Protecting a Multi-species Spawning Aggregation at Mona Island, Puerto Rico

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ABSTRACT

Fish spawning aggregation sites should be integrated into the design of marine reserves (MR) that seek to conserve biodiversity and manage local fisheries. Field research conducted since 2005 at Mona Island, Puerto Rico has provided useful data for this purpose. The remote islands of Mona and Monito are enclosed in the largest marine protected area and MR (no-take zone) in Puerto Rico. The MR originally designated around Mona and Monito Islands in 2004 was established using general management principles but not with specific information on fish distribution and abundance. Underwater visual surveys throughout the insular platform were performed using three methods (belt transects, roving and drift dives). At least 22 coral reef species including threatened groupers (*Epinephelus guttatus, Mycteroperca tigris* and *M. venenosa*) were documented spawning or with indirect evidence of spawning at aggregation sites located outside the 2004 MR boundaries. As data on the location of these aggregations became available the MR boundaries were modified in 2007 as an amendment to the local fisheries regulations. The new and expanded boundaries protect other spawning sites as well, since these generally occur on the insular shelf break, and depth (100 fathoms) was utilized to define the new boundary. These results demonstrate the viability of the approach used in this study for locating spawning aggregations to provide information for fisheries management and MR design. The expansion of the no-take zone boundaries at Mona Island provides heavily exploited groupers and other species with the potential for recovery and supports ecosystem-based management.
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KEY WORDS: Spawning aggregation, marine reserve, Mona Island

Protegiendo una agregación de Desove de Múltiples Especies en la Isla de Mona, Puerto Rico

Las agregaciones reproductivas de peces deben integrarse al diseño de reservas marinas (RM) para lograr metas de conservación y manejo de pesquerías locales. Investigaciones llevadas a cabo en la Isla de la Mona, Puerto Rico desde el 2005 han provisto datos para este propósito. Las remotas islas de Mona y Monito se encuentran dentro del área marina protegida y la RM (reserva marina o zona de no pesca) más grande de Puerto Rico. Esta RM fue establecida siguiendo principios generales de manejo aunque faltaba información especifica de la distribución y abundancia de peces. Se llevaron a cabo tres variaciones de censos visuales submarinos (transecto de banda, búsquedas limitadas por tiempo y buceos a deriva). Al menos 22 especies incluyendo especies de meros considerados como amenazados (*Epinephelus guttatus, Mycteroperca tigris* y *M. venenosa*) se documentaron desovando o con evidencia indirecta de desove en sitios fuera de los límites de la RM. Según se hizo disponible la información de las agregaciones de desove se modificaron los limites en 2007 mediante una enmienda al reglamento de pesca. La expansión de los limites de la zona de no pesca en la Isla de Mona le provee protección a otras agregaciones que comúnmente ocurren cerca del veril, ya que se utilizó la profundidad (100 brazas) para definir el nuevo límite. Estos resultados demuestran la viabilidad de la metodología que se uso en este estudio para localizar agregaciones de desove y dedicar esta información al manejo pesquero y el diseño de RM. Los nuevos limites de la zona de no pesca en la Isla de Mona proveen una oportunidad para la potencial recuperación de especies de peces que han sido sobreexplotados por la pesca y apoya el manejo basado en los ecosistemas.

PALABRAS CLAVES: Agregación de desove, reserva marina, Isla de la Mona

Protection D'une Agrégation Multi-Espèces d Frai Sur L'île de Mona, Porto Rico

Les agrégations de frai ont traditionnellement été orientées dans les pêcheries des Caraïbes. La protection du stock reproducteur par des fermetures temporelles et spatiales a récemment été mise en œuvre par les autorités locales et fédérales de gestion des pêcheries. Dans ces cas, il est important d'intégrer des informations sur les agrégations de frai dès qu'elles deviennent disponibles pour assurer les changements opportuns dans les actions de gestion, au besoin. Une recherche depuis 2005 sur l'île de Mona, à l'ouest de Puerto Rico a mis en évidence au moins 15 espèces, dont trois mérous menacé à un site d'agrégation multi-espèces. Les espèces ont coïncidé spatialement, bien que les mois de pic d'agrégation diffèrent et le frai n'a pas été observé pour toutes les espèces. La zone no-take à Mona et Monito créée en 2004 a été rédigée sans information scientifique et a exclu le site d'agrégation multi-espèces. Comme les données sont devenues disponibles, la zone no-take a été élargie pour inclure des zones de profondeur similaire en 2007. Afin de quantifier les tendances démographiques et l'efficacité de la zone no-take, des informations supplémentaires sur la dynamique temporelle et la distribution spatiale des poissons sont indispensable pour développer des méthodes appropriées afin de quantifier avec précision les changements dans l'abondance. La protection accordée à d'autres agrégations de frai non documentées autour de Mona et les Iles Monito par cette zone no-take est une première étape importante pour la récupération des mérous menacés, le maintien des pêcheries locales et la conservation des récifs coralliens de Porto Rico.

