions Scientific activities are carried out according to regulations

The Montecristi MPA is vulnerable to many natural and climate change related disturbances like PNE; increases in intensity of hurricanes and storms, ocean acidification, mass bleaching events due to sea surface temperature rise, sea level rise and flash flooding or prolonged droughts due to shifting precipitation patterns (Garza-Perez & Ginsburg, 2007). We do not have a way to prevent these natural impacts except to try and promote a climate change resilient MPA through a sustainable MPA management plan. However, the Montecristi MPA has an advantage in that it is in an area with a low population and is not exposed to as many anthropogenic stressors from the adjacent coastline compared to PNE. As a result, changes brought about by coastal development can be easily observed in a short period of time in the Montecristi MPA (it can be used as the control group) and can be rapidly applied to other MPA management practices in other areas of the country (Zapata et al., 2012).

3.1.3 Proposed Good Management Practices in the Dominican Republic Case Studies

MPAs in the Dominican Republic are different in many ways and each present a unique set of challenges for good management practices that have been partially met with two sustainable pilot research activities; a carrying capacity study in PNE and a zoning plan in the Montecristi MPA. The main problems facing Dominican MPAs (as with PNE and Montecristi) are overfishing, inefficient garbage control, water pollution by point sources, non-point sources and boats, damaging of species caused by visitor impact or take, few park infrastructures, no control of carrying capacity, lack of training and pay for environmental or park personnel and very little enforcement of MPA legislation (Brioso, 2008). For the Montecristi MPA, some steps that can be taken to increase good management practices are listed in Table 14.

It is important to preserve the fringing mangrove forests and sea grass communities within both MPAs as much as possible as they have key functions in the juvenile fish communities and an abundance of mangroves translates into an abundance of fish (López & Silva, 2012). Any anthropological impact (through dredging or filling in) of mangroves will automatically negatively impact the reefs and their fish communities. Mangroves and sea grass beds are also resilient to climate change and, as a result, make the MPA more resilient to climate change effects. In order to carry out the zoning plan in the Montecristi MPA control and training activities are needed (Table 15).

In particular, it is important to create ownership amongst park rangers, park officials and local communities by equipping them with the right tools and corresponding salaries to carry out MPA management jobs as this will build a stronger bond, promote better performance and ultimately lead to a better preservation of natural resources

Table 14: Steps to increase good management practices in the Montecristi MPA (Zapata et al., 2012)

1.	Evaluate remaining areas of the MPA using the Reef Check methodology.
2.	Evaluate critical areas of the reefs using AGRRA in order to obtain more current data and prevent further deterioration.
3.	Set up a network of permanent MPA monitoring sites in order to establish long-term baseline data that allows for future adaptive or corrective actions within the MPA
4.	Consolidate monitoring methods between Haiti and the Dominican Republic within the trans-border framework of the CLME thereby facilitating bi-national decision-making processes.
5.	Include trans-border ecosystem interactions (mangroves, reefs and sea grass beds) that are present in the bi-national marine platform.
6.	Carry out a more detailed investigation of the deeper reefs (more than 20 m deep) since most of the reef cover is in this area.
7.	Identify key fish spawning areas within the MPA in order to implement strict regulations around these areas and no take zones.
8.	Actively involving bi-national local fishing communities in these conservation processes and participatory MPA management
9.	Carry out regular trash clean ups of the MPA where possible (with the possible help of fishermen and other stakeholders) and manage adjacent coastal zones adequately.

(Garza- Perez at al., 2007). Innovative technology could be used to patrol MPAs, such as drones. This will also have a cascading effect on patrolling in adjacent MPAs like the Silver Banks MPA or the proposed Haitian Troies Baies MPA (first one to be established on the Haitian North Coast in 2015). The Silver Banks MPA is the largest humpback breeding ground in the world and is 80 nautical miles north-east of the Montecristi MPA (Brioso, 2008). Whale watching excursions are organized from Puerto Plata and Montecristi MPA to observe the humpback whales. Boats do not respect the Marine Mammal Protection Act (MMPA) nor the Endangered Species Act (ESA) even though the adjacent Silver Banks MPA management plan includes whale watching harassment rules (being within less than 100 m of a humpback whale) for whale watching vessels (Figure 25). Humpback whales are also sighted within the MonteCristi MPA between November and March and regulations need to be put in place and enforced for whale watching and these regulations need to be adapted for the Silver Banks MPA (López & Silva, 2012).

Table 15: Control and Training Activities for Zoning at Montecristi MPA (López & Silva, 2012)

Control Activities	Training Activities
1. Designating of zones with buoys 2. Establishing anchorage buoys to protect coral 3. Patrolling the coast to make sure buoys and zoning are being respected (especially the no-take zones with bi-national fishermen). 4. Regular collection of information from boats 5. Regular studies of catch to determine characteristics and composition 6. Regular studies of the health of the reef through observation and counting from a permanent network of monitoring sites in the MPA 7. Regular water control with parameters defined by SEMARENA 8. Regular trash collection and clean-ups in affected areas 9. Regular fishing of invasive species (lion fish) and putting them on menus 10. Regulation of wildlife sighting activities (humpback whale and dolphin observation) 11. Revise laws 64-00 and 202-04 to include zoning of Dominican MPAs 12. Enforcing of fines (non-monterary with poor)	1. Training program to promote good fishing practices for the following audiences: authorities, fishermen, fisheries and civil society. 2. Training in revised fishing practices that help the MPA 3. Training and carrying out of participatory management (communities, fishermen) which guarantees the sustainable management of the zoning areas 4. Involving adjacent communities in trash cleanups and environmental educational initiatives about the MPA 5. Increasing park personnel (and their salaries), support, gear and vessels to the MPA and training on patrolling methodologies 6. Training in Haitian Creole to be able to explain MPA regulation to Haitian fishermen and involve them

Figure 25. Irresponsible Humpback Whale Watching on the Silver Banks MPA. Clearly this boat is much closer than 100 m. ***Courtesy of www.laromanabayahibenews.com.***

In the literature, it is generally agreed upon that the success of the MPA management in PNE will be anchored on public support, understanding and sympathy (Kelly, 1992). An important factor in attaining this support in the PNE MPA is community outreach and education (Table 16).

Table 16: Steps that help community outreach and education in PNE participatory MPA Management (USAid, 2013)

1. Products that address:	**2. GOs and Community Discussions that address:**	**3. Promote:**
Problems in fisheries like open access resources, ecological impacts and limits to production	Carrying Capacity limits for the park	Proposals for alternative economic activities like tourism (especially in Mano Juan village)
Marine stewardship	The fact that resources are not unlimited and that earnings potential is lower than expectations of fishermen	Mechanisms to offset losses by fisheries due to zoning

Subsequent steps should be carried out in PNE to improve management of the park (Table 17). The declaration of Catuan Passage and its surroundings as a No-Take Zone is the most important first step for the sustainable management of the PNE MPA as determined by the Dominican SEMARENA and the scientific community (Chiappone, 2001 (part 3)).

3.2 Caribbean MPA ICRAN Demonstration Site Case Studies

There are two effective MPA programs in the Caribbean SIDS that are part of the 6% of well-managed WCR MPAs (CANARI, 2001): the Soufrière Marine Management Area (SMMA) in St. Lucia and the Bonaire National Marine Park (BNMP). The ICRAN demonstration sites of SMMA and BNMP were chosen because of specific successful practices. The SMMA is a successful model for adaptive "people management"; conflict resolution, zoning practices, planning management and community involvement in St. Lucia (ICRI, 2002). The BNMP is considered one of the best preserved reef systems in the Caribbean and is a successful model for "hands on conservation" including private

Table 17: Steps that help with improved management of PNE (USAid, 2014; Chiappone, 2001 (part 3))

1.	Enforce tourism carrying capacity assessment
2.	Control of invasive species like lion fish, gastropods
3.	Climate Change Monitoring within PNE with new weather stations
4.	Establish zoning schemes in the park that are enforceable: Declare the Catuan Passage, Calderas Bay, Catalinita Island as no entry zone and no take zones
5.	Establish updated delimitation of the park including all areas out to the 200 m depth contour.
6.	Coral reef nurseries and regeneration (16 structures have been installed and 14,068cm of PNE tissue is available from nurseries around Bayahibe)
7.	Coordination amongst many institutions for MPA management
8.	Climate change adaptation options should be incorporated into strategic municipal plans in Bayahibe (new projects in this field in 2015 are USAid's CLIMA-PLAN and CLIMA-ADAPT) for less impacts
9.	Develop jobs and techniques for PNE monitoring (marine guards, park patrols, drones) to be able to increase capacities for DNP administration
10.	Creation of community-based networks
11.	Promote projects that improve park infrastructure (even if non GO)
12.	Develop special conservation projects where scientific professionals work with PNE administration to increase the local knowledge base
13.	Develop sustainable financing mechanisms (now tourists pay $1 to enter). If the park entrance is increased to $5 it could generate over $500,000/ year if there are 500,000 or more visitors as projected. Tour operators, mooring buoy users, yachts and trail users should also pay fees. PNE can invest extra monies made into conservation and become self-sustainable.

sector participation (hotel industry and diving operations) and sustainable financing mechanisms (ICRI, 2002).They are both International Coral Reef Action Network (ICRAN) demonstration sites (ICRI, 2002). The SMMA and the BNMP were able to develop successful MPA management plans even though they stemmed from different needs. SMMA is the best-documented example of an MPA management plan that was developed in order to resolve user conflicts in the area; mainly between fishermen and tourism (CANARI, 2001).

3.2.1 La Soufrière Marine Management Area in St. Lucia

The Island of St. Lucia has three MPAs; SMMA, Pitons Management Area and point Sable Environmental Protection Area (Figure 26).

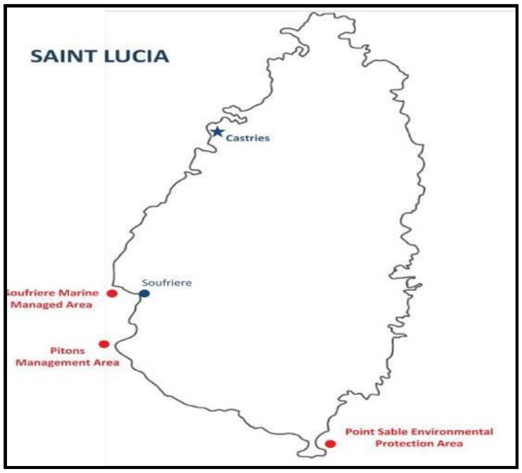

Figure 26: Map of Location of MPAs in St. Lucia (Gombos et al., 1994)

The SMMA is in the English-speaking Caribbean island of St. Lucia along its southwestern coast that includes 12 km of coastline and marine areas. However, the exact size is not known because there is not enough bathymetry data past the seaward boundary of 75 m depth (Gombos et al., 1994). The picturesque town of Soufrière is in the center of the Bay of Soufrière and it is famous for its twin volcanic peaks (the Pitons) (Figure 27), drive-in volcano, rain forest, intact coral reefs and numerous waterfalls (Pierre-Nathoniel, 2003). The SMMA has coral reef plateaus that are near-shore and are covered with sponges, soft corals and gorgonians; there is also a ship that was sunk by the Department of Fisheries in 1986 in the area that serves as an artificial reef (Gombos et al., 1994).

