Measuring the Performance of Marine Protected Areas: The Case of Little Cayman and Cayman Brac, Cayman Islands

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ABSTRACT

Cayman Brac and Little Cayman are small remote islands (< 30 km²) centrally located in the northwest Caribbean. These islands have no commercial fisheries to date, low fishing pressure and a relatively low population. Their Marine Protected Areas (MPAs) were established in 1986 and have never been assessed to determine their performances on coral reef fish assemblages after 24 years of conservation and active enforcement of no-take zones. With no commercial fisheries to date, this study targeted 53 species of fish considered important for reef health status and ecological function including the species most commonly targeted by fishers. For the targeted species, their biomass, size and density were investigated for comparisons between protected areas and non-protected fished areas. An Underwater Visual Census (UVC) was carried out around both islands during the months from January through to April 2009. Analysis of data collected showed no clear MPA effect concerning their efficiency, effectiveness and performance on their fish assemblages. Cayman Brac in particular only showed a significant difference ($p < 0.01$) in the north MPA when total mean fish size per transect were compared. Little Cayman's north MPA showed significant differences in total mean biomass per transect ($p < 0.001$) and total mean biomass per family ($p < 0.05$). In the south MPA of Little Cayman, significant differences were found in total mean biomass per transect ($p < 0.001$), and per family ($p < 0.05$), mean fish size per transect ($p < 0.001$), mean size classes per species ($p < 0.001$), including mean density per transect ($p < 0.01$) of MPA vs. non-MPA. Additionally, the ratios of herbivore to carnivore biomass were investigated for each MPA to determine trophic structure of each MPA. Overall, the MPAs of Cayman Brac showed no reserve effect on their fish assemblages; however the MPAs of Little Cayman exhibited a more effective MPA system, demonstrating a "reserve effect" in the southern MPA, but also indicating a vulnerability to over fishing.

KEY WORDS: Marine Protected Areas, coral reef fish, reserve effect

Evaluación de los Rendimientos de las Áreas Marinas Protegidas: El Caso de Little Caimán and Caimán Brac, Caimán Islandés

Cayman Brac y Little Cayman son islas pequeñas y remotas (< 30 km²) localizadas en el nor-oeste del Caribe. Estas islas tienen baja población, poca presión de pesquería artesanal y ninguna pesquería commercial activa. Las Area Marinas Protegidas (AMP) se establecieron en 1986 y nunca han sido monitoreadas para determinear su efecto sobre las poblaciones de peces arrecifales luego de 24 años de activa conservación y prohibición de pesquerias comerciales. Este studio se enfocó en 54 especies de peces consideradas importantes para la salud del arrecife y función ecológica, incluyendo species preferidas por los pecadores locales. Se midieron la biomasa, tamaño y densidades de las poblaciones para compararlas con áreas no protegidas. Se llevó a cabo un senso submarino (SSU) alrededor de las dos islas desde enero hasta abril de 2009. El análisis de los datos colectados mostró pocas diferencias en la efectividad de los AMPs comparado con las zonas no protegidas. En Cayman Brac, solo se encontró diferencia significativa ($p < 0.01$) en el AMP del norte cuando se compararon los promedios de tamaño de los peces por transecta. El AMP del norte an Little Cayman's AMP mostró un biomasa total por transecta significativamnte mayor ($p < 0.001$) y una biomasa ($p < 0.05$) por familia mayor que en áreas no protegidas. En le AMP del sur en Little Cayman se consiguieron diferencias significativas en la biomasa total promedio por trnasecta ($p < 0.001$) y promedio de tamaño por familia ($p < 0.0.001$), promedio de las classes de tamaño por species ($p < 0.001$), incluyendo promedio de densidades por transecta ($p < 0.01$), comparadas con áreas no protegidas. Adicionalmente la relación de biomasa entre peces herbívoros y carnivoros se investigó para cada AMP para determiner la estructura trófica dentro de cada AMP. En general, los AMPs de Cayman Brac no mostraron ningún efecto reversible en las agregaciones de peces. Los AMPs de Little Cayman por otro lado si mostraron un efecto de proteccion más efectivo y además, una vulnerabilidad a la sobrepesca.