MOTS CLÉS: Frai, agrégation, mérou, Iles Mona, Porto Rico

INTRODUCTION

Ecosystem based management (EBM) in the marine context seeks to incorporate ecological functions which support healthy populations in coastal and marine ecosystems. In fisheries, this approach requires an understanding of critical ecological units and linkages between units that are necessary for a functional ecosystem. Information regarding settlement habitats, spawning sites and migration corridors connecting these habitats becomes essential for decision-making regarding habitats and species conservation. Critical habitats must be integrated in the design of marine reserves (MR) and marine protected areas (MPA) if they are to ensure the viability of fish populations. Additionally, EBM is meant to be adaptive by incorporating information into the decision making process as it becomes available. Thus, special efforts are required to document, implement, enforce and measure the effectiveness of EBM strategies in order to maintain an adaptive management feedback loop.

Caribbean fisheries have targeted coral reef species for centuries, resulting in the depletion of some grouper populations, such as the Nassau grouper (*Epinephelus striatus*). Fish species that form spawning aggregations are at greater risk to fishing pressure due to their reproductive strategy, which includes long distance migrations, aggregate biomass for prolonged periods and predictability in space and time. Therefore, the effective protection of spawning aggregations is crucial in conservation efforts that seek to incorporate ecological function, as well as for the recovery of depleted grouper populations. This is especially true for remote islands, which are more dependent upon local sources of larvae for population stability. Once spawning aggregations cease to form at remote islands it is less likely their populations will recover, as demonstrated by the Nassau grouper.

In Puerto Rico spawning aggregations of grouper have been documented from Vieques (Sadovy *et al*. 1994, Matos -Caraballo *et al*. 2006), La Parguera (Shapiro *et al*. 1993) and the west coast insular platform (Sadovy *et al*. 1994). Intensive fishing has caused stock declines of some of these aggregations (e.g., Marshak 2007), while still others are known to have disappeared, most notably several Nassau grouper aggregations (Sadovy 1999). On Mona Island, Puerto Rico, reports from fishermen indicate that a large spawning aggregation of Nassau grouper existed but was extirpated in the 1970s (Colin 1982). Recent efforts to locate it have been unsuccessful but have provided new information on a multi-species aggregation site (Nemeth *et al.* 2007a), which includes various grouper species considered threatened on the IUCN Red List (Brulé and Garcia-Moliner 2006).

The Mona Channel, located between Puerto Rico and the Dominican Republic, is a partial bio-oceanographic barrier (Taylor and Hellberg 2003, Baums *et al.* 2006), implying that the Islands of Mona and Monito are possibly stepping stones connecting coral reef species of eastern and central Caribbean regions. The Mona Island Natural Reserve (NR) is currently the largest MPA in Puerto Rico (Aguilar-Perera *et al.* 2006a), with abundant coral reef habitats and relatively less impacted fish populations