Figure 27. The SMMA and Pitons Management Area (courtesy of the www.bestofstlucia.com)

Prior to SMMA being founded, the area suffered from poor water quality (that adversely affected the reef ecosystem and human health), severe overfishing, loss of coral reef cover, pollution and contamination from solid waste and general degradation of environmental quality and landscapes (SMMA, 2005). Problems manifested themselves in conflicts between dive operators, fishermen, yachts, tourism, local communities, hoteliers and government authorities (Table 18).

Table 18: Problems prior to the SMMA (Pierre Nathoniel, 2003)

1.	Fishermen and yachtsmen were in competition for the use of space for mooring, fishing and tourism activities
2.	Fishermen accused divers of deliberately damaging coral reefs and fishing equipment
3.	Fishermen accused researchers of deliberately taking reef samples and accelerating environmental degradation with unauthorized studies
4.	Conflicts about access with the local tourism industry (communities and hoteliers over recreational and fishing beaches, fishermen about a Soufriere Bay Jetty)
5.	Fishermen accused tourism vessels of compromising fishing and gear by passing too close
6.	Water taxi operators were harassing tourists and fishermen
7.	Damage by anchors on reefs by yachtsmen
8.	Unregulated commercial and recreational diving activities in areas that were fragile
9.	Degradation of water quality due to anthropogenic activities
10.	Degradation of coastal zones
11.	Solid waste accumulation (in particular plastics)
12.	Lack of awareness of the importance of the marine environment

Prior problems that still persist in the SMMA were due to coastal development, activities in relation to tourism, overfishing, mining of sand, increased natural disturbances and climate change (Gombos et al., 1994). In 1993 the Department of Fisheries of St. Lucia presented zoning and regulations for the MPA which were revised and approved and the Zoning Agreement "included maps showing the extent of proposed marine reserves, fishing priority areas, multiple use areas, recreational areas, and yacht mooring sites, legal provisions needed to manage individual activities such as fishing, diving, yachting, marine transportation, demarcation requirements, materials for user information, and training needs" (SMMA, 2005).

The SMMA (Figure 28) was established in 1994 with prior consultation from ENCORE and CANARI (USAid-funded) in order to effectively reduce user conflicts and reverse negative impacts to the ecosystem from increased tourism (CANARI, 2001). It is managed by the Soufrière Foundation which receives technical support from the St. Lucia Department of Fisheries under the guidance of a Technical Advisory Committee (TAC) that includes management authorities as well as user groups (SMMA, 2005). Fishermen were the most affected by the SMMA zoning through the loss of key fishing areas (Pierre-Nathoniel, 2003). Efforts were made to keep the public informed and participating throughout the process of the establishment of the MPA.

SMMA was under unstable management from 1997-1998 and an institutional review resulted in the formation of the Soufrière Marine Management Association with its board of directors (main stakeholders and advisory body) (ICRI, 2002). The SMMA is governed by the 1984 Fisheries Act and the 1983 Commission Act (CEHI, 2013). The setting up of the SMMA involved the implementation of an agreement, research and resource monitoring, the development of the fishing sector and the mitigation of impacts.

The SMMA has been successful mainly because of institutional strengthening (participatory decision processes with many stakeholders eliminating the usual "responsibility vacuum", transparency, institutional reviews and communications plans), successful conflict resolution (direct communication with stakeholders and resource

Figure 28. SMMA Zoning Map (Pierre-Nathoniel, 2003)

users), communication and public sensitization (through media, communication with communities and stakeholders) and involvement of self-supporting user groups and institutions (SMMA, 2005).

As a result of improved public acceptance, the SMMA has been able to enforce and maintain its MPA legislation. SMMA has created a sense of ownership amongst stakeholders by being able to reduce conflicts among users through participatory MPA management, increase general awareness about the environment, generate user fees becoming self-sustainable, increase fish stocks, improve the health of coral reefs, provide scientists with study areas and promote multidimensional and multi-sectoral successful collaborative management. However, this has been a complicated process and several issues that were dealt with poorly include the high sedimentation rates from the Soufrière watershed because of run-off, heavy rains from storms, development and algal growth from sewage that cause coral reef degradation and associated human health issues (CEHI

2013; Pierre-Nathoniel, 2003). There has been increased sedimentation since Hurricane Thomas in 2010 (CEHI, 2013). The MPA is still threatened by the overuse of dive sites, overfishing and illegal fishing within zones (CEHI, 2013). Initiatives and organizations that have addressed these concerns and have been successfully involved in SMMA management are: the CCI that promoted educational programs for stakeholders on marine resource management, the GEF-IWECO Project that focuses on watershed management (as this inevitably affects the MPA) and a program by USAid on early warning systems for watershed flooding to be carried out by the Water Resources Management Agency (WRMA) (CEHI, 2013).

Data collected from when the SMMA started in 2001 showed that fish stocks have tripled both in no-take and fishing areas with improved catches by fishermen (SMMA, 2005). Part of the reason for the increase in catches is due to the Government of Saint Lucia (GOSL) giving monthly stipends of about $400 to displaced fishermen as compensation (decreasing fishing effort) and agreeing upon the banning of gill nets as they caused the most damage to reefs (Pierre-Nathoniel, 2003). However, this also set a poor precedence for long-term management of the MPA because fishermen tended to seek additional compensation for lost fishing gear, personal activities and natural disturbances that had nothing to do with the MPA directly (Pierre-Nathoniel, 2003). Fishermen were encouraged to go to deep sea areas past the MPA to fish but costs, labor-intensiveness, skills and physical demands (a lot of fishermen are older) hindered this. Now that a younger generation of fishermen has been trained in long-line fishing for catching offshore pelagics, (like tuna) it has resulted in a reduction of pressure on coastal resources (Pierre-Nathoniel, 2003).

The SMMA has been chosen as an ICRAN demonstration site and has been provided with additional aid and resources so that the lessons learned are used as examples in other Caribbean MPAs. Because it has demonstrated successful community participation (in management and planning of the MPA), conflict resolution and successful zoning practices over a short span of time (ICRI, 2002), SMMA has won awards internationally through its conservation efforts including the1997 British Airways Tourism for Tomorrow Award, the IUCN Special Award for National Parks and Protected Areas and the 1997 World Underwater Confederation (CMAS) International Marine Environmental Award (GPIEM) (SMMA, 2005).

3.2.2 Bonaire National Marine Park (BNMP) in Bonaire

BNMP was established in 1979 (declared a national park in 1999) and includes the oceanic Southern Caribbean Island of Bonaire (approximately 100 km north of Venezuela separated by a deep water (1,700 m) trench) and Klein Bonaire. (STINAPA, 2006). BNMP is completely within Bonaire's territorial waters and jurisdiction; the Marine Environment Ordinance (A.B 1991 Nr.8), EU Environmental Laws, Ramsar and the Central Department of Nature and the Environment (MINA) protect it (De Mayer & Mac Rae, 2006). BNMP surrounds the whole island and goes from the high water mark to the 60 m depth contour and extends 200 m outwards from the coast (STINAPA, 2006). Bonaire has a well-deserved international reputation as one of the top 5 SCUBA diving destinations in the Caribbean (STINAPA, 2006). It is an important part of the Kingdom of the Netherlands and is considered one of the six Dutch Islands in the Caribbean recognized by the European Union (Figure 29) (DCNA, 2013).

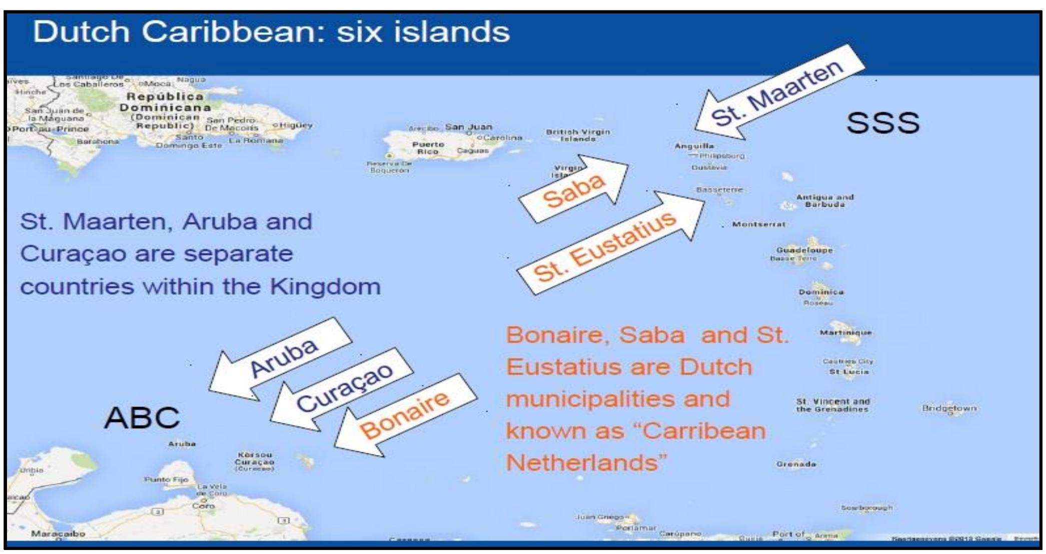

Figure 29: The Dutch Caribbean (DCNA, 2013)

The BNMP was created to reduce the destruction of marine resources, consisting of approximately 2,700 hectares of mangrove, sea grass and coral ecosystems with over 350 species of reef fish and over 50 species of stony coral, that generate massive income from tourism (De Mayer & Mac Rae, 2006). The United Nations Department of Social and Economic Affairs-Division for Sustainable Development and SIDS Unit also designated the BNMP as an MPA success story as a result of the following factors; educational efforts (for their own staff and local communities on sustainable tourism practices), conservation and preservation, the sustainable use of resources, financial mechanisms and the involvement of local people (STINAPA, 2006). The BNMP is around a volcanic island that has a unique bathymetry (Figure 30) in the WCR (depths range anywhere from 100 m plateaus to submarine canyons over 1500 m deep) that has not been investigated past the 60 m mark of the MPA. Bonaire is outside of the hurricane belt but the submarine trench and its unique rugged bathymetry between it and Venezuela can cause "wind reversal" (high seas on its leeward side) that cause extensive damage to the MPA when a hurricane or storm passes close by (STINAPA, 2006).

