CHAPTER FOUR

Marine Managed Areas and Associated Fisheries in the US Caribbean

Michelle T. Schärer-Umpierre[*,†], Daniel Mateos-Molina[†,‡,1], Richard Appeldoorn[†], Ivonne Bejarano[†], Edwin A. Hernández-Delgado[§,¶], Richard S. Nemeth[‖], Michael I. Nemeth[†], Manuel Valdés-Pizzini[#], Tyler B. Smith[‖]

[*]Interdisciplinary Center for Coastal Studies, University of Puerto Rico, Mayagüez, Puerto Rico
[†]Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico
[‡]Departamento de Ecología e Hidrología, Universidad de Murcia, Campus de Espinardo, Murcia, Spain
[§]Center for Applied Tropical Ecology and Conservation, Coral Reef Research Group, University of Puerto Rico, San Juan, Puerto Rico
[¶]Department of Biology, University of Puerto Rico, San Juan, Puerto Rico
[‖]University of the Virgin Islands, Center for Marine and Environmental Studies, St. Thomas, U. S. Virgin Islands
[#]Department of Social Sciences, University of Puerto Rico, Mayagüez, Puerto Rico
[1]Corresponding author: e-mail address: dmateos5@gmail.com

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Abstract

The marine managed areas (MMAs) of the U.S. Caribbean are summarized and specific data-rich cases are examined to determine their impact upon fisheries management in the region. In this region, the productivity and connectivity of benthic habitats such as mangroves, seagrass and coral reefs is essential for many species targeted by fisheries. A minority of the 39 MMAs covering over 4000 km^2 serve any detectable management or conservation function due to deficiencies in the design, objectives, compliance or enforcement. Fifty percent of the area within MMA boundaries had no-take regulations in the U.S. Virgin Islands, while Puerto Rico only had 3%. Six case studies are compared and contrasted to better understand the potential of these MMAs for fisheries management. Signs of success were associated with including sufficient areas of essential fish habitat (nursery, spawning and migration corridors), year-round no-take regulations, enforcement and isolation. These criteria have been identified as important in the conservation of marine resources, but little has been done to modify the way MMAs are designated and implemented in the region. Site-specific monitoring to measure the effects of these MMAs is needed to demonstrate the benefits to fisheries and gain local support for a greater use as a fisheries management tool.

Keywords: U.S. Caribbean, Coral reef fishes, Co-management, No-take zone, Enforcement, Fisheries resources, Compliance, Habitat connectivity

1. INTRODUCTION

1.1. Bio-physical settings

Puerto Rico (PR) and the U.S. Virgin Islands (USVI) are located on the Puerto Rican Bank along with the British Virgin Islands at the eastern extreme of the Greater Antilles (Figure 4.1). These two U.S. territories and surrounding waters out to 200 nautical miles (Nm) compose the U.S. Caribbean exclusive economic zone (EEZ). The Puerto Rican Shelf is delimited by the Mona Passage to the west, the Anegada Passage to the east and the Puerto Rico Trench to the north, which is the deepest point in the Atlantic Ocean. South of the Puerto Rican Shelf, the Virgin Island Trough separates the insular platform of St. Croix with depths up to 4200 m. Shallow marine ecosystems of the U.S. Caribbean islands are characterized by coastal coral reefs, near-shore fringing mangroves and extensive seagrass beds. Mangroves and coastal wetlands provide important ecological services, such as sediment and nutrient retention, storm buffering and, along with seagrasses, include areas of fish and shellfish nursery habitat essential for the juvenile phases of many commercially important species. Coral reefs extend throughout the insular platforms and provide the greatest area of

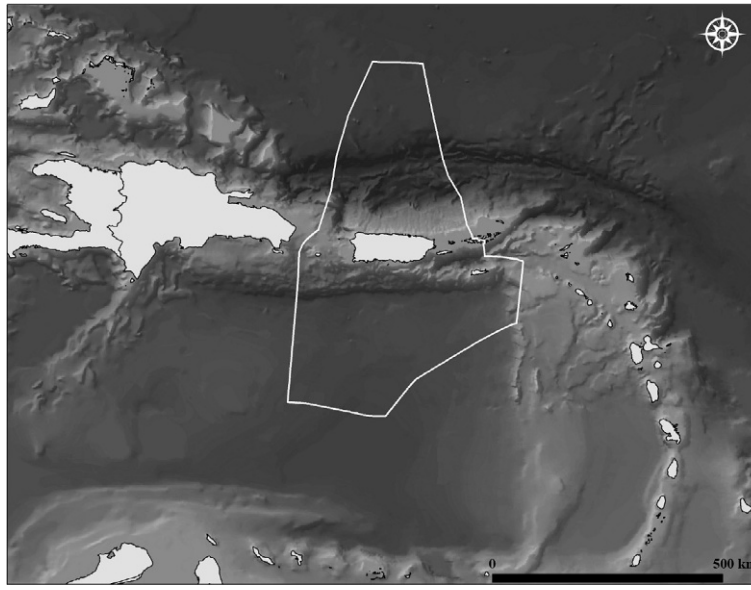

Figure 4.1 The U.S. Caribbean exclusive economic zone.

benthic habitat to depths of 80 m in sites with clear waters. Various marine species considered endangered or threatened (IUCN) are present such as sea turtles, manatees, whales and a few coral and fish species (Waddell and Clarke, 2008; Weil, 2005).