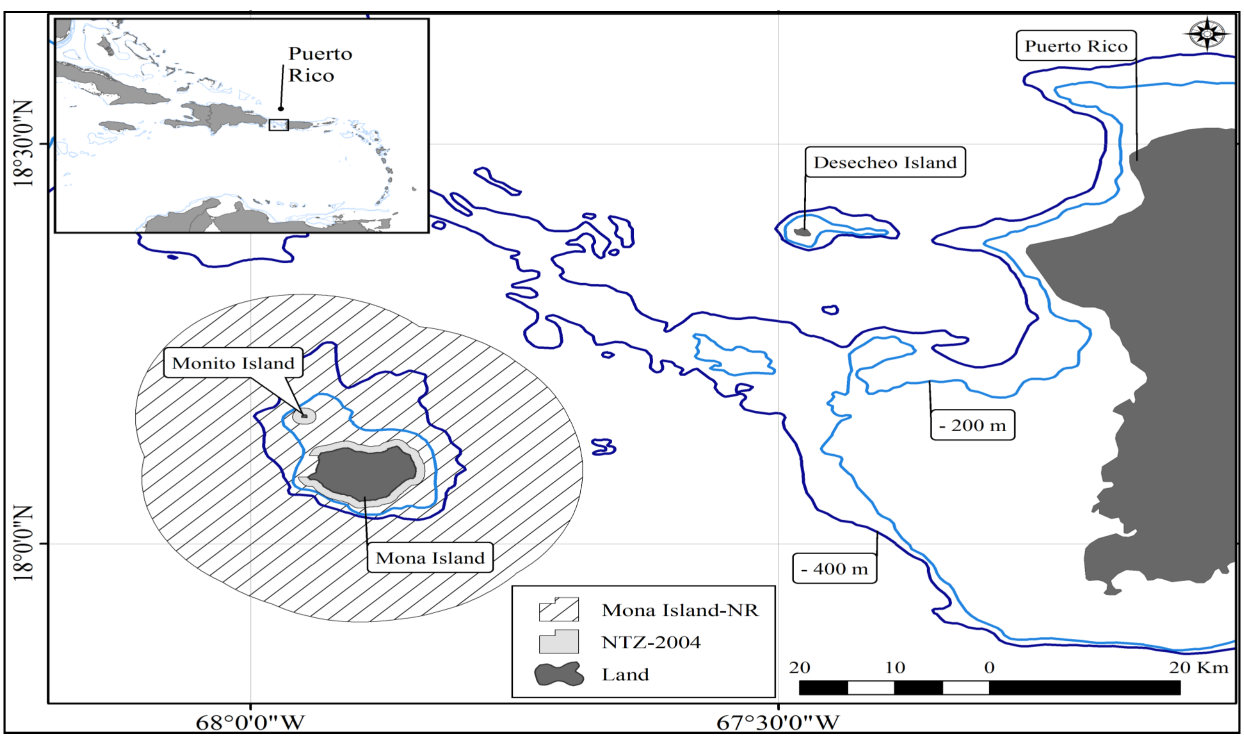

Figure 1. Mona and Monito Islands Natural Reserve (NR) and no take zone (NTZ) of 2004