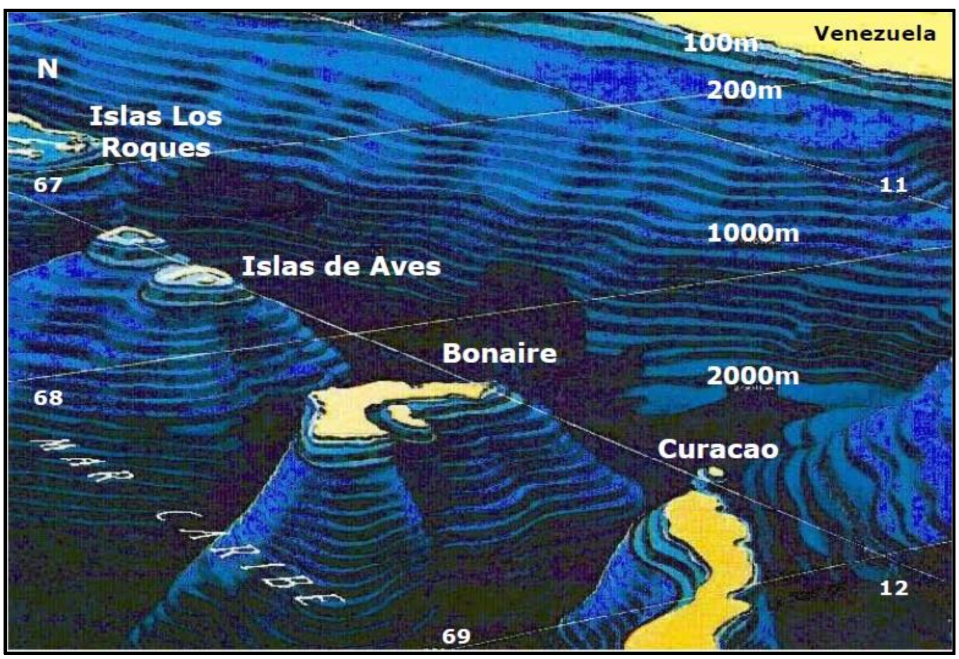

Figure 30: 3D Representation of Bonaire's Bathymetry (STINAPA, 2006)

The economy of Bonaire is highly dependent on tourism. BNMP introduced a fee system in 1991 ($20 US for annual admission) to be able to manage the MPA sustainably (UNEP, 2004). This fee system helps diving operators by minimizing impacts on reefs and allowing them to educate divers with briefings and orientation dives to make sure visitors know and respect the park regulations (UNEP, 2004). The BNMP MPA has an unusually high compliance to regulations and successful enforcement of rules compared to other WCR MPAs. This is enabled through an established trust fund of the Dutch Caribbean Natural Alliance (made up of park organizations, conservation NGOs and experts based in the Netherlands) that carries out fundraisers in the area and in the Netherlands generating additional revenue (DCNA, 2013). This is a great plus as park users feel confident and proud knowing that their fees go to the MPA by law and the funds do not get misallocated (STINAPA, 2006). Diving operators also get tangible returns like maintained sites, buoys and many outreach materials like brochures, posters and leaflets that help monitor the MPA and enforce regulations (ICRI, 2002).

3.3 Lessons Learned from Good Management Practices of MPA ICRAN Demonstration Site Case Studies

As stated beforehand, the ICRAN demonstration sites of SMMA and BNMP were chosen because of specific successful practices. The SMMA is a successful model for adaptive "people management"; conflict resolution, zoning practices, planning management and community involvement in St. Lucia (ICRI, 2002). The BNMP is considered one of the best preserved reef systems in the Caribbean and is a successful model for "hands on conservation" including private sector participation (the hotel industry and diving operations) and sustainable financing mechanisms (ICRI, 2002). Zoning in the SMMA is for multiple uses and a good model for the PNE and Montecristi MPAs. The Zoning Plan includes multiple use areas, recreational areas, marine reserves (no take), fishing priority areas and areas for yacht moorings. This type of zoning optimizes ecological, social and economic benefits making conservation and development more compatible (especially relevant for poverty-stricken areas) (ICRI, 2002). SMMA of a user fee in the form of an easy and transparent process which would be ideal for the shows that small and well-managed MPAs with supportive legal and institutional frameworks (with multiple stakeholders that share a clear goal and vision) have great positive impacts on conservation (Pierre- Nathoniel, 2003). There are important lessons that can be learned from SMMA and applied to PNE and Montecristi MPAs as far as MPA management (Figure 31). One of the most important ones is the establishment of a board (like TAC) to enforce regulations, like existing zoning, and oversee the multiple stakeholders. Lessons that can be learned from BNMP and applied to PNE and Montecristi MPAs can be observed in Figure 32. The most important one is the collection PNE and Montecristi MPAs in the Dominican Republic.

LESSONS LEARNED

Stakeholder Involvement, Empowerment and Community Support

- Increased participation and empowerment at the community level leads to an increased sense of ownership, recognition, and improved park knowledge, critical to effective decision-making and sustainability.
- International recognition of conservation efforts leads to increased popularity and pride.
- In order to avoid non-compliance with MPA rules, care should be taken to include adjacent communities which may use the MPA.
- Clear and open communication mechanisms increase stakeholders' commitments to conservation, sustainable use, and equitable sharing of profits; breakdown in communication may lead to conflicts and non-cooperation.
- The establishment of a TAC comprising key management authorities and user groups is important in addressing stakeholders' needs and implementing a MPA that will be accepted and enforced.

Development of Management Plans

- When implementing a MPA, its vision and mission need to be clearly identified and the role of all contractual parties clearly defined.
- Regular reviews of a reserve's management plan, highlighting its strengths and weaknesses, can help in the formulation of a more efficient and effective management structure.
- Management plan structures should give a MPA a strong legal basis.
- Lack of vision and failure to finalise draft management plans can contribute to disagreements and/or misunderstandings amongst stakeholders.

Tourism and Sustainable Development; Partnerships in Management

- When establishing partnerships between the public and private sector, a formal agreement should be outlined and clear role sharing should be defined.
- Development of a co-management system should neither neglect nor compromise the role of government in resource management.
- When developing tourism activities, it is important to ensure that profits are being shared equitably.

Figure 31: Management Lessons Learned from SMMA (UNEP, 2004)

LESSONS LEARNED

Stakeholder Involvement, Empowerment and Community Support

- A fee system can lead to complacency by management staff and stakeholders over funding issues.
- Local island residents should be given special consideration when levying fees to access their surrounding waters.

Tourism and Sustainable Development

- A high degree of dependency on the tourism industry as a major source of income can give the industry undue power to veto policies it does not agree with.

Sustainable Financing

- When implementing a fee system to allow for a MPA to be self-sufficient, it is important to think long-term.
- A fee system should be simple to enforce and collection should be easy and regulated.
- Monies levied by a fee system should only be used towards the upkeep and maintenance of a MPA, provision of education and outreach, conduct of research and monitoring surveys, and law enforcement activities.

Public Awareness and Education

- A fee system can have unanticipated positive impacts such as increased interest by tourists in park-related information and high level of compliance and support for volunteering programmes.

Figure 32: Management Lesson Learned from BNMP (UNEP, 2004)

Section 4: Critical Analysis- Challenges faced in Multidimensional MPA Management

4.1 Participatory MPA Management and Multiple Stakeholders

MPAs are increasingly being used as conservation tools in the Caribbean. About 55% of MPAs in the region use multiple stakeholder consultation within participatory MPA management, however, it can be cumbersome and time-consuming and requires specific know-how that is not always available in MPA management structures (CANARI, 2001). Five elements of the participatory processes have been shown to be successful in involving stakeholders; opportunity for input, influence over decisions, satisfactory exchange of information, transparent decision-making and agreeing upon fair decisions (Dalton et al., 2012). The aforementioned factors have been identified with various degrees of difficulty by researchers in relation to the success of MPA management in recent years.

4.1.1 The role of MPA stakeholders

A key step in participatory MPA management is the identification of key stakeholders, their roles and their collective motivation by a legitimate reason (Dalton et al., 2012). If the legitimate reason is not accepted by other stakeholders, the participation and involvement of the stakeholder (role) loses meaning within the multiple stakeholder group (López & Silva, 2012). A good way to start a participatory process is to invite multiple stakeholders to cooperatively debate, discuss and come up with rules about how the interaction with MPAs should be regulated (Dalton et al., 2012). Multiple stakeholders that should be included in MPA management planning could be; the general public, scientists, conservationists, government and non-government organizations, communities and any other resource users. Researchers and MPA managers agree that involving multiple key (so as to not render the process overbearing) stakeholders leads to decisions that have more support, management goals that are met by outcomes and realistic regulations that are more likely to be respected (Dalton et al., 2012). Different methods can be used to appeal to different audiences like social gatherings, stakeholder dinners, public meetings, MPA excursions, focus groups, citizen juries and consultations with experts (López & Silva, 2012).

A definite disadvantage of multiple stakeholders participating in MPA management is that usually the loudest voices tend to monopolize meetings (especially in the case of fishermen community leaders). However, this can be controlled by conveying transparent and fair participatory processes to all stakeholders. This is why it is important to make sure that every stakeholder understands their role and degree of participation as this shapes their perception of the success of MPA design, planning and management. It has been shown that an individual that participates in a higher quality process and is empowered is more likely to associate positive outcomes and perceptions with the MPA as opposed to negative MPA perceptions facilitated by poor participatory processes (Dalton et al., 2012). If common interests are defined and defended in multiple stakeholder processes (instead of the positions of individual stakeholders) collaborations will result and this is a win-win scenario (López & Silva, 2012). Hence, it is extremely important to plan how participatory stakeholder roles are defined as this has been shown to directly relate to perceptions of ecological and social outcomes and organizations in MPA management have an increased capacity to spend time allocating their resources to executing public participation processes that involve multiple stakeholders (Dalton et al., 2012).

4.1.2 The role of international and national organizations

Most Caribbean MPAs that have been operational for more than 20 years are usually managed by government agencies or national trusts, however, recently created MPA models include co-management with international and national organizations, NGOs and different management combinations (CANARI, 1998). International cooperation relieves economic crisis, lack of political will and lack of funding while taking the focus off the prioritization of global programs and placing it on WCR conservation initiatives (Montero, 2002). Current ocean issues, coastal zone management and multidimensional MPA management can be more comprehensively addressed through international partnerships where leadership is established (Montero, 2002). The current needs of coastal zone and MPA management surpass the capacities of an individual state or organization in the WCR. MPAs in areas of low tourism or with limited funding mechanisms are less likely to succeed without the help of external donor support (CANARI, 1998). As a result of the bio-geographical proximity of the Caribbean SIDS and their common pool of natural resources in the Caribbean Basin, collective long- term solutions to complex scientific and administrative issues in ocean and coastal areas involving international partnerships are more feasible in the WCR (Chiappone, 2001 (part 1)). Partnerships with national and international organizations give less fortunate MPA programs more leverage and more successful ones a leadership opportunity and access to more resources to remain successful (CANARI, 1998).

Most SIDS in the WCR require financial support from international organizations for adequate scientific research ideally assisting an MPAs in-country research and monitoring activities as they may be able to bring in adequate expertise and tools that may be absent locally (Chiappone, 2001 (part 1)). For example, ocean and coastal data has come from CICAR and IOCARIBE mechanisms for some program implementations in the WCR and this is important otherwise those MPA management plans would not be properly designed (Montero, 2002). Despite the significant amount of cooperation between international, national organizations and NGOs in the WCR, there have only been a few sustained regional MPA initiatives and more need to be promoted for the long-term sustainability of MPAs and MPA networks in the area. Some of the sustained regional initiatives are the research and monitoring of dissolved and disperse petroleum in Caribbean coastal and open seas (CARIPOL) and the monitoring and research of heavily polluted bays under UNEP and GLOSS programs (Montero, 2002). The lack of sustained regional MPA initiatives is largely due to lack of political will and economic limitations and this can be changed with the promotion of international partnerships and incentives. There is empirical evidence that suggests that high levels of cooperation amongst stakeholder groups, organizations and agencies (the SMMA consortia mentioned is a great test of this hypothesis) leads to more effective MPA and MPA network management (CANARI, 2001). The TNC PIP program is an example of a successful collaboration with the conservation community, international donors and conservation organizations in-country that are private and public (TNC, 2005).