1.2. Marine fisheries

The marine fisheries of PR and the USVI resemble those of other Caribbean Islands with similar geography and history. Aboriginal people of the Caribbean are known to have subsisted on near-shore marine resources prior to the 1500s, since archeological studies of the *Taíno* Indian middens have uncovered evidence of a diversity of molluscs, fish and sea turtles. Although limited in technology, there is some description of fishing weirs and traps used by the *Taíno* and adopted by early settlers of the islands. The impacts of artisanal fisheries upon Caribbean marine ecosystems were significant prior to the 1800s (Hawkins and Roberts, 2004; Jackson, 1997; Wing and Wing, 2001). Since the nineteenth century, the impacts of human development upon coastal and marine ecosystems have been extensive including pollution and sedimentation from agriculture, military activities, industrialization and shifts in land-use patterns (Valdes-Pizzini et al., 2012).

These are important points to bear in mind when studying the region's fisheries due to the shifting baseline syndrome (Pauly, 1995).

More recently, the fisheries of Caribbean islands suffered changes in technology that allowed expansion in terms of fishing grounds, effort and target species. The most notable of these advances include refrigeration, motorized vessels, the use of monofilament lines for nets and line fishing and GPS. Despite some incentives by the local governments to encourage the development of industrialized commercial fleets, much of the modern artisanal fisheries are limited to the insular platform (depths less than 100 fathoms), although some forays to neighboring islands were common in the recent past. This fleet is characterized by vessels less than 12 m in length and harvests are relatively small-scale, geared towards local markets as fresh product and generally not for exportation. Multiple species are targeted simultaneously and forays are multi-geared with hook and line or traps as the main gears followed by diving and nets. Fishers today target highly valued species inhabiting coral reefs and associated habitats of the insular platform or seek pelagic species in deep waters beyond the shelf break.

Snappers (Lutjanidae) and groupers (Epinephelidae) of shallow habitats produced the bulk of landings, however larger bodied species have been substituted by smaller sized snappers, groupers, as well as grunts (Haemulidae), wrasses (Labridae) and smaller parrotfishes (Scaridae). Spiny lobster (*Panulirus argus*) and conch (*Strombus gigas*) are highly important fishery targets, and some fishers have specialized gear to target deep-water snappers (*Etelis oculatus*, *Lutjanus buccanella* and *Lutjanus vivanus*) and pelagic species (*Coryphaena hippurus* and *Acanthocybium solandri*) due to their high value. Prior to 1990, many coral reef species that form spawning aggregations were targeted directly during that time (Beets and Friedlander, 1999) which led to the extirpation of some known aggregations (Olsen and La Place, 1978) and the commercial extinction of others such as the Nassau grouper (*Epinephelus striatus*).

The number of fishers (let alone the diverse categories it encompasses) in the U.S. Caribbean (PR/USVI) is difficult to estimate. In the 1970s and 1980s, the number of fishers was estimated at 2000. Recent censuses and surveys show a decline of 45% since the 1970s. The current estimate of fishers is of 1100 for both territories combined, with approximately 350 for the USVI (Kojis and Quinn, 2011; Matos-Caraballo and Agar, 2011). This is quite similar to the first census of Puerto Rican fishers conducted in 1803, when 1500 fishers were counted (Valdés-Pizzini and Schärer-Umpierre, 2011). Although the socio-economic importance of fisheries in the U.S. Caribbean has fluctuated since then, it has remained a relatively

minor part of the economy of these islands in comparison with agriculture (mostly sugar cane), industrial development, housing construction and tourism. In 2008, it was estimated that PR commercial fishers landed six million US$ for two million pounds of finfish and shellfish (Tonioli and Agar, 2011); however, this is probably an underestimate due to underreporting and unlicensed fishers (García-Quijano, 2009).

1.3. Fisheries management

Fisheries management within the U.S. Caribbean is quite complex due to the multiple levels of governance in the geo-political arena. At one level, the U.S. federal government has direct jurisdiction of the EEZ and indirect participation elsewhere in agreements with the local territorial governments. Federal jurisdiction starts at the seaward limit of the territorial jurisdiction, which in the USVI is 3 Nm and in PR to 9 Nm from the shore. The difference in the extent of territorial limits is due to the amendment of the Jones Act (1917) in 1980 that extended the PR limit to three leagues (~9 Nm). In PR, the first fishery law was enacted in 1936, but until the early 1970s no fisheries data were systematically collected. During the mid-1970s, the first comprehensive fisheries studies were conducted under the auspices of the Department of Agriculture of PR, and in 1976, the Caribbean Fishery Management Council (CFMC) was established to oversee fisheries in the U.S. EEZ. In 1998, the PR Fisheries Act was established to manage fisheries by the Department of Natural and Environmental Resources (DNER); however, the fisheries regulations which included MMAs for fisheries purposes were only implemented in 2004. Today, the territorial governments of PR and the USVI manage their fisheries resources in coordination with the CFMC, and in MMAs with shared jurisdiction both agencies agree on the regulations to be implemented on a site-by-site basis.

2. MARINE MANAGED AREAS

Some of the first evidence of efforts to protect the marine resources including gear limitations, seasonal closures and the establishment of protected areas in PR occurred during Spanish rule (Valdés-Pizzini and Schärer-Umpierre, 2011). In 1918, the U.S.-appointed governor to PR designated the first MMA to protect coastal mangrove forests due to demand for charcoal (Aguilar-Perera et al., 2006). Today, the designations of MMAs within the U.S. Caribbean have a variety of legal bases and different levels of jurisdiction. At the federal level, MMAs are designated based on the Magnuson

Stevens Fishery Conservation and Management Act and reauthorizations, which are managed by the CFMC. In the USVI, there are additional federal-level designations such as by the Department of the Interior, which has designated terrestrial and marine protected areas managed by the National Park Service (NPS) and extensions to these that were based on Presidential Proclamation (National Monuments).