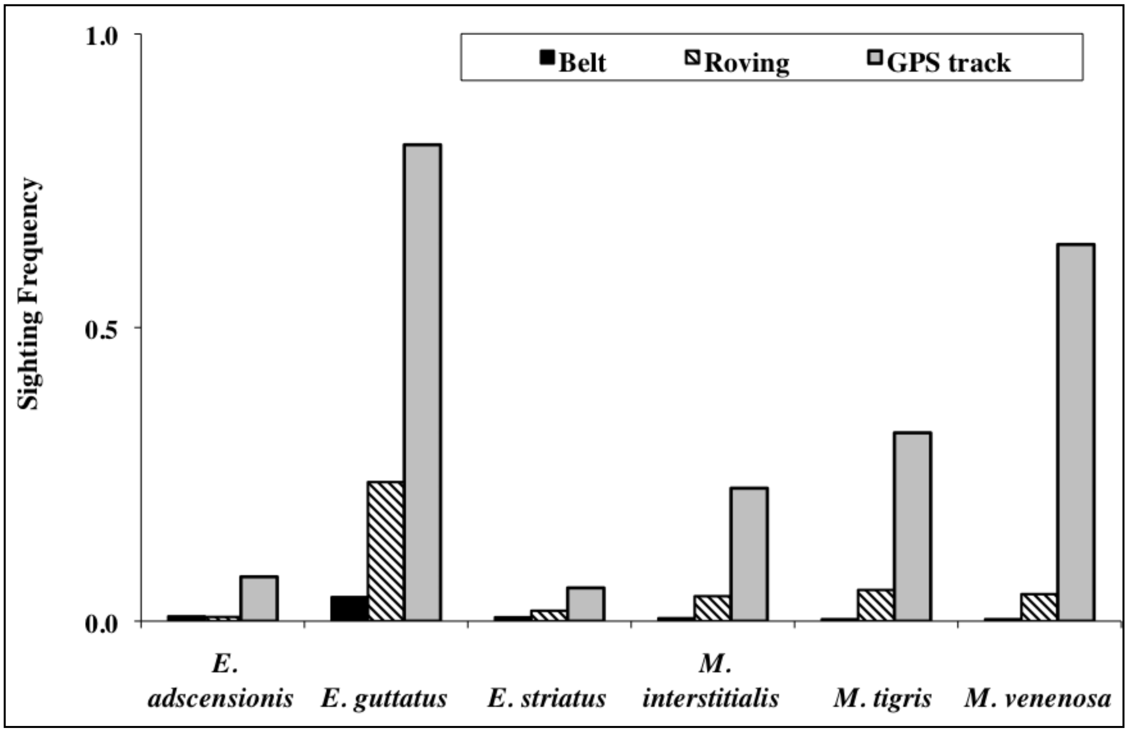

Figure 2. Sighting frequency of groupers at Mona Island with three underwater survey methods (Belt = 60 m^2 belt transects, Roving = 5-minute roving and GPS track = drift surveys).

(Stallings 2009). Therefore, including critical habitats within this MPA and protecting spawning aggregation sites with no-take regulations is essential for the recovery of threatened grouper species and the conservation of coral reef ecosystems. The decline of grouper populations at this site could have long-term impacts upon genetic connectivity in the region and affect marine eco-regional conservation strategies.

The purpose of this study was to evaluate the abundance of species that form spawning aggregations within the Mona Island NR specifically for coral reef fishes and groupers. Of those species present, could we locate their spawning aggregations? And finally, we wanted to know if these aggregations were within the NTZ boundary, and if not, how could we include them? Our approach consisted of collecting local ecological knowledge (LEK) and surveying the complete insular platform with three distinct underwater visual survey methods in order to determine the location of critical habitats and fish spawning aggregation sites. It was expected that the data resulting from this research could be integrated into the decision-making process following the EBM principle of adaptive management.

METHODS

Mona and Monito Islands (67.89° W, 18.09° N) are located in the Mona Passage between the Dominican Republic (66 km) and Puerto Rico (68 km) (Figure 1). Both islands occur on separate carbonate platforms formed approximately 15 million years ago (Late Miocene to early Pliocene) and uplifted from the seafloor due to tectonic movements (Frank *et al*. 1998). At Mona Island only the southern half of the insular platform supports shallow (< 30 m) coral reefs and seagrass habitats. Vertical cliff walls extending 40 m above and below sea level surround the northern coast of Mona Island and all of Monito Island. Trade winds from the east or northeast generate the predominant waves and surface currents in the Mona Passage.Both islands are uninhabited except for Department of Natural and Environmental Resources (DNER) rangers and biologists on Mona Island. Due to the distance from the main island of Puerto Rico visitors to Mona Island are predominantly fishers and campers, and hunters that visit the island from December to April. All campers require an advanced permit from the DNER to stay overnight; however boaters that remain on-board their vessels do not require permits. There are two main camping sites, Sardinera on the west coast, staff headquarters with pier, and Pájaros, which lacks permanent infrastructure except for a pier.

The Mona and Monito Islands NR designated in 1986 (Aguilar-Perera *et al.* 2006a) includes the waters up to 9 nautical miles from shore making it the largest marine protected area (MPA) in Puerto Rico, encompassing 1,576 km^2. Within the Mona and Monito Islands NR a no-take zone (NTZ), effectively a MR, was designated in 2004

Table 1. List of species observed with evidence of reproductive activity.

Scientific Name	Common Name	Evidence
Acanthostracion quadricornis	Scrawled cowfish	Spawning
Acanthurus coerulus	Blue Tang	Spawning
Balistes vetula	Queen Triggerfish	Nesting
Caranx latus	Horse-eye jack	Group formation
Clepticus parra	Creole Wrasse	Spawning
Diodon hystrix	Spot-fin Porcupinefish	Color phase
Epinephelus adscensionis	Rock Hind	Gravid
Epinephelus guttatus	Red Hind	Gravid and color phase
Epinephelus striatus	Nassau Grouper	Color phase
Halichoeres radiatus	Puddingwife	Spawning
Lactophrys triqueter	Smooth trunkfish	Color phase
Lutjanus jocu	Dog Snapper	Color phase
Mulloidichthys martinicus	Yellowtail Goatfish	Spawning
Mycteroperca bonaci	Black Grouper	Gravid and color phase
Mycteroperca interstitialis	Yellowmouth Grouper	Color phase
Mycteroperca tigris	Tiger Grouper	Gravid and color phase
Mycteroperca venenosa	Yellowfin Grouper	Spawning
Pomacanthus paru	French Angelfish	Spawning
Scarus taeniopterus	Princess Parrotfish	Spawning
Sparisoma chrysopterum	Redtail Parrotfish	Spawning
Sparisoma rubripinne	Yellowtail Parrotfish	Spawning
Sparisoma viride	Stoplight Parrotfish	Spawning