4.1.3 Coastal Community Involvement

The diversity of the WCR (not only in the Caribbean but also within a region of the Dominican Republic, for example) highlights the importance of community involvement in MPA planning and management efforts. WCR MPAs that have invested considerable effort into integrating programs that address the needs of local fishing communities are; St Eustatius and St Maarten Marine Parks, the SMMA in St. Lucia as mentioned, the Cayman Islands System and the Negril and Montego Bay Parks in Jamaica (CANARI, 2001). MPAs impact food security, employment and incomes of close by coastal communities so it is very important that they have a significant voice in stakeholder involvement. Stakeholder interests can vary within or outside a community in the WCR but they are usually associated with occupations; fishing-related (28%), recreation/ parks (38%) and in ocean transportation (37%) (Dalton et al. 2012). In a study of 31 MPAs in the WCR it was found that most community stakeholders in MPA management tended to be men possibly due to the fact that their employment is directly impacted by MPA management (as opposed to 25% women even though they head one third of households in the Caribbean) and 50% of those men were also active in other community organizations (Dalton et al., 2012). MPAs influence property rights, levels of conflict, empowerment, temporal and spatial patterns of use and the distribution of resources in coastal communities (Dalton et al., 2012).

In a survey asking why community members took part in stakeholder meetings it was found that; 37% wanted to learn about the MPA (including its rules and potential effects), 26% wanted to support their communities, 16% wanted to maintain their livelihoods, 13% wanted to protect the environment and 8% had other reasons (Figure 33) (Dalton et al., 2012).

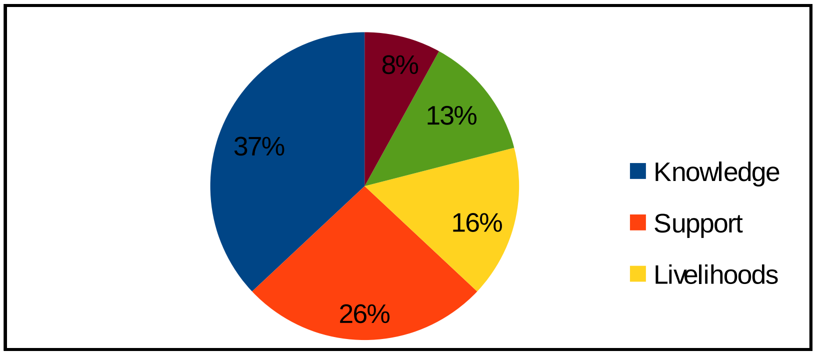

Figure 33: Community Reasoning behind Participatory MPA Management (Dalton et al., 2012)

The public perception of MPAs does not reflect actual measured biological conditions (Dalton et al., 2012). This leads us to deduce that perceptions about MPA performance are formed by a combination of knowledge (complex environmental issues and personal observations), belief (social and ecological conditions) and experience (interactions with others) (Garaway & Esteban, 2002; Montero, 2002). Communities associate MPAs with perceived changes in ecological conditions and the social fabric of the community (Camargo et al. 2009). The integrated management of a coastal zone or an MPA can be boiled down to being an intensely social process. Public awareness and environmental education (leading to a transformation in attitude towards MPAs) are key to successful marine and coastal resources management (Montero, 2002). Public meetings seem to be the most common mechanisms for MPA planning and management with community stakeholders (Camargo et al., 2009). Local impoverished communities are highly dependent on national parks for food security and livelihoods (fishing, tourism and illegal trafficking activities); especially in PNE and Jaragua National Parks in the Dominican Republic (CANARI, 2001). There are MPAs and protected areas with different activities, characteristics and conflicts in the Dominican Republic but all share the same common characterstics of poverty (Table 19).

Poverty (as we can see from the above table) and illiteracy are common in Dominican coastal communities involved in MPA management. The literacy rate is 88.2% nationally (www.state.gov) and lower on average in rural areas where underprivileged people may also not have the possibility or means to attend meetings because of their

Table 19: Community Activities and Characteristics in relation to MPAs in the Dominican Republic: (CANARI, 2001)

MPA	Tourism/ Recreation	Fishing	Other	Local Community Links/ Impacts	Conflicts/ Management Issues	Poverty Issues
Area Nacional de Recreo Cayo Levantado	X			X		Yes
Area Nacional de Recreo Boca Chica	X			X		Yes
Monumento Natural Isla Catalina	X	X		X		Yes
Parque Nacional Cabo Cabron		X	Agriculture	X		Yes
Parque Nacional del Este	X	X	Research	X		Yes
Parque Nacional Jaragua	X	X	Research	X	Tourism developers vs Park Managers	Yes
Parque Nacional Los Haitises	X	X		X		Yes
Parque Nacional Monte Cristi	X	X	Salt Mining	X		Yes
Parque Nacional Submarino la Caleta	X					No
Reserva Biologica Gran Estero		X		X		Yes
Santuario de Mamiferos Marinos	X	X		X	Fishers vs. Park Rangers	N/A.. in the middle of the ocean

economic situations and/or the location of their houses (cost of transportation, etc). Community member involvement is key in improved community cooperation and compliance to MPA rules in the Caribbean hence incentives should be given for underprivileged rural people to attend (transportation, pocket money from a fund, etc.). Education outreach programs to increase awareness, inform and educate local communities on conservation issues and management strategies should be developed in conjunction with fishermen and their communities (Garaway & Esteban 2002; Chiappone, 2001 (part 1)). For illiterate fishermen and other community members, aspects of the MPA management process can be portrayed as enactments, video presentations, radio shorts and discussions. Tools used for collecting scientific data in communities will be different to tools used for participatory data (for e.g. verbal questionnaires for community members with local knowledge based on prolonged time spans of resource use and others). Participatory assessment data collection methods also include asset and social mapping, rapid rural appraisals (RRA), social impact analysis, analysis of institutions in the area, participatory monitoring and evaluation (PME) and conflict management and negotiation (FAO, 2011).

4.2 Potential Drawbacks of Multidimensional MPA Management and Possible Alternative Models

MPAs can promote the recovery of coral reefs and their reef communities but they are not short-term or easy solutions. This section looks at the other side of the coin and at some of the potential drawbacks that multidimensional MPAs may have. On an ecosystem level, the complex interactions between all components of the MPA must be understood in order to design appropriate MPA management tools to be able to guarantee long-term success stories and this is not easy to do. Current MPAs in the WCR are generally lacking in design and planning and may not protect the most vulnerable areas thereby not filling the role they are intended for (Alvarez et al., 2011). MPAs are not immediate conservation solutions and the positive effects of protection become apparent only after a considerable amount of time following their establishment. At first, some Caribbean MPAs may decline continuously in biomass, coral cover and fish stocks for years (tangible results after 4-14 years on average) before they begin to recuperate depending on the MPA size, the condition of the surrounding area and legislation enforcement (PNE was established in 1974) (Alvarez et al., 2011).

Various readings suggest that MPAs are great tools for reef restoration and preservation but should not be relied completely upon for restoring coral degradation due to climate change (Selig et al., 2012). Incomplete comprehension of complex multidimensional MPA management in relation to climate change can lead to any number of scenarios in the marine ecosystem. One example is that MPAs do not react well to thermal stress events from ENSO phenomena when temperatures surpass the optimal range for coral growth and this could be exacerbated due to design and management factors that further contribute to declines in coral growth; MPA location in relation to currents, proximity of urban areas and anthropogenic activities, degree of zoning enforcement and their connectivity to other MPAs to name a few (Selig et al., 2012). Climate change impacts on MPAs can vary greatly and are not fully understood. Interestingly enough, some hurricanes in 2005 reduced bleaching effects in MPAs in the Caribbean (including the Dominican Republic) by mixing deeper and cooler waters into surface waters allowing corals to recuperate from the warm temperatures they were subjected to (Wilkinson & Souter, 2005). Global analyses on bleaching have found that MPAs are not successful in recuperating from the detrimental effects of anomalies in sea surface temperatures over time as they have not been proven to mitigate thermal stress or allow for protection from severe thermal stress events (Alvarez et al., 2011, Selig et al., 2012). MPAs can have unintended negative biological impacts on the architectural complexity of reefs by allowing the proliferation of herbivore populations like parrot fish (increases biomass) through reductions in fishing that can actually accelerate the bio-erosion of coral reefs MPAs are trying to protect (Alvarez et al., 2011). MPAs are not stand alone solutions and need to be complimented by additional important measures that help reduce anthropogenic activities that cause climate change (Selig et al., 2012). These can be downsides of MPAs, but the benefits they provide far outweigh them.

Additional measures that address climate change factors may add complexity to the already difficult task of executing a multidimensional MPA management plan, so one may ask oneself why one would go to the trouble of implementing it. Some argue that conserving reef fish populations and sustainable fisheries for local communities are already attainable and worthy goals in their own right. These can be carried out with immediate localized efforts without compromising livelihoods with complex management plans. One may ask oneself why one would go through the complex process of participatory MPA management to impose laws that restrict fishing that are questionable in their efficacy when visible short-term results are needed (Aronson & Precht 2006). Multidimensional MPAs and MPA networks are not short-sighted stand-alone solutions. Even the most directly measurable short-term results of No-Take Zones in MPAs have disadvantages as can be seen in Table 20, but again, long term advantages of MPAs far outweigh them.

Table 20: Disadvantages of No-Take Zones in MPAs (Chiappone, 2001(part 2))

1.	Fishing is concentrated on smaller stock portion
2.	Fishermen have access to less stock and there is a reduction of short-term yield
3.	Fisheries benefits are only long-term
4.	Restricted areas encourage poachers
5.	Restricted areas require additional enforcement and patrolling
6.	Strong local resistance mostly because of poverty factors
7.	Lack of precision about location, number and sizes of reserves
8.	Costly detailed and long-term research for justification
9.	Not useful for migratory species in WCR
10.	Resistance of fisheries managers to MPA model
11.	Complexity of including all life history stages of species in reserves

There are alternate models of marine resource management that work, but they are not as comprehensive as MPAs. The single- taxon management model can be effective and powerful in achieving conservation goals (for example increasing *Diadema antillarum* populations and addressing climate change issues) without going into the complexities of an MPA management plan (where the predators of *Diadema antillarum* are also protected and coral resilience is reduced as a result) (Alvarez et al., 2011). Co-managed and traditionally managed areas may be more beneficial in addressing conservation needs and balancing immediate socioeconomic needs in poverty- stricken areas (Kareiva, 2006). Socioeconomic and ecological analyses of many conservation efforts in the Caribbean make it clear that MPAs are not necessarily always the solution; in some cases it has been estimated that it is more important to give a community the support to develop their own conservation plans instead of suggesting an MPA management plan (Kareiva, 2006). Depending on how an MPA is managed, it could cause serious economic stress to fishermen and recreational sectors and there are alternate environmental management models to consider. (Alvarez et al., 2011) "Research demonstrates that numerous variables, not directly apparent from the legal and policy typologies, may affect and even determine the long-term success of an MPA. These variables include development of systems to implement specific international obligations, nationalization and clarification of governance structures, the articulation and effective operation of area-specific policies to guide administrative action in respect of all activities impacting the protected area, availability and effective deployment of human and material resources, and meaningful community participation" (Homer, 2004). Long-term successes of multidimensional MPAs depend on many variables, but they are the most effective and sustainable management options in most areas of the WCR because of its great political, social and economic complexity (Herrera- Moreno, 2011).