PALABRAS CLAVE: Area Marina Protegida, peces arrecifales, efecto reversible

Evaluation des Performances des Aires Marines Protegées: Le Cas de Little Cayman et Cayman Brac, Cayman Islands

MOTS CLÉS: Aires Marines Protegées, poissons coralliens, evaluation des performances

INTRODUCTION

Marine environments, such as coral reef ecosystems are of vital importance to coastal communities in the tropics whom rely on them as a food source and income by exploiting their fisheries (Roberts 1995, Jennings and Polunin 1996), but are vulnerable to anthropogenic threats such as climate change, disease, pollution and overfishing (Jackson, et al. 2001, Hughes et al. 2003 Gardner et al. 2003, Wilkinson 2008, Hughes et al. 2010). Additionally natural perturbations including recurrent hurricanes in particular the Caribbean region has had damaging long term effect on coral reef habitat and function (Nyström et al. 2000., Wilkinson 2008). Marine parks have become popular new tools for conservation and fisheries management, providing refuge coral reefs and their associated organisms. Actually, no-take Marine Protected Areas (MPAs) preserve the fish assemblages mainly from all kinds of fishing and extractions, whereby allowing a "build -up" of fish biomass (Polunin and Roberts 1993., Roberts 1995b., Gell and Roberts 2003)

Studies have shown that strict no-take zones allow fish stocks to be restored to their natural population numbers over time in addition to providing fish and larvae to outlying fished area by Spillover effect (Roberts and Hawkins 2000, McCoy et al. 2009). In the last decade, an increasing number of studies have investigated "reserve effect" based on comparison of fish biomass, abundance, density and individual fish size distribution between protected areas and unprotected openly fished areas (Dugan and David 1993, Polunin and Roberts 1993, Roberts 1995, Wantiez et al. 1997, Harmelin-Vivien et al. 2008, McCoy et al. 2009).

A recent study (McCoy et al. 2009) in Grand Cayman was carried out testing the performances of the MPA on the fish assemblages with surprising results. Though there are no commercial fisheries, and relatively low human impacts in Grand Cayman, fish biomass and size of individuals was significantly higher inside the Marine Parks. Moreover, the "occurrence" of species and the ratio between herbivorous and carnivorous fishes was more balanced inside the MPAs. This study suggest that recreational fishing, primarily using lines and spears, can have a severe negative effect because of the inherent selective nature toward certain fish species (McCoy et al. 2009), though few studies have ever examined the impact of this kind of fishing on fish assemblage in coral reef habitats (Westera et al. 2003).

In the Cayman Islands, many studies have been carried out on coral communities but few involved fish assemblages (Burgess 1978, 1994, Pattengill-Semmens and Semmens 2003). The previous cited study (McCoy et al. 2009) was the first article focused on the response of fish community to the establishment of the MPA in Grand Cayman, after 24 years of protection. However, no studies, to date, have been done on MPAs performances in Little Cayman and Cayman Brac, considered the "Sister Islands". This present study represents the first analysis of Little Cayman and Cayman Brac fish assemblages and will constitute a baseline for future studies.

These two islands are small, geographically remote and protected from extreme anthropogenic impacts due to a limited number of inhabitants (Cayman Brac <1 ,500, Little Cayman < 200).

The aim of this present study is to assess effects of the Little Cayman MPAs and Cayman Brac MPAs system on coral reef fish assemblages by comparing fish populations between protected and non-protected areas Reserve effect was tested by comparisons of six variables: mean fish biomass and size per transect and per species, mean density of fish per transect and the ratio between the biomass of herbivorous fishes to carnivorous fishes.

Identified hypotheses for this study are as follows:

i) There are no differences between the different variables measured on protected and non-protected sites, and
ii) These biological values are high and balanced around the two islands.

METHODS

Study Site

The Cayman Islands consist of three islands, Grand Cayman, Little Cayman and Cayman Brac, located between 19°15' and 19°45' N latitude and between 79°44' and 81°27' W longitude. They are the peaks of a submerged ridge, which runs westwards from the Sierra Maestra mountain range of Cuba. These three Overseas Territories of the United Kingdom are the most arid and isolated of West Indian islands unusually flat and formed entirely from calcareous marine deposits (Logan, 1988).