extending 0.5 nautical miles from shore around all of Monito and most of Mona Island and covering a total marine area of 32 km^2 (Figure 1). This NTZ designation was included in local fisheries regulations # 6768 (DNER, 2004), which is based on Puerto Rico Law # 278 (DNER, 1998). The NTZ included submerged areas of the insular platform including areas of deep (> 30 m) habitats on the northern coast of Mona Island and around Monito Island as well as shallow (< 30 m) coral reef habitats on the southern portion of the insular platform of Mona Island. The half-mile limit of the NTZ around Mona Island did not include the shelf edge zone of the insular platform along the south and southeast where coral reef development is extensive.

Data on the abundance of fishes and their distribution were investigated through underwater surveys at randomly selected sites around Mona Island. Fish abundance and size (fork length) was collected in stationary belt transects (60 m^2) and roving surveys (5 minutes) designed to detect species rarely quantified in belt transects (e.g. large groupers). With this information and a digitized benthic habitat map (100 m^2 MMU) the important habitats for each species were identified.

Information on spawning aggregations was gathered through a combination of sources including: interviews to fishers with local ecological knowledge (LEK), anecdotal reports, scientific literature, and underwater visual surveys following protocols of the Society for the Conservation of Reef Fish Aggregations, SCRFA (Colin *et al.* 1982). Fishers from the western coast of Puerto Rico were interviewed to gather information specifically on the fisheries activities of Mona Island that targeted coral reef fishes in spawning aggregations (snappers and groupers).

Based on the LEK, reports and scientific literature on spawning seasonality we targeted underwater visual surveys along drift dives in specific areas of the insular platform of Mona and Monito Islands to locate aggregation sites. Survey dive tracks were recorded with a global positioning system (GPS) unit attached to a buoy in order to quantify the area searched and map the position of observations. Geographic coordinates of the survey tracks were matched with fish observations by recording time of observation on a dive-watch synchronized to GPS satellite time. With this information we created layers of potential spawning aggregation sites. For target species we recorded size (fork length, FL), abundance, and spawning clues such as behavior, coloration and morphological characteristics. Repeated underwater surveys were conducted at sites where aggregations were suspected in order to determine species abundances and record direct or indirect observations of spawning activity (Colin *et al.* 2003).

RESULTS

Belt transects were conducted at 613 points between October 2005 to March 2006, and at 283 of these sites roving surveys were also employed (Schärer, 2009). During these surveys evidence of reproductive characteristics was observed for two species: the rock hind (*Epinephelus adscensionis*) and red hind (*E. guttatus*), the former were observed with distended abdomen and the latter in territorial displays and a distinct color phase on the southern coast of Mona Island near the shelf break. Spatial