There has been a history of a lack of uniformity and success in MPA management regionally. There is a perception that many MPAs remain marine 'paper parks' just like their terrestrial counterparts (McClanahan et al., 2006). Hence, it would seem that environmental management should be carried out with more localized efforts in the WCR and that it should address specific issues instead of adopting the multi-pronged MPA and MPA network approach. What this line of thought needs to take into account is that MPAs and MPA networks are not short-sighted conservation models and MPA management is only partly about science (and there are major scientific uncertainties, uniformity and lack of data) (Chiappone et al., 2001). There is good evidence that MPAs are valuable efforts that can address all the legitimate concerns with comprehensive, worthwhile and justifiable commitments for long-term sustainability and resilience to climate change.

Section 5. Conclusion/ Recommendations

5.1 Large Caribbean Network Solutions and Connectivity are Critical for Regional Conservation of Biodiversity

"An MPA network can be defined as a collection of individual MPAs or reserves operating cooperatively and in synergy, at various spatial scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve" (IUCN, 2008). The connectivity of Caribbean MPAs and coastal areas and their benefits to biodiversity has been illustrated over areas that span hundreds to thousands of kilometers (Hallock et al., 1993). WCR MPAs need to be appropriately sized and placed to function collectively so they can fulfill their critical biodiversity goals as an MPA network (IUCN, 2008). MPA networks are encompassing regional approaches that are critical for the regional conservation of biodiversity, enduring sustainability of fisheries resources and collective ecosystem-based resilience to climate change (Ottenwalder, 1996; Roberts, 1997). MPA Networks are comprised of different MPAs with components of important habitats and biodiversity that are critically interconnected because of the movement of plant propagules and animals (IUCN, 2008). MPA networks are part of a management approach that is broadening its perspective to the benefit of people and the environment because they are critical in achieving what individual MPAs cannot.

5.1.1 Large Caribbean MPA Network Solutions

Under the United Nations Convention on the Law of the Sea (UNCLOS from 1982), each WCR country is responsible for managing the marine environment of its territory. Due to the closeness of a large number of countries, almost the entire marine environment of the WCR falls within one EEZ or another resulting in the fact that their management falls under national jurisdiction (UNEP, 2008). The Guianas- Brazil Region, Southeastern US and the Gulf of Mexico have their own LMEs within the WCR (Fanning et al, 2007). Hypothetical Exclusive Economic Zones (EEZs) and Large Marine Environments (LMEs) in the WCR are shown in Figure 34.

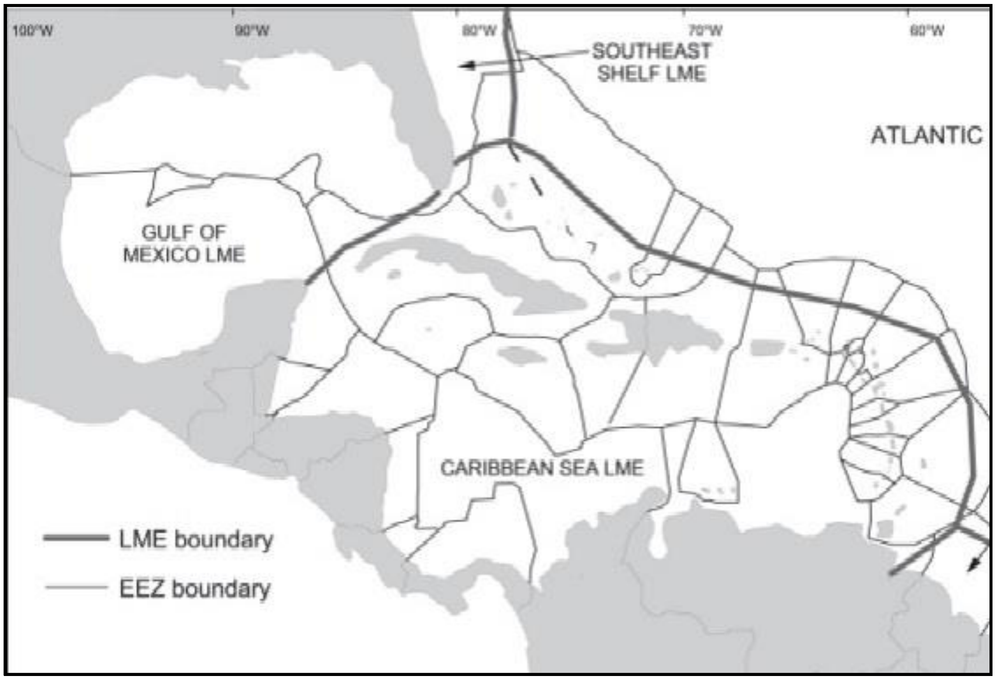

Figure 34: The Hypothetical EEZs and LMEs of the WCR (Fanning et al., 2007)

The current extent of MPAs in the region is dispersed and represents only 1.5% of all coastal and marine systems in the Caribbean and MRs cover only 0.1%. (Guarderas, 2008). Hence, it is beneficial to consolidate these fragmented areas into larger networks. Successful MPA networks promote full protection of critical areas, effective management, risk spreading and biological and ecological connectivity (IUCN, 2008). Additionally, given the challenge of a wide variety of MPAs with differing local legislation, socioeconomic factors and language barriers in the WCR, it is important for MPAs to establish homogeneity in biodiversity conservation and legislation for optimal MPA management results. The most efficient way to ensure this is through MPA networks. MPA networks are valuable management tools as science continues to show more evidence of the importance of resilience in the face of climate change, natural disasters, biological connectivity and social, political and economic fluxes (IUCN, 2008). The existing wider networks of collaboration of MPAs across the WCR are mainly three; the Caribbean Large Marine Ecosystem (CLME), Caribbean Marine Protected Areas Management CaMPAM and the Caribbean Challenge Initiative (CCI). The CLME is an intervention of the GEF to facilitate the sharing of natural resources, improve governance sustainability and create a more homogenous network of MPAs (UNDP, 2005). “The overall goal of the CLME project is the sustainable management of the shared living marine resources of the Caribbean LME and adjacent areas through an integrated management approach that will meet the World Summit on Sustainable Development target for sustainable fisheries" (UNDP, 2005).

CaMPAM is more of a research institution that promotes the important task of collecting and sharing information on WCR MPAs in a database (also online; campam.gcfi.org) and was created in 1995 under the UNEP-CEP and the SPAW Protocol of the Cartagena Convention (UNDP, 2005). Researchers, managers, educators, administrators, the private sector, NGOs and non-NGOs have formed a network for the exchange of information in CaMPAM. CaMPAM conducts research on effective MPA management and organizes workshops and training sessions for MPA managers all over the wider Caribbean (UNEP-CEP, 2007).

The Caribbean Challenge Initiative (CCI) is an initiative of The Nature Conservancy (TNC) and started in 2008 with the goal of protecting 20% of the marine and coastal habitats of WCR countries by 2020 (CCI, 2013). According to TNC three goals of the Caribbean Challenge are; the creation of MPA networks across 21 million acres, establishing sustainable funding mechanisms for effective management and promoting climate change adaptation of these areas (TNC, 2005). Governments participating include Antigua & Barbuda, Bahamas, British Virgin Islands, Dominican Republic, Grenada, Jamaica, Puerto Rico, St. Kitts & Nevis, St. Lucia, and St. Vincent & the Grenadines and this is expanding (TNC, 2014). These countries and their designated CCI marine corridors can be observed in Figure 35.

Figure 35: Countries and Location of Marine Corridors in the CCI: A marine corridor between the Dominican Republic, Puerto Rico, USVI and BVI (TNC, 2014)

It is beneficial for any Caribbean nation to integrate their MPAs into any of these three aforementioned MPA networks as nations implementing legislation together and deciding on how to implement regional policy cycles through participatory processes is more efficient for WCR conservation (Grober-Dunsmore & Keller, 2008). The current systems of MPA networks shows promise but they need to be adapted to represent the different bio-geographic provinces and eco-regions (they are present in some and absent in others) which allow for the protection of biodiversity, in particular, of migrating species (Guarderas, 2008). These bio-geographic regions (regions with a particular biodiversity distribution that share similar characteristics) are illustrated in Figure 36. They were determined through an array of geopolitical and bio-geographical (similar flora and fauna plant distributions over a geographic area) considerations (Bustamante & Paris, 2008). The regions contribute to interconnected sustainable ecological, social and economic development goals within the political complexity and the high biodiversity of the WCR (Bustamante & Paris, 2008). The listed MPA networks are a good start, however, they should be adapted to cause the least loss of biodiversity possible across regions and more networks should be developed (networks within networks). Loss of biodiversity causes a loss in economic security (the WCR tourism industry depends on healthy coral reefs and viable beaches that can be promoted through MPAs) and a loss in food security (reef catches and fisheries) (Cherian, 2006).

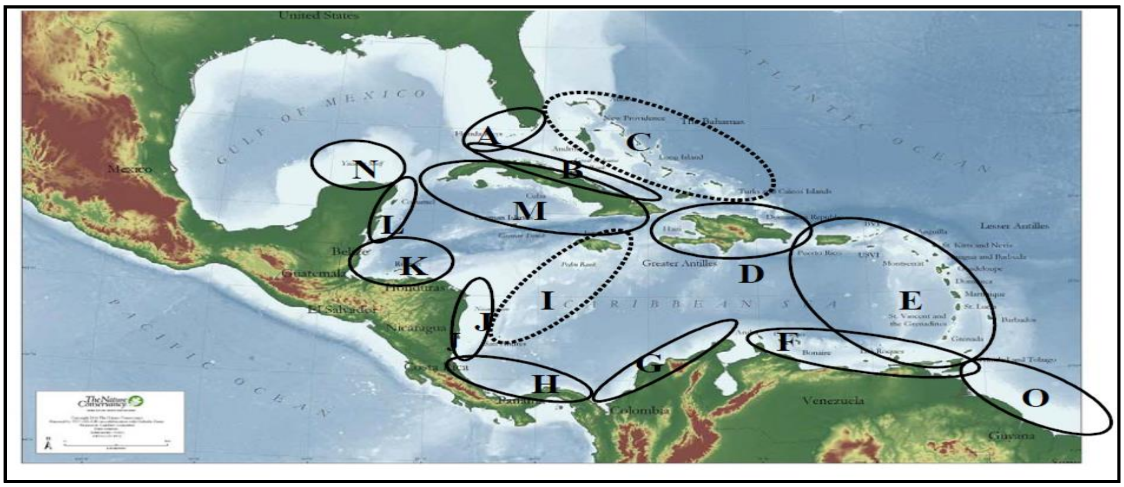

Figure 36: Proposed TNC Bio-geographic Regions for the WCR (Bustamante & Paris, 2008) (A- Florida; B - N Central Cuba- Cay Sal; C - Bahamian; D. Hispaniola; E - Puerto Rico – Lesser Antilles; F- S Caribbean; G - Continental Colombia; H - Panama-Costa Rica; I - Colombian Archipelago & Jamaica; J - Nicaraguan Rise Islands; K - Gulf of Honduras; L - Mexican Caribbean; M - NW-S Cuba & Cayman Islands; N - Campeche Bank; O - Guianan)

It is important in MPA network planning and management to take into account different abiotic components like bathymetry and current. We can further appreciate the bio-geographic necessity of delineating MPA networks to further marine connectivity (especially for pelagic migratory species) by aligning them in relation to the bathymetry and currents of the WCR (for optimal marine corridors) between MPAs (Figure 37).