The study was carried out in Little Cayman and Cayman Brac, respectively located at 105 km and 130 km north east from Grand Cayman (Figure 1), the largest and most populated (197 km², 60,000 inhabitants). In comparison, these two islands are considered small, and undeveloped (26 km² for Little Cayman and 36 km² for Cayman Brac) with a population of < 300 and <1500 respectively. They are positioned close together, separated by a stretch of just **7** km (with abyssal depths of >1000 m between them).

There are two distinct reef terraces in Cayman Brac, the north east coast and the southern coast of Little Cayman: the shallow terrace reef (5 - 12 m), comprised of two environments, lagoons and a fringing-reef complex, and the deep terrace reef (12 - 25 m), plunging vertically to abyssal depths. In the northwestern side of Little Cayman, within the Bloody Bay / Jackson Point Marine Park, the deep terrace is absent and the shallow terrace extends out to 300 m from the coast before plummeting vertically to abyssal depths (Fenner 1993). The narrow insular reef-shelf measure ranges from 200 m in width at some locations along the north and south coast extending to 1.5

km maximum in width at the east and west ends of each island. The structure of the reefs, principally constituted by "spur and groove" formations, greatly differ according to the exposure of the coast. The north to north easterly approach of storms in the winter and the predominantly south to south easterly approach of weather system in the Summer, including tropical storms and hurricanes results in two margin types: a high energy exposed-windward margin (south coast) and a moderate energy protected-windward margin (north coast).

The MPAs in Cayman Islands were established in 1986. Little Cayman has two Marine Parks, with one distributed on each side of the island. Bloody Bay / Jackson Point Marine Park, on the northern side covers 1.72 km² of the island shelf and the Preston Bay Marine Park, on the southern side covers 1 km² (Figure 1). Combined, the parks represent 14.5 % of the total shelf area of Little Cayman. Three Marine Parks are located around Cayman Brac: two in the south covering 2.86 km² and 0.38 km² of the shelf area, the third one, located on the northern side, covers 0.45 km². These three parks combines gives a total shelf area protection of 17.8 % of the island. The locations of different MPAs around the islands are presented in Figure 1. In the Cayman Islands, residents are permitted to fish within protected areas provided that they do so from the shore or beyond the 25m depth contour of the deep terrace reef.

Method of Visual Census

Sampling was carried out during the months of January through to April 2009, between 0900 hours and 1500 hours. In order to study potential reserve effect, 16 comparable reef sites were randomly selected around Little Cayman and 12 sites around Cayman Brac. Half of the studied sites around each island were located inside the Marine Park, which represent eight protected sites at Little Cayman and six protected sites at Cayman Brac (Figure 1). Fish counts were made at two depths; the shallow terrace reef (10 - 12 m) and the deep terrace reef (16 - 18 m), except the north side of Little Cayman where the deep terrace is missing and the shelf edge rarely exceeds 10 m within the Marine Park, forcing all surveys to be done within the 10 - 12 metre depth contour to be comparable (Table 1).

Table 1.

		Little cayman		Cayman Brac	
		North	South	North	South
Protected sites	Shallow terrace	4	2	2	2
	Deep terrace	–	2	1	1
Non-protected sites	Shallow terrace	4	2	2	2
	Deep terrace	–	2	1	1
All sites	Total	8	8	6	6