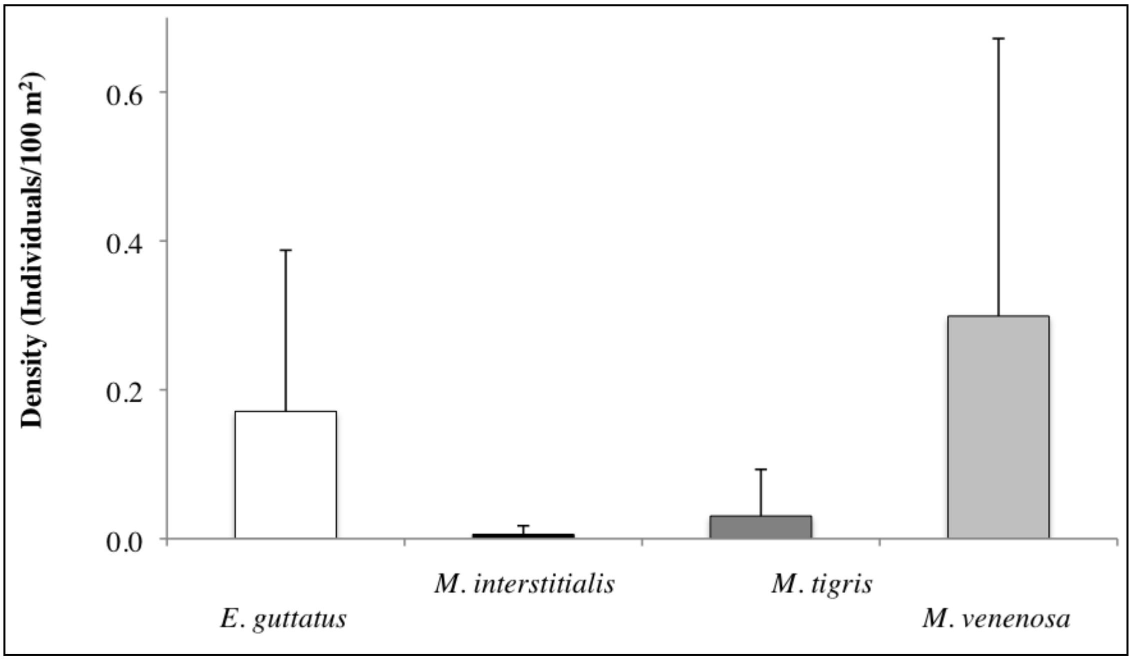

Figure 3. Mean density (individuals/100m^2) of four grouper species found at one multi-species aggregation site, data pooled from 2005 through 2010.

distributions of fish discriminated by size revealed most of the early juvenile settlement habitat for epinephelids occurred in seagrass or rocky habitats in back-reef lagoons near shore (Aguilar-Perera *et al.* 2006b), most of which were located within the NTZ limits.

During three years (2004 to 2007), 53 GPS track surveys were conducted searching for spawning aggregations, involving approximately 38 hours underwater. Belt transects and 5-minute roving surveys detected groupers in very low frequencies compared to the drifting GPS track surveys (Figure 2). GPS-tracked drift surveys were more successful at sighting groupers and with this method four potential aggregation sites were identified, three of which were located outside the limits of the NTZ.Information from LEK provided information on Nassau grouper aggregations, which were mainly targeted between the 1950s and 1970s at Mona Island. Fishers recalled captures of Nassau grouper with developed gonads during winter months (December to February). Captures of this species ranged between 500 and 1,500 lbs per 5-day trip (~167 lbs/day/vessel). Most fishers no longer target shallow water species as declines in grouper populations made trips to this remote site economically unfeasible.

Overall 22 species including threatened groupers were observed with signs of reproductive behavior, such as color phases, sound production (Mann *et al.* submitted), and displays associated with courtship, distended abdomens and, or spawning (Table 1). At one site parrotfish, surgeonfish, triggerfish, wrasses, goatfish and at least four grouper species coincided spatially although peak aggregation months differed. Red hind (*Epinephelus guttatus*) were observed in high densities (relative to other months) during January, February and March, while yellowfin grouper (*Mycteroperca venenosa*), tiger grouper (*M. tigris*) and yellowmouth grouper (*M. interstitialis*) aggregated in higher density between February and May (Nemeth *et al.* 2007a). In comparison with other grouper species, relatively high densities were observed for yellowfin grouper and red hind at one aggregation site (Figure 3). Furthermore yellowfin grouper were found in densities 9 times higher than tiger grouper. Although tiger grouper presented signs of imminent spawning (e.g. color phase, displays and distended abdomen), they were observed at two of the aggregation sites in low numbers (maximum 12 individuals). No Nassau grouper seemed to be aggregated, only two adults with bi-color phase were observed at Monito Island, suggesting this population has not recovered despite management efforts to reduce their captures.