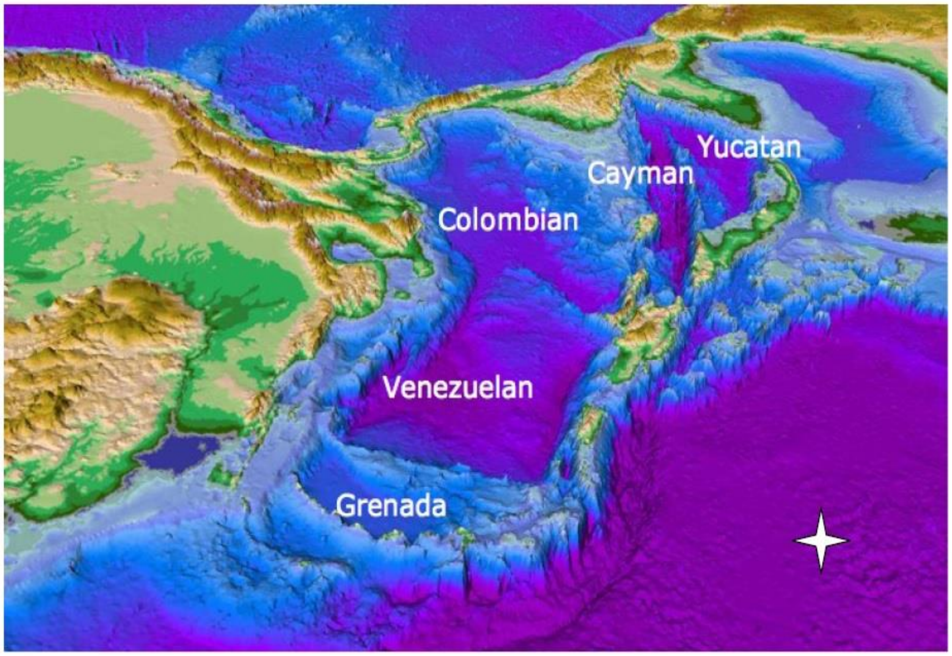

Figure 37: Satellite data of the Basins of the WCR; the Cayman Basin has depths that surpass 5000 m (Bustamante & Paris, 2008)

Understanding the connectivity among these bio-geographic regions and their MPAs is key to the conservation of fisheries and biodiversity in the WCR. A combination of mitigation and adaptation policies need to be integrated into coastal zone management plans and MPAs in order to combat climate change in coastal areas (Nicholls & Lowe, 2012). This becomes especially complex in the WCR where MPA networks are great integrated management of marine resources across the region. MPAs forcibly conserve ecosystems that extend beyond their designated boundaries and MPA networks are windows into a better understanding of the connectivity across spatial scales, time scales and species that are so important in the management of WCR MPAs (Grober-Dunsmore & Keller, 2008).

5.2 Recommendations for Information Collection and Communication within MPA Networks

As a result of MPA networks having multiple objectives and stakeholders in different countries of the WCR, information collection and communication is extremely important for the successful management of MPA networks (data on spatial scales and species, data on time scales, passing legislation, participatory management, policy cycles, etc). It is ideal to have good data collection and standardization (agreed-upon indicators amongst stakeholders) and correct monitoring and evaluation processes across MPA networks. There are crucial gaps in data among MPAs in the Caribbean (Bustamante & Paris, 2008). This needs to change for the connectivity of the MPA network to make sense. One of the key indicator sets used within MPA networks are biological responses (biomass, size and density of animals) (FAO, 2011). Indicators for fisheries within MPA networks could be catch rates and fish density and can be used to generate fisheries management measures. Socioeconomic indicators could be changes in income, disparities of wealth, effects of MPAs on economic equity among coastal communities (fishermen, divers, seasonal workers, etc.). Other indicators based on governance could be the linkage of the MPA to local, national and regional policy objectives or adequate financial expectations in relation to logistics (FAO, 2011).The most relevant information is needed and a broad range of data and sources of information should be used. Information gathered within MPA networks should be useful, practical, holistic, balanced and flexible (IUCN, 2008). Data should come from primary and secondary sources; scientific research and participatory research with communities that use MPA resources (elders, fishermen, dive operators, etc.). These two types of data are complimentary and important in MPA and MPA network planning, monitoring and evaluation processes.

Data collection and processing in MPA networks can be enhanced with the following steps:

1. Develop MPA profiles (to highlight their connectivity) for each MPA within the network in conjunction with the interested stakeholders. These profiles are essential tools for MPA planning and are used as baseline data for future monitoring and evaluation of the MPAs. The profiles should include at least four assessment components; ecological and biological, social, economic and financial and governance and institutional. From a fisheries management perspective, detailed information on fisheries is important for the areas (fish stocks, which should be focal species to be conserved, information on adult and juvenile fish, areas where by-catch are high, sea bottom quality and morphology, etc.). The analysis of fishing vessel logs, conducting scientific surveys or placing observers on fishing vessels can help achieve this goal. This may also need to be done seasonally to account for fluctuations in fish distributions within MPA networks. Participatory mapping or estimations from local fishermen may also be useful in fisheries management across the MPA network. One must also assess if the evaluators are internal (biased) or external. Ideally, there should also be an implementation feasibility assessment for each MPA within the network (IUCN, 2012).

2. Create working groups like the TAC in SMMA where there is a lot of exchange of information, technical discussions and learning experiences among interested stakeholders. This will create a learning network of sorts that can be used to pull together and collect information on a local, national and regional level. A formal agreement may have to be made between stakeholders in the MPA networks to allow access to relevant information for reporting in different countries depending on protocols. One must identify, in conjunction with the stakeholders, if there are any significant gaps or discontinuities in data for the MPA network.

3. Use different evaluation tools; an MPA network score card that measures progress on a broad scale, provides indicators of change and can be compared. One can also use

questionnaires that measure effectiveness of MPAs within the network (progress made towards goals, achievement of short-term, mid-term and long-term targets, monitoring of progress and outcomes written as smart objectives) to obtain an overall score of MPA network health. These tools can be disseminated through snail mail, email, on websites to fill out or during working group meetings. Robust performance indicators and baseline data should always be included in carefully designed monitoring systems for MPA networks (IUCN, 2004).

4. Determine if and MPA is already part of another MPA network. If this is the case, one also needs to collect data from this larger plan or network or see if it is already available in order to avoid duplicity.

5. Conduct on-site visits, investigations and inspections with designated staff in conjunction with working group members of each of the MPAs in the MPA network. This can be especially useful when there are information gaps identified by stakeholders or verification of data is needed. In these cases one can rely more on the good judgment of the stakeholders while information is being collected. If scientific baseline data is missing, one may have to rely more on participatory data. Also, the relevance of such data can sometimes best be inspected and checked firsthand for the effectiveness of adaptive management measures. (IUCN, 2004)

6. Use decision-making support tools such as the ones described below.

a. Use an online platform that can be established by the MPA network for data collection from the working groups. Each working group from an MPA is allowed access to the site and trained on how to enter data (type, formats, etc) in order to establish the best database for generating accurate indicator values across the MPA network. This platform could include GIS tools (using MarSIS as an example in the Grenadines), remote sensing tools, scenario development tools and modeling tools (here one could ideally incorporate climate change models for different MPAs in the network). E.g. Marxan and Marzone have been developed in Canada (and accepted by NOAA) as GIS based decision-making tools to help MPA managers with zoning issues (Office of the Auditor General of Canada, 2012).

b. Use other online platforms like the global and regional CaMPAM MPA, LMMA and CLME network data platforms. One could assist in the expansion of this effort. These can be used to produce summary reports on additional MPAs or networks (Fanning et al., 2011)

c. Use Google Apps (just an idea) like "Explore the Ocean" launched by the Sylvia Earle Alliance through Mission Blue. The Global Foundation for Democracy and Development (GFDD) has given workshops in conjunction with Mission Blue on how to use this platform in the Dominican Republic. This system is used to create online "Hope Spots" (biodiversity hotspots) databases with participatory information. Mission Blue is a global network of marine protected areas.

7. Deal with information and data insufficiency situations that can arise in MPAs with high biodiversity in tropical areas (this is definitely the case in Les Trois Baies provisional MPA in Haiti and to some extent in Los Haitises National Park in the Dominican Republic and the others). If there is a real shortage of information, one should resort to international law such as UNCLOS which state that MPA management should be based on best available data and should not be delayed in the absence of information. In these cases, participatory data collection is even more important (on site and from different sources).

8. Determine that reports are clear to multiple stakeholders who may not be receptive to scientific and management jargon.

5.3 Recommendations for good management practices in Dominican MPAs

The Dominican Republic should rely on a country specific climate integrated MPA management plan (Gable et al., 1990; Herrera-Moreno et al., 2011). Management strategies (many have been mentioned in the PNE and Montecristi MPA case studies) for MPAs need to urgently include the protection of coral reefs (Guarderas, 2008). Effective no-take compliance within MPAs is a general WCR problem (only 16% reported compliance) including the Dominican Republic where there is no compliance at all as resource users do not want to compromise their livelihoods and receive no compensation from the government for not fishing (Guarderas, 2008). The no-take compliance issue is exacerbated in MPAs that border Haiti (Monte Cristi and Jaragua MPAs) where it is even more difficult to impose no-take policies because of illegal Haitian fishermen, inadequate patrol boats and illegal drug trafficking routes through MPAs. In fact, drug traffickers have established entire bases (with no road accesses) within Dominican MPAs where park personnel are also involved (Heredia, 2009).

Good ways of strengthening MPA practices in the Dominican Republic are: 1) improving the enforcement and implementation of existing MPAs through a military program (this was effectively done in the past under President Balaguer (Heredia, 2009); 2) adding new MPAs and MRs to existing networks that promote national connectivity and sustainability (especially in the all-inclusive Punta Cana/ Bavaro Region) and 3) establishing new networks of MPAs (in-country and international) or mixed-use MPAs to try to provide protection where little exists (again, especially true for the Punta Cana/ Bavaro Region) (Guarderas, 2008). Other additional steps to take are to increase investigation and monitoring (investing in modern hydrological stations and buoys) of coastal and marine ecosystems and fisheries as much data is missing to base future management decisions on (Heredia, 2009). Baseline data is needed to be able to properly estimate MPA changes including climate change effects, reduce overfishing correctly, supervise health problems (red tides, ciguatera) and promote alternate sources of revenue for fishermen like environmentally sensitive aquaculture (Tilapia farms have been erroneously established in vulnerable areas due to lack of baseline data (Geraldes 2001).