Within territorial jurisdictions, MMAs are designated through two main mechanisms, administrative and legislative. In the case of PR, DNER recommends sites of ecological and cultural value to the Planning Board, which then finalizes the administrative process with a formal legal designation, but no regulations. The bulk of the MMAs in PR were designated in 1978 as part of the Coastal Zone Management Program (CZMP). Alternatively, the legislatures of PR and the USVI can designate marine reserves (equivalent to no-take zones) or protected areas (marine parks). This has been the case for at least five MMAs designated recently in PR, and at least two in the USVI, many of which are no-take zones (NTZs) where fishing is prohibited year-round. In PR, the regulations for MMAs can be based on the Forestry Law or the Fisheries Law. Currently, there is no specific overriding legislation or any coordinated plan to designate networks of MMAs. In the USVI, the CZMP is also the basis for some designations through the Department of Planning and Natural Resources. However, there is no established law to unify the selection, designation and management of MMAs in the region (Gardner, 2002).

For the purpose of this volume, we define MMAs as those areas of marine waters designated by legal mechanisms (local or federal) including submerged marine areas within the boundaries of the designation. We excluded coastal lagoons or wetlands located inland, unless they have a seaward extension with submerged marine areas within the MMA's boundaries. Data were extracted from published documents, maps and data obtained directly from management agencies as well as the National Marine Protected Area Inventory (NOAA, 2014). The extent of the marine submerged area within the limits of each designation was calculated in a geographical information system and the results are summarized in Table 4.1 and displayed in Figures 4.2 and 4.3.

Thirty-nine MMAs met the criteria defined above, 26 located in the territorial waters of PR, 7 in USVI and 6 in the EEZ (or combination). Approximately 4035 km^2 of submerged habitats are incorporated in these MMAs, 10% of this total area has some type of no-take regulation that protects fisheries resources during some part of the year. The USVI had a greater proportion (50%) of area of MMAs with no-take regulation compared to PR

Table 4.1 Summary data for all marine managed areas in the U.S. Caribbean including the site where it occurs: exclusive economic zone (EEZ), Puerto Rico (PR) or U.S. Virgin Islands (USVI)

Name	Site	Composition	Year	Type	Timing	Marine area	No-take area
Abrir la Sierra	EEZ	S	1996	S-NTZ	Dec. to Feb.	29.5	29.5
Bajo de Sico	EEZ	S	1996	S-NTZ	Oct. to Mar.	31.4	31.4
Grammanik Bank	EEZ	S	2005	S-NTZ	Feb. to Apr.	1.5	1.5
Hind Bank MCD	EEZ	S	1989	NTZ	Year-round	44.6	44.6
Lang Bank	EEZ	S	1993	S-NTZ	Dec. to Feb.	11.7	11.7
Tourmaline Bank	EEZ	S	1993	S-NTZ	Dec. to Feb.	31.4	31.4
Arrecife de Isla Verde	PR	S	2013	NTZ	Year-round	0.94	0.94
Arrecifes de Guayama	PR	S	1980	NR		8.1	
Arrecifes de la Cordillera	PR	M	1980	NR		99.9	
Arrecifes de Tourmaline	PR	S	1998	NR		74.6	
Bahías Bioluminiscentes de Vieques	PR	M	1998	NR		79.6	
Boquerón State Forest	PR	M	1998	NR		172.7	
Cabezas de San Juan	PR	M	1998	NR		266.9	
Caja de Muertos	PR	M	1980	NR/ NTZ	Year-round	55.1	0.39
Canal Luis Peña	PR	S	1999	NTZ	Year-round	6.3	6.3

Continued

Table 4.1 Summary data for all marine managed areas in the U.S. Caribbean including the site where it occurs: exclusive economic zone (EEZ), Puerto Rico (PR) or U.S. Virgin Islands (USVI)—cont'd

Name	Site	Composition	Year	Type	Timing	Marine area	No-take area
Caño La Boquilla	PR	M	2002	NR		105.8	
Corredor Ecologico del Noreste	PR	M	2013	NR		263.1	
Cueva del Indio	PR	M	1998	NR		15.5	
Finca Belvedere	PR	M	2003	NR		40	
Guánica State Forest	PR	M	1985	NR		14.2	
Hacienda La Esperanza	PR	M	1998	NR		50.6	
Isla de Desecheo	PR	S	2000	NTZ	Year-round	7.4	7.4
Isla de Mona & Monito	PR	M	1997	NR/NTZ	Year-round	1512.7	81
Jobos Bay	PR	M	1981	NERR		9.8	
La Parguera	PR	M	1998	NR		324	
Pantano Cibuco	PR	M	1998	NR		19.9	
Punta Cucharas	PR	M	2007	NR		13.8	
Punta Guaniquilla	PR	M	2002	NR		8.6	
Punta Petrona	PR	M	1979	NR		30.9	
Punta Yeguas	PR	M	2001	NR		262.4	
Río Espíritu Santo	PR	M	1998	NR		117.7	
Tres Palmas de Rincón	PR	S	2004	NTZ	Year-round	0.89	0.89
Buck Island Reef	USVI	M	2001	NM	Year-round	76.9	76.9
Mutton Snapper Spawning Aggregation	USVI	S	1993	S-NTZ	Mar. to Jun.	8.9	8.9

Table 4.1 Summary data for all marine managed areas in the U.S. Caribbean including the site where it occurs: exclusive economic zone (EEZ), Puerto Rico (PR) or U.S. Virgin Islands (USVI)—cont'd

Name	Site	Composition	Year	Type	Timing	Marine area	No-take area
Salt River	USVI	M	1992	NP	Year-round	3.3	3.3
St. Croix East End	USVI	M	2003	MP/NTZ	Year-round	150.3	12.9
St. Thomas East End Reserves	USVI	S	2011	MP/NTZ	Year-round	9.3	9.3
Virgin Islands Coral Reef	USVI	S	2001	NM	Year-round	51.4	51.4
Virgin Islands	USVI	M	1962	NP		23.5	

The composition of the area may be submerged (S) or mixed (M) if it includes a terrestrial portion, the year of establishment (Year) and the type; seasonal no-take zone (S-NTZ), no-take zone (NTZ), marine conservation district (MCD), natural reserve (NR), marine reserve (MR), national estuarine research reserve (NERR), national park (NP), national monument (NM) and marine park (MP). Timing indicates what part of the year the no-take zone is in effect. All areas calculated in km^2.