Most spawning aggregation sites encountered at Mona Island were located outside the NTZ boundaries established in 2004. This information was promptly presented to the management authority in charge of fisheries management regulations at the DNER. The opportunity to incorporate this information in a timely manner was possible through a Fisheries Regulations Board, which was created by the DNER in 2005. This board was composed of multiple stakeholders including fisheries managers of local and federal jurisdictions, scientists, outreach specialists, NGO representatives, fishers and the secretary of DNER. The board agreed with the proposal to modify the

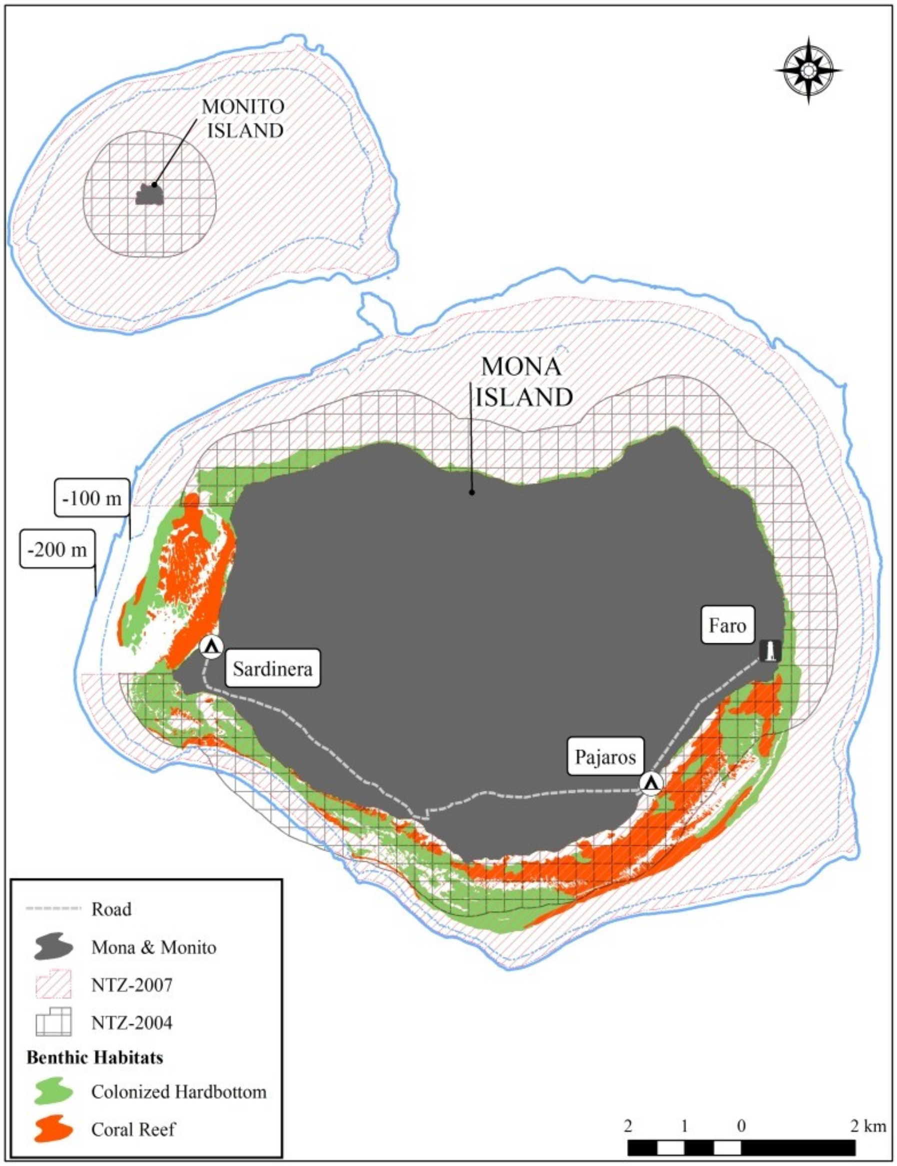

Figure 4. Overlap of the 2004 and 2007 no take zones (NTZ) at Mona and Monito Islands NR upon shallow (< 30 m) benthic habitat map of Mona Island.

Mona Island NTZ limits to include spawning aggregation sites following the recommendation presented by one of us (MTS). The justification for this recommendation was based on the need to protect threatened groupers (*M. bonaci, M. interstitialis*, *M. tigris* and *M.venenosa*), recognizing that these species are protected seasonally (February to April) as a special conservation unit (Grouper Unit 4) in U.S. Federal jurisdictions that surround this MPA. In addition it was suggested that for compliance and law enforcement purposes a depth contour boundary of the NTZ was easier to identify in the field with a depth finder than distance from shore, which requires radar or GPS technology. The new boundaries of the Mona and Monito Island NTZ were ratified as amendment # 7326 to the existing fisheries regulations (DNER, 2007). This amendment extended the boundary of the NTZ to include the extent of the insular platform, defined as the 100-fathom (182 m) bathymetric contour around both islands, while a swath on the west coast of Mona remained open to fishing (Figure 4). The expansion of these limits increased the area protected from fishing by 50 km^2 for a total marine area of 82 km^2. The designation prohibits fishing throughout the year within the NTZ boundary that includes most of the shallow nursery habitats (i.e. seagrass) (Schärer 2009) and critical areas of multi-species fish spawning aggregation sites.