Other steps could be to reinforce a nation-wide coastal management plan as part of municipal land use planning processes, establish a methodology to observe and quantify the evolution of coastal zones and their ecosystems, create and maintain a reliable national oceanographic database according to international norms, create educational national outreach programs about coastal and marine zones that address different audiences in the public and include the component of climate change in all of the above (Herrera- Moreno & Betancourt 2001, Cherian, 2006). The above points are much easier for MPA management to carry out as part of an international MPA network (like CLME or CaMPAM) instead of relying on national resources that are inevitably affected by a lack of political will and corruption. Good management practices for marine protected areas in the Dominican Republic would have to include an educational program at the national level, the implementation of co-management agreements for these areas, increased monitoring and enforcement control of MPAs, increased materials from institutions and equipment (boats to monitor MPAs and park personnel), financial sustainability of MPA areas, strategic partnerships with NGOs (national and international), multi-lateral organizations, local government and municipalities (Heredia, 2009).

There needs to be an effective gathering and management of scientific information (balance scientific rigor with immediate management necessities) in order to direct MPA decisions and set priorities towards cost-effective protection (Chiappone, 2001(part 3)). It is important to note that in Cuba and the Dominican Republic fishing and tourism is of equal importance in MPA systems (50% each), whereas in other areas of the Caribbean tourism accounts for 80% of MPA use (CANARI, 2001). It would be beneficial, in this light for Cuba and the Dominican Republic to engage in a joint MPA network program (which would also include parts of Haiti). From 1954 until 2004 scientists have mainly focused on the eastern and southern coastal areas of the Dominican Republic and not enough research has been carried out on coastlines adjacent to MPAs and possibly 60% of the Dominican coastline remains unstudied. (Geraldes et al., 2003). (Geraldes et al., 2003). One could encourage more joint investigations funded by both governments as carried out by Ecomar (Herrera-Moreno & Betancourt, 2001). Some Dominican MPAs like Montecristi, Jaragua and Samana have been researched and have been included as pilot areas under the GEF/UNDP/ONAPLAN *Conservation and Management of Coastal Marine Biodiversity in the Dominican Republic* project (Herrera-Moreno & Betancourt, 2001).

It would be of benefit to increase tourism to MPAs in the Dominican Republic by encouraging user fees as has been mentioned in the sections on the Case Studies and to model it after the BNMP Demonstration Site. However, there is no political or financial support for these types of initiatives in the Dominican Republic and, again, it would be easier to carry this out with the backing of an MPA network. Table 21 is a qualitative list of Coastal Zone Management problems that affect all MPAs that need to be addressed individually in the Dominican Republic.

We have seen that both SSMA and BNMP have high levels of MPA management and completely functional fee systems (CANARI, 2001). These fee systems should be urgently applied to Dominican Republic MPAs in order to promote self-sustainability. The Dominican Republic saw a record number of 4.7 million tourists in 2013 (most of them were in the Punta Cana, Bavaro Region) and tourism is one of the main sources of income for the country (WRI, 2010). A national network of MPAs should be established together with an MPA in the Punta Cana/ Bavaro all-inclusive tourist region as MPA fees could be supported by the economies of the local communities (tourists would pay a fee to use coastal resources as part of their all-inclusive package, for example). With coastal and marine resources rapidly being depleted and the area being highly vulnerable to climate change effects (rapid erosion of beaches, flooding, etc.) sustainable solutions to conservation of marine and coastal resources should be a priority and a fee-system would generate income that would facilitate this. If steps are not taken to properly manage these coastal zones the future of the booming all-inclusive tourism industry will be jeopardized as tourists will go elsewhere in the long-run, especially with neighboring Cuba opening up (WRI, 2010). See Figure 38 for the vulnerability of the Punta Cana /Bavaro Area (easternmost coast of the Dominican Republic facing the Mona Channel) to climate change. The red lines are areas of high vulnerability and the green areas are prone to storm surges.

Table 21: Qualitative list of Coastal Zone Management problems that affect MPAs in the Dominican Republic (Heredia, 2009)

1.	Contamination of estuaries, lagoons, coastal areas and MPAs with organic and inorganic waste from point source and non-point sources
2.	Privatization of beaches and coastal zones.. HUGE PROBLEM ON ALL COASTS
3.	Deposits of waste in coastal zones and around MPAs; rock ash, medical waste and heavy metals from other countries
4.	Building of ports and canals in inappropriate areas
5.	Destruction of coastal vegetation
6.	Destruction of dunes
7.	Destruction of turtle nesting grounds due to four wheeling and illegal activities
8.	Dredging of waters off coastlines that cause beach erosion
9.	Destruction of marine life (manatees and dolphins) due to jet skis, boats and/ or illegal capture and fishing
10.	Proliferation of land- based marine parks that distort public understanding of MPAs as a result of 9 (Ocean World Cofresi, etc)
11.	Destruction of capes, beaches, watersheds, mangroves, river mouths and estuaries for construction materials
12.	Extraction of sand from protected areas to rebuild eroded tourist beaches
13.	Destruction of reefs (black coral in particular) for jewelry and other decoration
14.	Destruction of sea grass beds to allow for a "picture perfect" tourist beach
15.	Lack of planning in coastal infrastructure (60 meters from high water mark rule is not respected in most tourist areas)
16.	Drying of lagoons and mangrove areas for the direct building of tourist infrastructures
17.	Overfishing in all areas and lack of enforcement of existing laws
18.	Loss of areas for artisanal fishermen
19.	MPAs carrying capacities are not respected AT ALL
20.	Not enough surveillance by boats and other technologies..Illegal Drug Traffickers
21.	General lack of awareness and general education of the population about MPAs and CZMT/ tied in with illiteracy and low educational level of the Dominican Public
22.	Climate change effects not well understood within the MPA setting by most local authorities

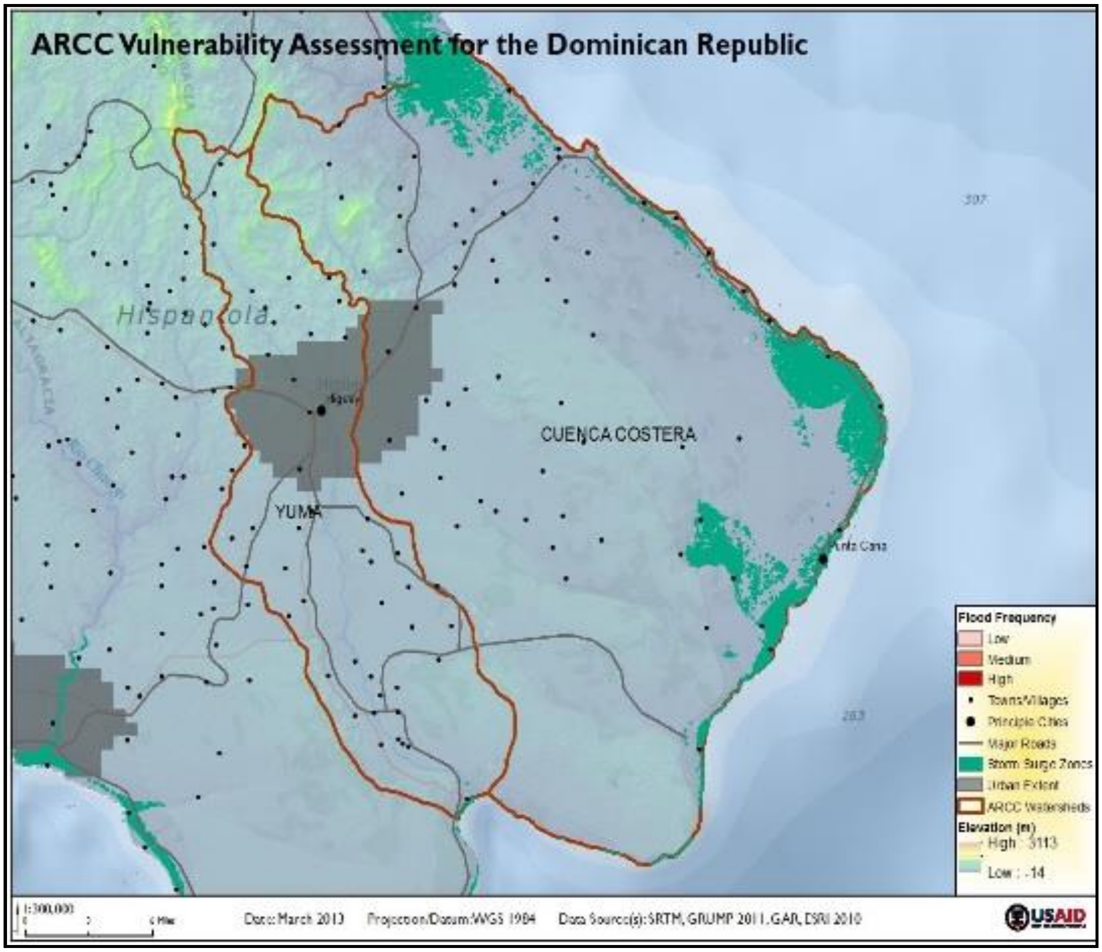

Figure 38: Vulnerability of Punta Cana/ Bavaro Region to Climate Change Effects (USAid, 2013)

Dominican MPAs need to evolve from being "paper parks" to functional protected areas. For MPAs and CZMT to be successful in the Dominican Republic there needs to be more technical expertise in-country and professionals need to be educated and trained in the field. Currently there are no degrees offered at Dominican universities in CZMT. Only UASD offers a degree in Marine Biology and INTEC has a Master’s Degree Program in Environmental Education which includes aspects of CZMT. Both universities offer postgraduate courses in climate change. More programs and courses need to be developed in marine and coastal resources management in the country.

Another major stumbling block is the lack of political will to address MPAs and the lack of transparency of administrative and legal structures that regulate human development activities which affect them. A situation exacerbated by an exploding urban population along Dominican coastlines. For MPAs to have enforced legislation and homogenous management there needs to be one centralized Dominican institution acting as the main decision-maker on a governmental and non-governmental level. Currently CNCCMDL publishes national reports on climate change for all sectors (including MPA management) and suggests legislation, SEMARENA has its own programs and several international and national NGOs have management programs in MPAs (Thomson, 2003). The aforementioned do not coordinate with each other to degree. A suggestion to improve coordination would be through the formation of a Directorate of Conservation and Coastal and Marine Resources at SINAP which would designate a technical team for each region with planning and monitoring authorities for MPAs in those regions (Thomson, 2003). Institutions responsible for protecting and patrolling coastal areas need to be trained in MPA legislation enforcement and supported by the Dominican Government such as Sectur, the Port Authority, CODOPESCA and the Dominican Coast Guard (Heredia, 2009). Changes of government in the Dominican Republic make it difficult to keep institutions on track because new governments normally do not continue the work of old governments (every 4 years in the Dominican Republic). Regardless of which political party is in power, MPAs in the Dominican Republic need better protection from political change as this allows them to adapt to climate change while maintaining valuable national genetic biodiversity (Herrera-Moreno & Betancourt, 2001).