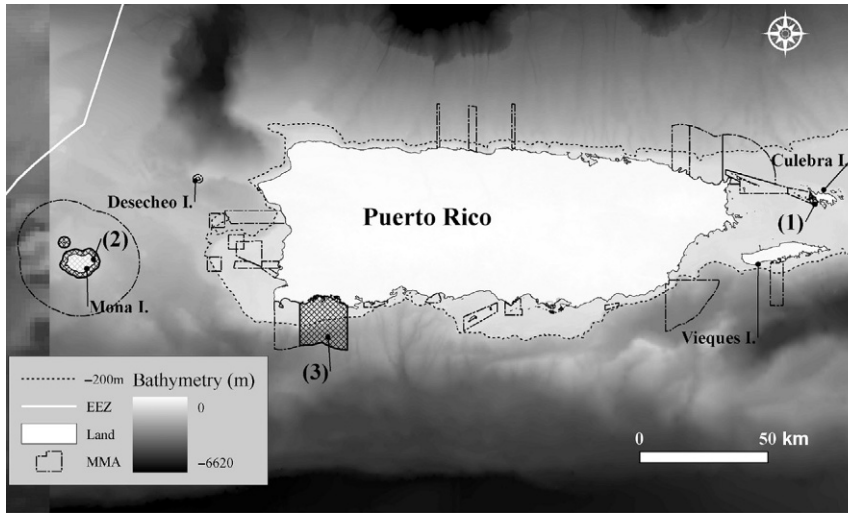

Figure 4.2 Marine managed areas in Puerto Rico, numbers indicate case studies.

(3%). In EEZ waters, 70% of the ecosystems within MMAs are designated with seasonal no-take regulations and only one site (30% of the area) has year-round protection: the Hind Bank Marine Conservation District (MCD) south of St. Thomas.

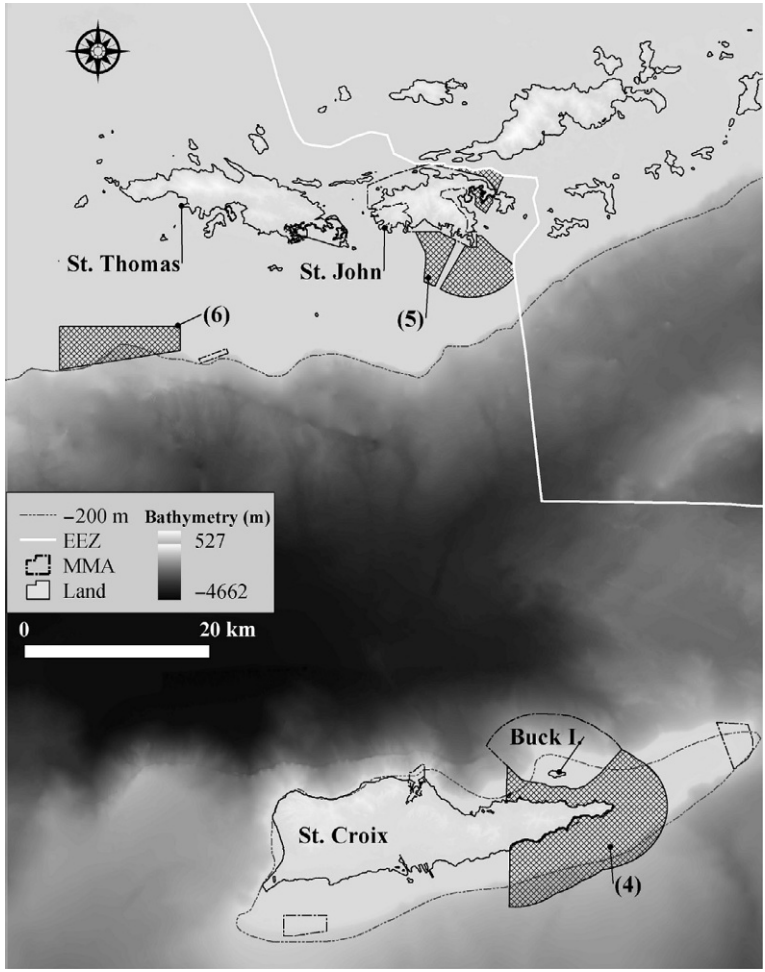

Figure 4.3 Marine managed areas in the U.S. Virgin Islands, numbers indicate case studies.

Overall, 12 MMAs have year-round, NTZs within boundaries delineating 295 km^2 of submerged habitats, whereas six sites have seasonal no-take regulations covering 114 km^2. Twenty-one sites covering approximately half of the area (2001 km^2) lacked no-take regulations. Most of the seasonal no-take regulations of the MMAs encompass the months of December through June with the aim of protecting species of shallow water groupers or snappers that aggregate to spawn at this time.

3. CASE STUDIES

3.1. Canal Luis Peña Natural Reserve

The PR Planning Board designated Canal Luis Peña Natural Reserve (CLPNR) in Culebra Island (east of PR) as the first no-take in PR in 1999. It was designated to encourage the recovery of fish communities by protecting habitats within former U.S. Navy training grounds. The original concept proposed by local fishers, base communities and the local government of Culebra Island was to develop a co-management, participatory process. The site has historically encompassed multiple uses ranging from military training activities, fishing and coral extraction for construction (nineteenth and twentieth century) to recreational uses. Although a management plan was published in 2008, very few of the proposed management actions have been implemented and no co-management agreement has been established.