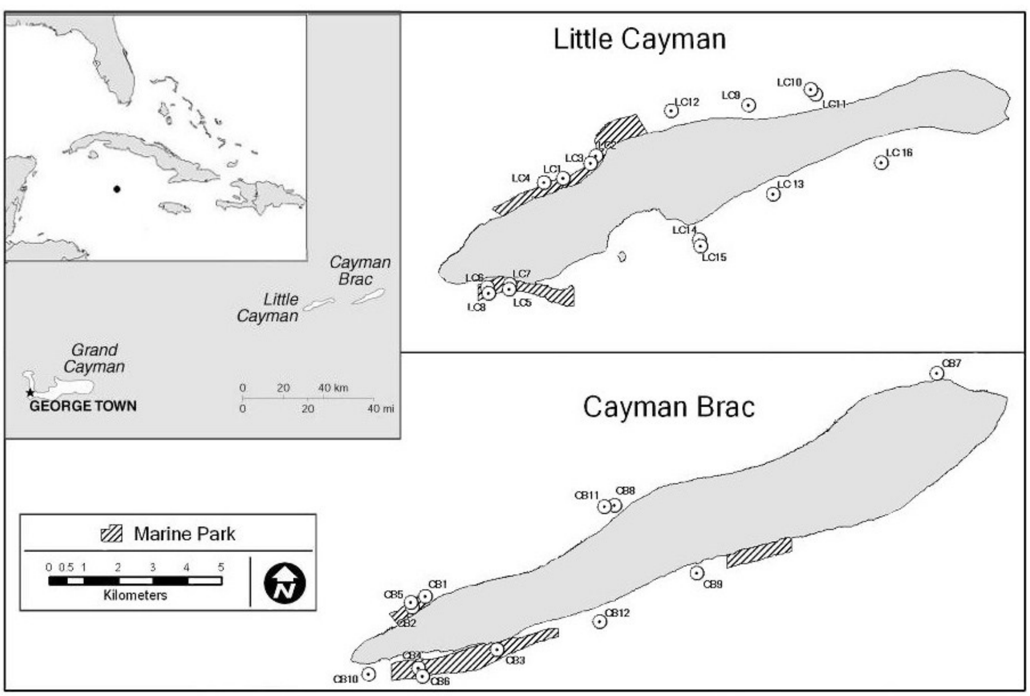

Figure 1: Location of Cayman Islands in the Caribbean and location of the studied sites around Little Cayman and Cayman Brac. Hatched zone corresponds to the Marine Protected Area.

Data were collected by Underwater Visual Census (UVC), using belt transects, (Samoilys and Carlos 2000). At each site, fish were censused along three transects (50 m x 5 m) with a 10 m gap in between transects, sampling 750 m² of reef area per site. The diver swam along transects with a graduated PVC T-bar and recorded the number of individuals, species and total length of fish (in 9 size classes of 5 centimeter increments), within 2.5 m on either side of the transect line and 5m above it. Pre-determined target fish identified within the transect belt were identified and counted, with 53 coral reef species, belonging to 16 fish families, constituting the list of targeted fish species (Table 2). However, six species were not observed during our censuses in Little Cayman: *Epinephelus itajara*, *Caranx latus*, *Lutjanus jocu, Lachnolaimus* maximus, *Pomacanthus arcuatus* and *Aluterus scriptus*). Similarly five species were absent during censuses at Cayman Brac: *Epinephelus itajara, Lutjanus jocu, caranx latus, Haemulon plumieri* and *Aluterus scriptus*.

Table 2.

Species	Trophic groups	Species	Trophic groups
Serranidae		**Acanthuridae**	
Epinephelus striatus	C1	*Acanthurus coeruleus*	HB
Epinephelus cruentatus	C1	*Acanthurus chirurgus*	HB
Epinephelus guttatus	C1	**Scaridae**	
Cephalopholis fulvus	C1	*Sparisoma viride*	HB
Mycteroperca tigris	P	*Scarus vetula*	HB
Lutjanidae		*Scarus taeniopterus*	HB
Lutjanus mahogoni	C2	*Scarus iserti*	HB
Lutjanus analis	C2	*Sparisoma aurofrenatum*	HB
Lutjanus jocu	C2	**Pomacentridae**	
Ocyurus chrysurus	C2	*Holacanthus ciliaris*	C1
Lutjanus apodus	C2	*Holacanthus tricolor*	C1
Labridae		*Pomacanthus paru*	C1
Lachnolaimus maximus	C1	*Pomacanthus arcuatus*	C1
Bodianus rufus	C1	**Chaeotodontidae**	
Halichoeres radiatus	C1	*Chaetodon striatus*	C1
Thalassoma bifasciatum	C1	*Chaetodon capistratus*	C1
Haemulidae		*Chaetodon ocellatus*	C1
Haemulon flavolineatum	C1	**Balistidae**	
Haemulon sciurus	C1	*Balistes vetula*	C1
Haemulon plumieri	C1	*Melichthys niger*	OM
Haemulon macrostomum	C1	*Cantherhines macrocerus*	C1
Aulostomidae		**Muraenidae**	
Aulostomus maculatus	C2	*Gymnothorax funebris*	P
Sphyraenidae		*Gymnothorax moringa*	P
sphyraena barracuda	P	**Carangidae**	
Kyphosidae		*Caranx ruber*	P
Kyphosus sectactrix	HB	**Mullidae spp**	C1

In order to standardize counts and sampling effort, census began at least 15 minutes after deploying each transect and the time of census was limited to a maximum of 15 minutes for consistency. The collection of data began after a training period to familiarize species recognition. Fish replicas of different shapes and sizes were used to estimate size classes and mean standard error of size estimates was -1.09 cm.