DISCUSSION

The collection of data necessary for ecosystem-based management (EBM) is placed-based and requires a variety of approaches. Standard coral reef monitoring efforts will not be sufficient. For example, in Puerto Rico, routine monitoring occurs only on permanent transects located within Natural Reserves containing the most extensive coral reef areas. However, the determination of critical habitats, and hence appropriate MPA and zoning limits requires a broad-scale survey with high spatial resolution, as was done at Mona Island using belt transect and roving diver methods. Even these were not sufficient to locate critical areas such as spawning aggregations. For key grouper species (*E. guttatus, E. striatus, M. bonaci, M. interstitialis, M. tigris* and *M. venenosa*) sightings in underwater visual surveys using the belt transect method or roving diver method were rare. Both initial LEK and targeted GPS track drift dives were necessary to identify and confirm aggregations sites. Surveys at aggregation sites during reproductive seasons provide a unique opportunity to measure population abundances of these threatened species, information not obtained from reef fish monitoring efforts. For these, the approach of using GPS tracked drift surveys is clearly advantageous, especially in areas of high current. For example, the sighting frequency of red hind (*E. guttatus*) in GPS track surveys was almost 20 times higher than in belt transects and 3.4 times higher than roving surveys. However, it is important to consider that the migrations these species undergo during reproductive seasons (Nemeth 2007b) can affect our ability to detect them and understand their distributions.

While this approach is promising, to quantify population trends and the effectiveness of management actions further information is essential, such as the temporal variability (daily, lunar and monthly) in abundance and spatial distribution within the aggregation. Measuring these patterns would lead to a better understanding of aggregation dynamics and the development of appropriate strategies for allocating sampling effort in space and time to quantify changes in fish abundances. Protecting the few remaining spawning aggregations is an important first step in achieving this objective and remote MPA areas subject to reduced fishing pressure, such as Mona and Monito Island NR are essential for achieving this goal.

The results of this study established that the half-mile boundary of the NTZ designated in 2004 was insufficient for the protection of key spawning aggregation sites and probable migration corridors for multiple species of coral reef fishes. Spawning aggregations of threatened groupers were located in shelf break zones similar to other locations (Sala *et. al* 2001, Claro and Lindeman 2003, Nemeth *et al.* 2006 and Heyman and Kjerve 2008). Shelf breaks are known to be an important spawning habitat for a variety of species, and at Mona Island the shelf break zone is partly located outside the half-mile limit. In this case EBM was fortuitously applied, as the identification of important habitats was fed-back into the decision-making process to modify the NTZ boundary.

The expansion of this NTZ is an important step for the protection of grouper species considered vulnerable in the Caribbean. However, the protection of multi-species spawning sites could provide greater conservation benefits ('more bang for your buck') as various species are protected year round. Nonetheless the implementation and enforcement of the NTZ at this remote MPA is logistically challenging. Increased outreach efforts focused towards managers and local stakeholders as well as timely enforcement efforts during peak spawning seasons may help in the recovery of threatened populations of groupers. These actions may help avoid the disappearance of grouper spawning aggregations as reported elsewhere in the Puerto Rican jurisdiction.

ACKNOWLEDGMENTS

We are indebted with interviewees that shared their knowledge of Mona Island's fisheries and also with volunteer divers that helped in field surveys as well as the crew of *Orca Too* and *Tourmarine* for transportation to Mona Island. The Department of Marine Sciences of the University of Puerto Rico at Mayaguez (UPRM) provided dive vessel support. The DNER provided research permit (#04-IC-004) and logistical support. This publication is a result of funding from the National Oceanic and Atmospheric Administration (NOAA), Center for Sponsored Coastal Ocean Research, under awards NA05NOS4261159 to the UPRM for the Caribbean Coral Reef Institute as well as the NOAA Coral Reef Ecosystems Studies Program (NA17OP2919) awarded to UPRM.

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