Before the no-take designation, fish communities were depauperate, with low densities and low biomass of most commercially important species (Hernández-Delgado, 2000). Three years after no-take designation abundance and biomass increased, including a 515% increase in total fish biomass (Figure 4.4), 438% in herbivore biomass and 1249% in piscivore biomass

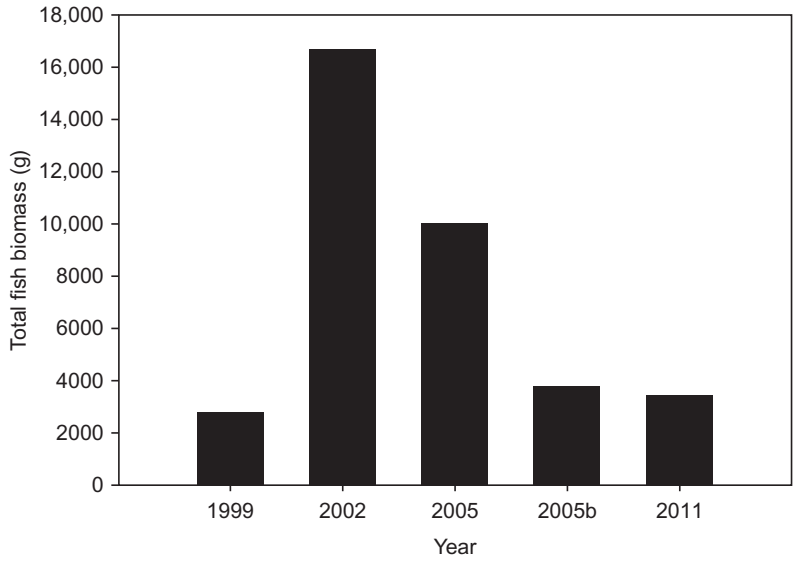

Figure 4.4 Trend in fish biomass (g) within the core area of the CLPNR after designation. Data from year 2005 was collected before and after (2005b) the coral bleaching event.

(Hernández-Delgado et al., 2006). *Epinephelus guttatus*, an important fishery target, were found to be significantly larger inside the reserve, but this could be linked to a greater proportion of appropriate habitat within the boundaries (López-Rivera and Sabat, 2009). However, lack of governance and sustained enforcement resulted in a subsequent decline and no net recovery of fish nor coral reef benthic communities (Hernández-Delgado and Suleimán-Ramos, 2014). Massive coral bleaching in 2005 caused further fish biomass decline with no net recovery. The CLPNR represents an excellent case study of the significance of designating a NTZ supported by local fishers and base communities that resulted in the rapid recovery of fish communities. However, this recovery could not be sustained due to the lack of compliance coupled with damaging land-use practices in Culebra Island and climate change-related impacts, which have resulted in a declining trend of coral reef resources.

3.2. Mona and Monito Islands Natural Reserve

Mona and Monito Islands are located in the middle of the Mona Passage west of PR, a known partial biogeographic barrier (Baums et al., 2006; Dennis et al., 2005). These islands out to 9 Nm from shore comprise the largest MMA in the U.S. Caribbean with a significant, year-round, NTZ (extending to 1 Nm from shore). Although the Nature Reserve was designated in 1986, the NTZ was not established until 2004 (Aguilar-Perera et al., 2006). In 2007, the boundaries of the NTZ were amended to incorporate key grouper spawning aggregation sites. The DNER has jurisdiction over this area, and only government staff inhabit the island permanently. Visitors arrive by charter or private vessel for camping, hiking, recreational hunting and fishing with permits issued by the DNER. Although this site has been inhabited only sporadically (*Taínos* up to 1400s; guano miners in the 1700s), it was the focus of intense fishing for sea turtles and grouper spawning aggregations prior to its designation. More recently, commercial fishing for deepwater snappers and recreational fishing for pelagic species have been the most common uses of the MMA. A recent study evaluated the performance of some coral reef fishes to the NTZ five years after designation (Mateos-Molina et al., 2014). A 50% increase in abundance and biomass was detected for small life stages and species. Large bodied groupers and snappers, considered top predators, were still rare and did not show any trends in abundance or biomass. One of the smaller groupers, the coney (*Cephalopholis fulva*), doubled its abundance and biomass in no-take areas as well as outside. This

response may be due to increased availability of ecological niches due to the lack of larger sized predators or the reproductive strategy of this species. At this offshore location, the lack of larval connectivity from areas with resident populations may be limiting the recovery of larger coral reef fishes.

3.3. La Parguera Natural Reserve

The area around La Parguera, in southwestern PR represents a complex marine ecosystem consisting of extensive mangrove stands and sea grass beds inshore, protected by the most well-developed series of coral reefs around the island (Morelock et al., 1977). This is augmented by a broad extent of submerged patch reefs, extensive shelf-edge reef, and well-developed mesophotic coral ecosystems that extend to depths of 80 m or more (Sherman et al., 2010). The abundance and spatial proximity of these habitats render La Parguera as one of the most diverse and productive areas of the coastal environments around PR, with a high degree of ecological connectivity, especially exhibited through the movement of fishes (Appeldoorn et al., 2009). Concern for the protection of La Parguera dates from the 1960s with the recognition of the importance of Bioluminescent Bay. However, management plans were not enacted until 1978 when the CZMP was approved and the PR Planning Board designated La Parguera Natural Reserve (LPNR) with an inland extent of 1 km and seaward extent of 3 Nm, later expanded to 9 Nm in 1998. During the early 1980s, La Parguera was the focus of a contentious debate over the establishment of a U.S. National Marine Sanctuary that was not designated (Fiske, 1992). In 1995, PR adopted the La Parguera Special Planning Area, which extended from the shoreline to the top of nearby hills defining the majority of the proximal watersheds. Yet, no regulations or zones were established within the NR, despite a concerted, multiyear, multi-institutional effort to establish a NTZ (Valdés-Pizzini and Schärer-Umpierre, 2014). Neither was any special effort given to increase enforcement of island-wide fisheries regulations in light of the recognized importance of La Parguera's ecosystem.