Data Analysis

Length estimates of observed were used to estimate biomass (weight) per unit area of reef by using the allometric length-weight conversion (Bonhsack 1988) and expressed in (g/m²) using surface area sampled:

$$W = a\mathrm{TL}^{b}$$

Where W is weight in grams, parameters a and b are constants obtained from the literature (Froese and Pauly 2005) and TL is total length in centimeters. The diet of the different trophic groups has been listed (Table 1), according to data from Randall (1967) and species were classed into five trophic groups:

i) herbivores (HB),
ii) omnivores (OM),
iii) piscivores (fish feeders) (Predators: P),
iv) invertebrates feeders (Carnivores 1: C1),
v) fish and invertebrates feeders (Carnivores 2: C2).

Fish density, size and biomass were tested for normality (Shapiro-Wilks test). Data from within the MPAs was compared to data outside the MPAs using a student's t-test when level of replication allowed and the data met the test's assumptions of normality. Otherwise, non parametric test (Wilcoxon-Mann-Whitney) was used for comparisons. Since paired MPAs are located on opposing sides of each island and subjected to contrasting environmental conditions, comparisons between MPA and non-MPA sites were separated and analyzed according to aspect (northern and southern).

Conservation Values

In this study, conservation values were adapted to allow us to characterize the efficiency of the MPAs in Little Cayman and Cayman Brac. We considered six biotic variables: mean fish biomass per transect, mean fish biomass per fish families, mean fish density per transect, mean size of individuals per transect, mean size of individuals per fish species and proportions between herbivores-omnivores and carnivores. By doing this, it was possible to give a value to each Marine Park according to their effect on fish assemblages, in allocating one point for each variable that was significantly higher inside the evaluated MPA.

RESULTS

A summary of the different mean values measured at Little Cayman and Cayman Brac, on protected and non-protected sites is presented in Table 3 (mean biomass, mean density and mean size of individuals). Significant differences between MPA and comparative non-MPA sites were noted. Data from Grand Cayman, originally from McCoy et al. (2009) were added to the table for comparison.

Fish Biomass

Mean fish biomasses, in g/m², was calculated for each transect covered during the census and are presented in Table 3. Comparisons of mean fish biomass calculated on protected and non protected sites showed a biomass significantly higher inside MPAs at Little Cayman (p = 0.01). These values of fish biomass were two times higher inside Marine Parks than out (Little Cayman:72.46 g/m² and 30.41 g/m² in the south respectively; 90.49 g/m² and 46.78 g/m² in the north respectively) and were similar to the mean fish biomass measured on Grand Cayman MPA: 71.78 g/m² inside MPA and 44.66 g/m² outside MPA.

Based on these values, the highest relative mean fish biomass in the Cayman Islands would appear to be within the Bloody Bay / Jackson Point Marine Park (north MPA of Little Cayman), with a mean fish biomass of 90.59 g/m².

Biomass per family was studied at Little Cayman (north and south) in order to show which fish family contributed the most to fish biomass inside MPAs (Figure 2). In the north MPA of Little Cayman, three fish families participate to the higher mean biomass: *Haemulidae* and *Balistidae* with a mean biomass two times higher inside the MPA, and *Lutjanidae* with a mean biomass four times higher inside the MPA (p < 0.05). In the south MPA of Little Cayman, *Kyphosidae*, *Lutjanidae* and *Scaridae* participate actively to increase the biomass inside the MPA, with a biomass respectively six, two, and one and half times higher inside the MPA (p < 0.05).

Around Cayman Brac, no significant difference in fish biomass was found between protected and non-protected sites. With an average of 47.13 g/m² inside MPAs and 48.36 g/m² outside MPAs, both north and south MPAs, these values are very low and correspond to the mean biomass we found in non-protected sites around Grand Cayman: 44.66 g/m².