Coastal Zone Management and MPA Management are not mentioned in detail as a mechanism for the sustainability of coastal marine resources under the Dominican 64-00 law and this needs to be urgently updated (Heredia, 2009). Under Law 64-00, the 1962 Fishing Law (5.914) and the 303 Decree from SINAP for the protection of mangroves (Law 319/ 1997) as well as the law for the protection of marine species within MPAs (200/1999) need to be updated as this would allow for more competent MPA and CZMT management practices (Heredia 2009; Geraldes, 2003).

Given the enormous economic and cultural importance of the coastal environment to the Dominican Republic, there should be an increased effort placed on the collection of data on chemical pollutants and this should be a serious concern (Van Lavieren el al., 2011). An effort needs to be made to improve and monitor land management adjacent to reefs in MPAs and MPA networks in order to improve water quality and minimize the effect of POPs (Heredia, 2009). The Dominican Republic does not have appropriate information on the risk of toxic chemicals. Contaminant loads and the risk that pollutants pose to the environment and public health and this needs to be updated (Van Lavieren et al., 2011). Another effort is needed to improve the environmental quality of coastal zones and adjacent land areas instead of focusing on specific instances of pollution that need to be mitigated in a crisis mode (Van Lavieren et al., 2011). In order to embark on these efforts, investment in appropriate infrastructure in order to properly process industrial and domestic waste water and deal with runoff from the tourism sector (especially in the eastern Dominican Republic) and industry (in the Ozama and Haina Rivers that limit Santo Domingo) is required. A new waste water treatment plant named la Zurza II is being built (funded in part by Deutsche Bank) along the Ozama River to help with the elimination of raw sewage along Santo Domingo's coastlime (CRIS Program, USAid, 2014).

In summary, MPA management practices in the Dominican Republic require a major overhaul. Fisheries need to be more sustainable (with better yields), conflict management needs to be integrated into adjacent areas of the MPA and buffer zones (watersheds and adjacent marine areas), more public participation in the management processes of MPAs needs to take place and there needs to be better dissemination of MPA information to the public and stakeholders in the form of media, meetings and information (Geraldes, 2003). The public and government perception of MPAs and CZMT needs to evolve. Early MPA management and climate change adaptation is more effective, less expensive and improves resilience as opposed to the restoration of a seriously polluted or damaged MPA (Herrera-Moreno & Betancourt, 2001). The Dominican People do not have a strong sea tradition as other neighboring countries and the population mostly lives with its back towards the sea. In order to keep the public interested in participating in decision-making processes of MPAs, entertaining and simple campaigns would be effective. Below (Figure 39) one can see an idea where it is made evident that sharks are a sign of a healthy ecosystem and a properly managed MPA (food fish could also be included in the last image so there are not only sharks).

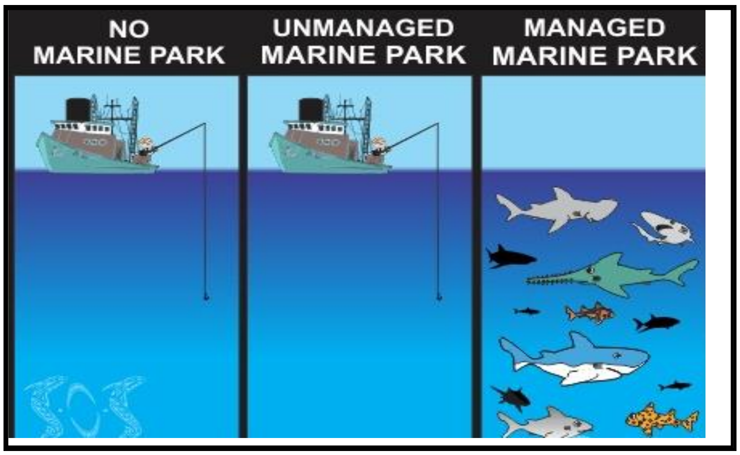

Figure 39. Original Media in favor of Marine Parks (supportsharks.org)

A huge obstacle for Dominican MPAs is to try and address financial constraints. The lack of resources and lack of transparency in the allocation of international funds plague MPAs on a national level. The funds simply disappear. Again, the inclusion of Dominican MPAs into regional MPA networks would allow for stricter regulation and supervision of finances (Heredia, 2009). Given the Dominican Republic's dependency on the International Monetary Fund and the Inter-American Development Bank (BID in Spanish), loans contingent upon stricter policies on the integration of climate change factors and environmental sustainability could promote the enforcement of MPA legislation nationally. Corruption is a big hurdle in sustainable environmental policies in developing countries like the Dominican Republic (coastal and non-coastal) and those in power will not willingly apply them, inform the public about them or make them a priority. A better understanding of the economic value of an MPA by the public and government, including the relationship between socioeconomic activities and changes in

MPAs, will further promote necessary changes in MPA management and will inevitably strengthen societal and political support for these changes (Heredia, 2009).

Revised management processes for Dominican MPAs (Table 22) should make sure that:

Table 22: (Chiappone, 2001, part 1)

1.	Management objectives are social choice based
2.	MPAs should be managed taking into account the human context
3.	MPAs should be managed within their natural limits
4.	Change is part of the MPA Management Process
5.	MPA management should be done at a suitable scale
6.	MPA management needs to act locally but think globally (MPA networks)
7.	MPA management must be carried out according to social choice
8.	Scientific Tools and Data should be used by MPA Managers
9.	Caution should be carried out during MPA Management
10.	MPA management is multidimensional and multi-disciplinary

5.4 The Multidimensional MPA approach as a win-win solution

Without integrated approaches to coastal zone and multidimensional MPA management many WCR nation economies (that heavily depend on tourism and fisheries) will not be sustainable long-term (Van Lavieren et al., 2011; Claudet 2011). I have mentioned some of the disadvantages of multidimensional MPAs. However, overwhelmingly, I have discussed the huge array of benefits that MPAs can offer all throughout this paper. Fish density and diversity is directly proportional to the duration of protection of an MPA area (Alvarez et al., 2011). MPAs result in an average increase in coral cover of 1-2% per year (Selig et al., 2012). MPAs foster the increase of herbivorous fish (parrot fish) which decrease micro algal dominance (growing on exposed surfaces of dead coral) caused by climate change and marine diseases (like white band disease) accelerating the recovery of corals within the MPAs (Aronson & Precht, 2006). Single limited-take MPAs as opposed to multidimensional MPAs are often not of adequate size to conserve biodiversity that is representative of the region or to provide adequate protection for species with complex life histories across wide areas (Guarderas, 2008). MPAs have been shown to help encourage reef-building coral dominance and have had positive effects on coral cover over time (as opposed to non MPA areas where unprotected reefs kept declining) by facilitating coral recruitment, limiting algal growth and also through the management of fisheries (eliminating destructive methods i.e., trawling) (Selig et al., 2012). We have seen that MPAs can build up reef resilience if management is largely focused on reducing human induced damage in order to promote natural climate change resilience mechanisms (Wilkinson & Souter, 2005)

A multidimensional MPA that integrates the preservation of biodiversity (with accompanying promotion of ecotourism) and resilience to climate change will be successful as long as technical capacities are enhanced and access to information and cooperation is facilitated among the widest range of regional and national stakeholders (Cherian, 2006; Montero, 2002; Claudet 2011). It is clear, that multidimensional MPA management consortia work well as long as they are fine-tuned over time in order to increase their effectiveness (as in the cases of SMMA and Bonaire) (CANARI, 2001). Multidimensional MPAs and MPA networks fulfill both social, economic and ecological objectives while fulfilling their roles as effective climate change resilience mechanisms. Dominican MPAs are all affected by poverty and effective multidimensional MPA management can help improve the quality of life in adjacent communities (CANARI, 1998). MPA networks increase the overall effectiveness of multidimensional MPA management in the Caribbean and, in particular, in the Dominican Republic by providing more regional political leverage, transparency and finance mechanisms. Table 22 in Appendix A lists some of the numerous benefits of multidimensional MPA management that I have provided in this paper. They protect ecosystems, improve fishery yields and enhance non-consumptive opportunities (modified from Chiappone, 2001). MPAs and MPA networks that are complemented with strategies to try to regulate the effects of adjacent land use are successful win-win solutions in the WCR (Mora, Camilo. 2008). In comparison to other alternatives, MPAs and MPA networks are the best conservation, socioeconomic and climate resilience long-term win-win solutions in marine resource management for the Dominican Republic. However, effective management and policy on a broad scale to address environmental issues and anthropogenic climate change effects, multidimensional MPAs and MPA networks alone will not be as effective as ecosystem-based climate change resilience mechanisms. Stand-alone MPAs and MPA networks are isolated protected areas in a sea of degradation (IUCN, 2008). They need to be integrated as tools into international commitments and strategies to build resilience to climate change for an increasing world population with access to finite resources.

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Appendix A

Ecosystem Structure/ Function	**Improve Fishery Yields**	**Expand Understanding**	**Non-consumptive opportunities**
• keep biodiversity intact at all levels • protect food webs • safeguard ecological processes • maintain trophic structure • protect natural population structure • retain keystone species • sustain species presence and abundance • prevent loss of vulnerable species • preserve natural community composition • eliminate second-order impacts • maximize system resilience to stresses • avert cascading effects • maintain physical structure of habitat • preclude threshold effects • preclude fishing gear impacts • avoid incidental damage • retain natural behaviors and interactions • maintain high quality feeding areas	• protect spawning stocks • increase spawning stock biomass • raise population fecundity • enhance reproductive capacity • increase spawning density • provide undisturbed spawning sites • ensure viable spawning conditions • improve spawning habitat • boost egg and larval production • provide export of eggs and larvae • enhance recruitment • supply spill-over of juveniles and adults • reduce chances of recruitment over-fishing • decrease over-fishing of vulnerable species • mitigate adverse genetic impacts of fishing • reduce inadvertent and bycatch mortality • protect diversity of fishing opportunities • maintain sport trophy fisheries • simplify enforcement and compliance • help reduce conflicts among users • provide information from unfished	• foster understanding of natural systems • provide experimental sites for natural areas • permit knowledge continuity of unaltered site • retain memory of natural systems • enable study of relatively intact ecosystems • allow study of natural behaviors • provide long-term monitoring areas • reduce risks to long-term experiments • offer foci for study • enhance synergy from cumulative studies • allow research and monitoring that require natural sites • provide controlled natural areas for assessing anthropogenic impacts	• enhance and diversify economic activities • improve non-consumptive recreation • improve peace-of-mind • enhance aesthetic experiences • increase wilderness opportunities • promote spiritual connection • foster sustainable employment opportunities • diversify and stabilize economy • enhance conservation appreciation • create public awareness • reduce room for Irresponsible development • foster constructive social activity • encourage holistic approach to management • provide otherwise unavailable educational opportunities

	populations necessary for proper management of exploited stocks • improve management and increase efficiency with limited resources and data • insure against stock collapse due to management failures and speed recovery • increase understanding and acceptance of management • facilitate stakeholder and user involvement in management		