There have been substantial changes documented in LPNR in the last 30 years, most likely due directly or indirectly, to anthropogenic stressors including urban development, fishing and tourism. Fishing pressure has resulted in the loss of most large-bodied fishes and spawning aggregations, reducing the frequency of occurrence of 10 out of 13 species sampled in the early 1980s and again in 2000s (Figure 4.5). The common large parrotfishes and groupers are no longer present, while medium-sized red hind

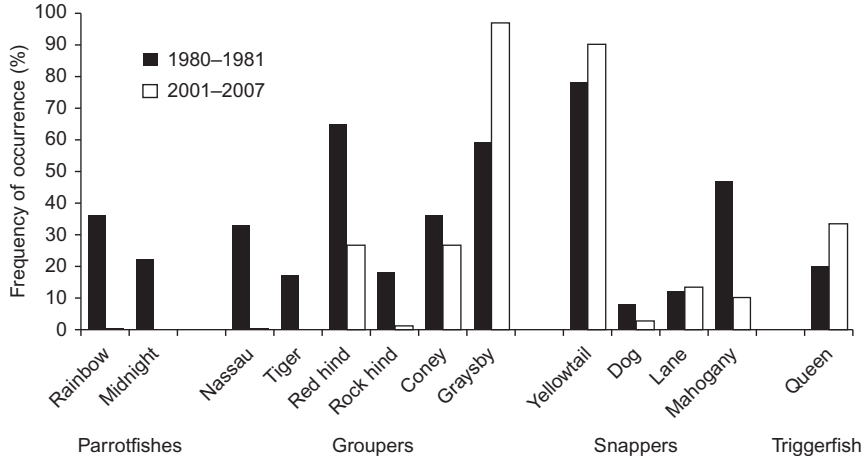

Figure 4.5 Frequency of occurrence (%) in visual surveys of reef fishes from the early 1980s (Kimmel, 1985) and the mid-2000s (Pittman et al., 2010). Values for the latter are multiplied by a factor of 3.33 to adjust for differences in survey times: 50 min for the initial study; 15 min for the latter.

(*E. guttatus*), rock hind (*E. adscensionis*) and mahogany snapper (*Lutjanus mahogoni*) were observed considerably less frequently. There has been little change in the more pelagic yellowtail snapper (*Ocyurus chrysurus*), while the graysby (*Cephalopholis cruentata*), the smallest grouper, has become more frequent in occurrence. Many formally abundant species on the shelf are now only found off the steep insular slope (Bejarano et al., 2014) in mesophotic depths.

3.4. St. Croix East End Marine Park

The East End Marine Park is located over the 10 km of the easternmost shelf of St. Croix (USVI) and extends 3 Nm from shore. It was established in 2003 as the first multi-use marine park managed by the USVI government for natural and cultural resources by protecting, replenishing and sustaining healthy populations of key species, habitats and biodiversity (The Nature Conservancy, TNC, 2002). This park is used for multiple recreational and commercial activities, including ecotourism, camping, swimming, snorkeling, diving, boating and fishing. Historically, this site was used for fishing of conch and lobster, as well as netfishers catching parrotfish, among other species (Valdés-Pizzini et al., 2010). In the past, large-bodied fish used the northeastern habitats of the island and there was a Nassau grouper spawning aggregation site in East End. However, intensive and unregulated fishing led

to the extirpation of this aggregation by 1971 (Olsen and La Place, 1978). There are four different types of managed areas within the park although zoning was designed based on limited data (Island Resources Foundation, 2002), which did not allow the establishment of an ecological baseline to measure their subsequent performance. Recent research assessing the distribution, diversity and status of the marine environment within the park and land-based stressors has helped fill this gap (Pittman et al., 2013). Although determining the ecological performance of areas closed to fishing requires future monitoring, outcomes so far suggest that the current zoning contributes little to the protection and replenishment of fished populations. Assemblages within NTZs are mostly small-bodied and juvenile fishes that are not primary target species of the fishery, while fish biomass and adult density of fished species is high in areas open to fishing (Pittman et al., 2013). Historical data (Pittman et al., 2008) show that large-bodied fish (e.g. tiger grouper) used the habitats in the northeastern part of the island, but only a few adult Nassau groupers (0.3% of survey sites) were sighted within the park. Thus, the current zoning needs to be reviewed and modified so that it can be based on robust data, as well as include a more complete range of species and habitats. Alternative strategies for the conservation of priority species need to be developed, or current objectives need to be redefined to achieve more realistic replenishment and protection goals.