Ratio Between Herbivorous and Carnivorous Fish Biomasses

Ratios between two groups of fish (carnivores and herbivores-omnivores) allowed us to investigate the distribution of trophic groups inside and outside the MPA. The first group was comprised by the herbivores and omnivores (HB-OM), the second grouped carnivores together: P (Predators), C1 (invertebrates feeders) and C2 (fish and invertebrates feeders) (CA). We compared the ratio R between biomass of these two trophic groups. A ratio equal to one (1) will show a balanced fish community, with the same proportion between carnivores and herbivores. Results are presented in Figure 3.

On the southern side of Little Cayman, significant difference were found between ratio measured on protected sites (R= 0.38) and ratio measured on non-protected sites (R= 0.27). Additionally, the mean biomass of carnivores represented 28% of the total fish biomass inside the MPA and 21% outside the MPA (p < 0.05). Although these values were more pronounced at Grand Cayman (20% of the total mean biomass outside the MPA versus 39% inside the MPA for carnivorous fishes), this difference between

Table 3.

	Little Cayman (south)	Little Cayman (North)	Cayman Brac (South)	Cayman Brac (North)	Grand Cayman
Density (ind/100m²)					
Protected	28.13	36.67	18.18	28.4	26.17
Non protected	23.73	26.30	21.64	29.96	28.81
Statistic Test	W = 89.5	W = 108	W = 34.5	W = 41.5	T = 0.974
Difference	*	NS	NS	NS	NS
Biomass (g/m²)					
Protected sites	72.46	90.59	39.23	55.02	71.78
Non protected sites	30.41	46.78	43.94	52.79	44.66
Statistic Test	W = 124	W = 108	T = -0.295	W = 26	T = 2.644
Difference	***	**	NS	NS	**
Mean Size of fish (cm)					
Protected sites	21.80	22.62	20.75	21.89	22
Non protected sites	17.88	20.89	19.19	19.58	19.8
Statistic Test	W = 130	W = 95	W = 53	W = 64	W = 1159
Difference	***	NS	NS	**	***

the biomass of carnivores and herbivores in the southern MPA at Little Cayman showed an unbalance and possibly disturbance of the trophic structure by people illegally fishing the protected sites. No significant differences between MPA and non-MPA were found on the northern side of Little Cayman even with a mean biomass of carnivorous fishes corresponding to 41% (R = 0.71) of the total mean biomass inside the MPA and 27% (R = 0.38) outside the MPA.

At Cayman Brac, no difference was found between the proportion of herbivores and carnivores between protected and unprotected sites, with the same percentage of carnivores inside and outside MPAs which represented 30% (R = 0.42) of the total mean fish biomass.

Mean Density of Fish

Mean density of fish was significantly higher inside the MPA located in the south of Little Cayman ($p < 0.05$) with 23.73 individuals/100 m² on non protected sites and 28.13 individuals/100 m² on protected sites.

No differences were found at Cayman Brac between mean densities of fish measured inside and outside MPAs ($p > 0.05$). Thus, on the different studied MPAs of Cayman Islands, only one MPA (The Bloody Bay / Jackson Point Marine Park) showed a mean fish density significantly higher than the outlying fished areas.