3.5. Virgin Islands Coral Reef National Monument

The Virgin Islands Coral Reef National Monument (VICRNM) consists of five areas offshore of the island of St. John, which is adjacent to the Virgin Islands National Park, and both are administered by the U.S. NPS. The VICRNM was established in 2001 by Presidential Order to increase efforts by the U.S. federal government mandated by the Coral Reef Conservation Act. All extractive uses are prohibited within the VICRNM with the exception of fishing for baitfish in Hurricane Hole Bay and fishing with hook and line in a slot south of St. John, activities that require special permits. The unprotected region, which splits the larger area in two (Figure 4.3), was specifically requested by fisherman to allow continued access to an important fishing area. Additional management efforts include the prohibition of vessel anchoring within the reserve, and mooring buoys are maintained by the NPS for this reason. The NPS has been intensively investigating marine resources with an emphasis on coral reef ecosystems for the last two decades leading to a focused effort, since 2001, to monitor the composition and

abundance of the reef fish assemblage (Friedlander et al., 2013a,b). The results to date indicate a lack of difference in the abundance of fishery species within or outside of the VICRNM. Results suggest that the absence of ecological criteria in the designation process resulted in more complex habitat outside of the reserve (Monaco et al., 2009), conditions that have prevented the expected recovery of depleted fish populations.

3.6. Hind Bank Marine Conservation District

The Hind Bank MCD, south of St. Thomas (Figure 4.3), was first established in 1990 as a seasonal NTZ to protect a commercially important spawning aggregation of red hind (Beets and Friedlander, 1999). The MCD became a much-expanded permanent closed area in 1999, with fishing and anchoring prohibited throughout, thus protecting critical coral reef habitats. The MCD extends 12 km westward along the southern edge of the Puerto Rican Bank into the southern extent of the Virgin Passage. The majority of the seafloor is less than 50 m in depth and is composed of topographically complex coral reefs that are the center of the largest known mesophotic coral reef complex in the U.S. Caribbean (Smith et al., 2010). These coral reefs are dominated by dense *Orbicella* spp. (Armstrong et al., 2006) and were classified by Smith et al. (2010) into three distinct habitat types: high coral banks, flat basin and hillock basin. The hillock basin is unusual in that it is a highly heterogeneous area containing thousands of 2–10 m high coral knolls. Historically, the MCD contained an important Nassau grouper (*E. striatus*) spawning aggregation site that was extirpated in the late 1970s due to overfishing (Olsen and La Place, 1978). Other species of grouper, snappers and jacks also form spawning aggregations within the MCD. This MMA has resulted in an increase in the density of larger size classes of commercially important groupers, snappers and parrotfishes (Nemeth and Quandt, 2005), and also facilitated the recovery of the red hind, whose biomass increased 550% between 1997 and 2003 (Nemeth, 2005). Today, red hind represents one of the most common reef fish in the St. Thomas commercial fishery. The increases in the spawning stock at this site and the movement patterns of tagged red hind up to 33 km away suggest that this MMA has benefitted the fisheries of downstream areas, namely, the platform west of St. Thomas, eastern coast of PR and the offshore islands of Vieques and Culebra (Nemeth, 2005). Continued protection of this important area will enhance other fishery resources of the region and continue to protect the critical coral reef habitat that they rely upon.

4. DISCUSSION

Edgar et al. (2014) classified marine protected areas according to five criteria (NEOLI): no-take, enforced, old (>10 years), large (>100 km^2) and isolated (based on habitat discontinuities). They suggested that conservation benefits increased as more criteria were met, but that significant improvements required at least four of these criteria. In the U.S. Caribbean, most MMAs do not meet more than one of these criteria.

4.1. Area of habitat

The size of an MMA is important due to the extent and diversity of habitats within it as well as the proportion of fish and invertebrate populations that are protected from anthropogenic impacts. In the U.S. Caribbean, insular shelves are narrow, fish distributions are closely coupled to habitat and fishing generally operates at small spatial scales; hence, it has been proposed that MMAs that encompass areas from the shore to edge of the insular shelf are best for protecting the diversity of habitats necessary to support all species across all life stages, especially for fishes that undergo ontogenetic migrations (Appeldoorn et al., 2011; Mumby, 2006; Mumby et al., 2004; Pittman et al., 2004). The study of fish movements and habitat use at the landscape level has evidenced the spatial scales of protection necessary to include nursery, migration and spawning habitats. However, in the case of Red Hind Bank MCD, which does not include shallow nursery habitats, the large area of prime coral reef habitat within the MMA has led to increases in the biomass and spawning stock of red hind. Therefore, the inclusion of spawning aggregations in NTZs is critical for those species with long-distance migrations to spawning sites. Only the Mona and Monito Island Natural Reserve includes a diversity of habitats ranging from shore to shelf, including multi-species spawning aggregations within the NTZ, although populations of many of these larger bodies fishes have not shown signs of recovery. LPNR also includes a large area of the habitat matrix from shore to shelf break and had spawning aggregation sites at the deeper sites, but lack of regulations controlling fishing activities have precluded the recovery of overfished populations.

4.2. Seasonal versus year-round

The main rationale for the seasonal no-take regulations in the U.S. Caribbean is to protect a particular species during spawning aggregations.

During this time, which may last a few months, individuals remain in high density and are highly vulnerable to fishing. Also, due to hyper-stability (Erisman et al., 2011) much of the spawning stock can be removed without overt signs of overfishing, such as decreased rates of capture. Most of the seasonal no-take MMAs (five of seven initially) were designed to protect the red hind during its reported spawning season from December to February. Research studies evaluating the effect of the seasonal NTZ regulations have shown mixed results. Significant increasing trends in population characteristics over time were found at the Red Hind Bank MCD, which was seasonally protected (1990) before becoming year-round no-take (1999), and at Lang Bank, St. Croix, only seasonally protected since 1993 (Nemeth et al., 2006). Data suggest the recovery of red hind spawning populations at both sites with seasonal no-take, however, the rate of change detected at the Red Hind Bank MCD were much higher after the site became a year-round no-take, including a doubling of maximum density during the spawning aggregation. The inclusion of the time periods prior to and after spawning may have benefitted those individuals that migrated through the MCD as well as protected the spawning stock during times that spawning may have been after the closed season, given the natural variability in temporal dynamics of spawning aggregations. The protection of a large area of continuous prime habitat year-round for over 15 years has led to the recovery of the red hind populations and benefitted local fisheries. The duration of protection may explain differences in the degree of recovery between here and Lang Bank in St. Croix (Nemeth et al., 2006, 2007). In contrast, the three seasonally closed MMAs around red hind aggregation sites off the west coast of PR did not show any increases in abundance, with directed fishing effort for red hind increasing substantially over the subsequent decade before, during (outside closed areas) and after the period of closures when red hind may still have been on the spawning grounds. PR has since adopted an island-wide closed season for red hind during these months (December to February).