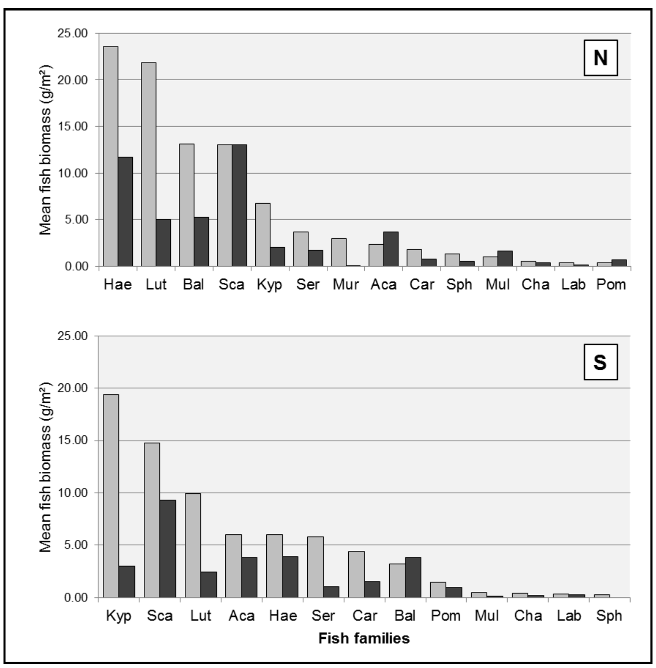

Figure 2. Mean biomass (g/m²) of Scaridae (*Sca*), Lutjanidae (*Lut*), Carangidae (*Car*), Sphyraenidae (*Sph*), Mullidae (*Mul*), Balistidae (*Bal*), Pomacanthidae (*Pom*), Acanthuridae (*Aca*), Serranidae (*Ser*), Haemulidae (*Hae*), Labridae (*Lab*), Chaetodontidae (*Cha*), Kyphosidae (*Kyp*) and Muraenidae (*Mur*) on protected sites (*gray*) and non protected sites (*black*); on the northern sites (N) and on the southern sites (S) of Little Cayman.

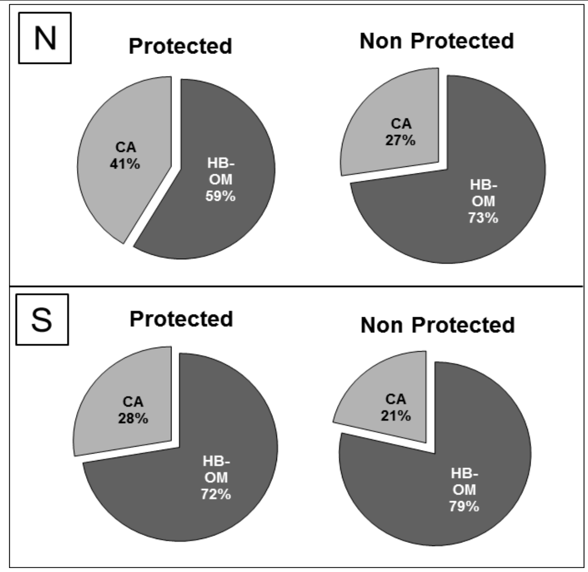

Figure 3. Proportions of Herbivores-Omnivores (HB-OM) and of Carnivores (CA), on protected and non protected sites, at Little Cayman northern side (N) and Little Cayman southern side (S).

Mean Size of Fish

The mean size of fish was estimated on each transect, in cm, and grouped in nine size classes. We analyzed the mean size of fish per transect and per species. The results are presented in Table 3. Significant differences of fish size between protected and non protected areas were found in two cases: In the south MPA of Little Cayman, fish were 4 cm bigger inside the MPA ($p < 0.001$). Mean size of fish located inside the Marine Park was 21.80 cm and 17.88 cm outside the Marine Park. When we compared size of fish by species, on average Nassau grouper was 15 cm bigger, mutton snapper was 12 cm bigger, yellowtail, Spanish hogfish and Mahogany Snapper were 5 cm bigger, inside the MPA.

In the northern MPA at Cayman Brac, the mean size of fish inside the MPA was 21.89 cm and 19.58 cm outside the MPA, giving a difference of 3 cm between areas ($p = 0.01$). However, no differences were found when we compared the mean size of fish species by species. Though comparisons of mean size of fish were not significant for all studied areas (North side of Little Cayman and south of Cayman Brac), similar combined values of fish size were found at the Sister Islands when compared to Grand Cayman where mean size of fish were 22 cm within the MPA and 19.8 cm outside the MPA, respectively.

Conservation Values

In Little Cayman, a notation of 6/6 was given to the MPA located in the south and a notation of 2/6 for the MPA located in the north (Bloody Bay / Jackson Point MPA). For the case of Cayman Brac, only one point was accorded to the MPA located on the northern side, this was due to the size of fish significantly bigger inside the Marine

Protected Area when compared to outside the Marine Protected Area. There were no differences for the five other variables between the protected and the non protected sites.

DISCUSSION

Due to the remote location of Little Cayman and Cayman Brac and the lack of any significant infrastructural development on either island, mixed results were surprising. The southern side of Little Cayman showed an efficient MPA, with differences on fish community, whereas the MPA located in the south of Cayman Brac did not have any impact on the fish community. In our hypothesis, a lack of differences between protected and non protected sites was expected due to the absence of fishing pressure within the MPAs. However, the MPA located in the south of Little Cayman showed a strong reserve effect, possibly indicative that it is being effective, or that protection has maintained a healthier reef area and fish assemblages as had been there prior to designation as an MPA.

In the north of Little Cayman, we found some differences between the biological variables we measured inside and outside of the MPA, though all were not significant, they did indicated a small reserve effect and a vulnerability of this MPA to modifications on the fish assemblage structure.

The impacts of artisanal and recreational fishing practices have been given little or no attention and have been largely overlooked for a long time (Cooke and Cowx 2004, 2006, Hawkins and Roberts 2004, Morales-Nin et al. 2005). However, given the fact that there are no commercial fisheries in the Cayman Islands and according to the results published on Grand Cayman (McCoy et al. 2009), these kind of fishing practices can have damaging effects on fish communities leading to differences between the fish assemblage structure inside and outside of MPAs.

In Cayman Brac, no reserve effect was found around the island, which could possibly be indicative of an environment naturally protected by an absence of anthropogenic pressure. But around this island, biological variables such as fish biomass, size of individuals and fish density are especially low. For example, the lack of significant differences between fish biomass inside and outside the MPA located in the south of Cayman Brac should be the result of a low level of fishing pressure along this coast and should foster and promote a high value of fish biomass. However, the mean biomass measured along this coast was 41.58 g/m², approximately the same biomass measured on non-protected fished sites at Grand Cayman.

The size and location of MPAs has often been used to explain the mixed results obtained at the Sister Islands (Cayman Brac and Little Cayman), since contrarily to Grand Cayman, the different marine parks at the Sister Islands represent small areas and their locations were chosen by the public, not for the high biological values (Petrie and Bush 1991). Indeed, all studied MPAs at Sister Islands were less than 3 km², while the MPA of Grand Cayman, demonstrating effectiveness and efficiency was more than three times bigger. The optimum size of a MPA has been debated for decades (Aswani and Hamilton 2004) and a recent review showed that any sized marine reserve increases fish density and diversity, although larger one would be more effective (Claudet et al. 2008). An interesting study from Halpern (2003) has showed that the effect of a reserve on biological measure appears to be independent of reserve size demonstrating that the St. Lucia reserve, with 0.0026 km² is associated with significantly larger values in the biomass and size of the organisms within the reserve.

Marine parks have in general a positive impact on fish community by increasing biomass and abundance. However, this impact is often less important and less obvious on coral reef community (Coelho and Manfrino 2007) because they cannot prevent corals disease and bleaching events. Cayman Brac has been repeatedly effected by hurricanes of Category 3 or higher over the past few decades, with the most recent being a direct hit by Hurricane Paloma in November 2008, a strong Category 4 storm devastating the small island (Croy McCoy, *pers. Comm.)*, which could explain why its reefs are in worse condition than those of Little Cayman, where despite their proximity, damages were much lower. In a recent study (Gall 2009) it was demonstrated that reefs at Cayman Brac were not different inside and outside the MPA, but were badly damaged. The lack of contrast between protected and non protected areas in Cayman Brac is unknown but further studies should reveal wither it is due to size of MPA, degraded habitat quality, high fishing pressure in adjacent waters or a combination of these factors. Similar findings in the US Virgin islands (Rogers and Beets 2001) also showed no significant differences in number of species, biomass or mean size of fishes possibly due to habitat degradation and high fishing pressure in addition to stresses outside the control of the park managers (e.g. hurricanes). Furthermore Monaco *et al.* (2007) compared the fish community inside and outside of the same Marine Park in the US Virgin Islands and concluded that due to degraded habitat and the lack of structural complexity within the Marine Park, the potential for reef fish to increase in numbers and biomass maybe compromised.

Low levels of fish biomass around Cayman Brac can equally explain the fishing pressure in Little Cayman. Further to the habitat degradation and the decline of fish, Little Cayman waters are more plentiful in term of fish and very attractive to the residents of Cayman Brac.

The case described here is an example of the marine ecosystem fragility in a very small scale. In view of natural or anthropogenic pressures, small impacts can have grave consequences on biological communities in upsetting the delicate balance of marine environments and their ecological functions.

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