4.3. Level of enforcement

Management consists of both planned regulations and enforcement as necessary components; without one, the other is incomplete and relatively meaningless. Governance structures are necessary for achieving this balance. We have already shown that many MMAs in the U.S. Caribbean were not adequately designed and regulated to achieve their respective goals.

Unfortunately, no-take areas in the U.S. Caribbean also present nonexistent or ineffective enforcement and therefore fail to achieve compliance with local regulations and other federal and territorial statutes. The economic cost of this lack of compliance with regulations is a significant constraint to evidencing the effects, if any, of the NTZs. In addition to the measures of the biological, fishery and ecological indicators, the studies of NTZ effectiveness require some measure of compliance and law enforcement interventions, which may confound results and conclusions. Areas with high levels of compliance require little enforcement, but traditional measures of governance that limit the uses of marine or natural environments have not been evidenced in the Caribbean. Most of the regulations are top-down, directed from external bodies governing elsewhere or lack meaningful public participation in fisheries management.

The political history of the Caribbean primed the local surrogate governments and the metropolitan authorities with the task of managing, unilaterally, the resources and making the appropriate decisions, without the participation of the diverse communities of users. Increased political autonomy in recent years also meant an increase in power over those decisions and actions that framed the current status of fisheries management throughout the region. Arguably, the incorporation of the human dimension—a critical parameter in Ecosystem-Based Management—has not been a priority, or a key element in the process. And yet, the main problems are social and need to be addressed before any success is attainable in management (Appeldoorn et al., 2005; Valdes-Pizzini et al., 2012). However, the region (and PR/USVI) is changing, with a number of experiments in community-based management, highly participatory schemes and co-management experiences with MMAs, which also include—with the expected tensions—local communities and organizations, as well as powerful Island-based and international NGOs.

Co-management approaches among different enforcement entities (government, NGOs and local communities) appear as a viable alternative to the low enforcement capacity. Good examples of these are two of the smallest NTZs in PR, Tres Palmas Marine Reserve in Rincón and Arrecifes Isla Verde Marine Reserves where neighbors initiated the designation and have taken up much of the education and enforcement responsabilities, involving local municipal police to capture poachers when the DNER agency law enforcement agents are unavailable. Similarly, community involvement played an important role in the establishment and early success at CLPNR, but failure to follow-up with the planned co-management structure

ultimately led to its collapse. St. Croix East End Marine Park, on the other hand, has an enforcement program, but its success is limited by inefficient coordination among the different parts involved in the management of the MMA.

5. CONCLUSION

Multiple MMAs in the U.S. Caribbean demonstrate a diverse range of sizes, ages and regimes yet provide limited evidence to measure their impact upon fisheries resources. Year-round NTZ designation including prime habitat and spawning aggregations can provide the greatest benefit to fisheries as long as local communities favor compliance and enforcement is coordinated. The limited data available suggest that fisheries management in the region with MMAs as a tool will require evidence that can be used to support their application to benefit local economies. Most areas existing today represent mere extensions of coastal managed areas without specific management goals or actions. Assessments exist for only a handful of MMAs, and these primarily show little impact. In most cases, it is clear that the MMAs are underperforming in large part from not meeting the multiple criteria identified as key by Edgar et al. (2014). Thus, assessing the overall potential of MMAs to improve resource condition should not be based on the overall record but rather directed toward those areas where proper design, management and monitoring exist. Here, there are some bright spots. The Red Hind Bank MCD to some extent meets all five criteria and has been an unqualified success relative to its original goal of protecting spawning red hind. Similarly, the Mona and Monito Island Natural Reserve has shown some improvement after only 5 years. While enforcement is poor, its distance from PR serves to reduce fishing effort relative to the main platform. Recovery of this MMA may be slowed by limited connectivity to other areas. Historically, enforcement of MMAs, even for NTZs has been poor to nonexistent, and this has been identified as the primary problem determining their effectiveness. Recent efforts to establish governance programs and co-management may improve this situation over time. In island settings with narrow shelves, total area within an MMA may not be as important as capturing critical habitat, such as spawning sites and migration corridors or ensuring protection from the shore to the shelf-edge (Appeldoorn et al., 2011). From this perspective, we view essential fish habitat (EFH) not on a species basis (since all habitats are used across all species) but rather on a multi-species basis where key areas of diverse habitat promote connectivity among habitats and

productivity across species (Cerveny et al., 2011). Issues of total area can be ameliorated if MMAs are planned not in isolation but within a context of a network design, with areas characterized by high multi-species EFH serving as core areas. We conclude that the success of MMAs in achieving management goals can only really be assessed when both proper biological and socio-economic criteria were used to design, implement and manage MMAs. However, establishing the necessary criteria has come from practical trial and error as much as from scientific theory, and the lessons learned here should be used to guide future efforts. Lastly, assessments of MMA efficiency must consider the effects of water quality and climate change, especially when considering corals and other benthic resources. Therefore, the criteria of Edgar et al. (2014) may benefit from the addition of habitat quality criteria for effective MMA design.

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