What can two years of monitoring tell us about Venezuelan coral reefs? The Southern Tropical America node of the Global Coral Reef Monitoring Network (STA-GCRMN)

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Abstract: In spite of their economic importance, coral reef communities of the world are rapidly decreasing, and an adequate management planification is needed . The benthic and fish communities of Dos Mosquises Sur and Madrizquí at Los Roques National Park, and Caiman and Cayo Norte at Morrocoy National Park, in Venezuela were monitored during 2003 and 2004. The CARICOMP method was used to describe the benthic community, and the AGRRA protocol was applied to the fish community assessment. The benthic cover of five broad living categories (i.e. corals, algae, sponge and octocorals) differed across the sites (Nested ANOVA, $p < 0.05$), but there were no statistical differences between parks. Despite being on different parks, the benthic cover in Dos Mosquises Sur and Cayo Norte was similar (76% based on Bray-Curtis), whereas Caiman differed greatly (57- 68%) from all other sites. The cover of hard coral, algae, sponges and octocorals was similar between 2003 and 2004 in all four sites. Similarly, the fish community structure of both parks did not change over time, and was dominated by herbivores (Pomacentridae, Scaridae and Acanthuridae). However, commercially important carnivores (e.g. Lutjanids and Serranids) were more abundant in Los Roques than in Morrocoy. Although it was expected that the benthic cover and fish community would reflect greater differences between Los Roques and Morrocoy, only the fish community appeared healthier in Los Roques, whereas Cayo Norte (Morrocoy), had a coral cover similar or higher than both sites of Los Roques. Thus, our results suggest that in Venezuela, oceanic reef sites are not necessarily 'healthier' (i.e. higher coral cover) than land-influenced coral communities. The addition of three new sites and the reincorporation of Caiman has improved and expanded the monitoring capabilities in Venezuela and it represents the first step towards the consolidation of a coral reef monitoring program for the country. Rev. Biol. Trop. 58 (Suppl. 1): 51-65. Epub 2010 May 01.

Key words: GCRMN, coral reefs, benthic organisms, reef fish, monitoring, CARICOMP, AGRRA, Venezuela, Caribbean.

Over the past few decades coral reefs have undergone important changes world-wide (Hughes *et al.* 2003). Since the 80's, the decline in coral cover has been often reported for the Caribbean (*e.g.* Gladfelter 1982, Dustan & Hallas 1987, Hughes 1994, Jackson *et al.* 2001, Gardner *et al*. 2003). In this region, the combination of both natural (*i.e.* storms and hurricanes) and anthropogenic impacts (*i.e.* sewage, eutrophication, coastal development, coral mining and over fishing), as well as other factors, such as epizootic events, had produced important changes in the structure and function of reef ecosystems (Carpenter 1990, Aronson & Precht 2001, Jackson *et al.* 2001, Guzmán *et al.* 2004). In order to detect and understand these changes, different monitoring programs and protocols (*e.g.* CARICOMP, AGRRA) have been developed.

In Venezuela, as in many other Caribbean countries, coral reefs represent the more important marine ecosystem in terms of biodiversity,

profitable tourism, fisheries and other economic activities (Zubillaga 2001, Weil 2003). Corals and coral reefs in Venezuela have a narrow distribution as they are confined to specific sites (mostly oceanic islands) where conditions for reef growth prevail (Weil 2003). Along the Eastern coast of Venezuela, reef development is limited by high sedimentation rates and low salinities that result from the Orinoco River influence (Weil 2003), and also by low temperatures produced by seasonal upwelling (Pauls 1982). The steep slope that characterizes the central coast of Venezuela prevents extensive fringing reef formation; however, marginal coral communities are common (e.g. Ortíz 2002). The most extensive continental coral reefs are found at the Central-Western Venezuelan mainland (San Esteban and Morrocoy National Parks). Nevertheless at Morrocoy, coral reefs collapsed after a mass mortality event in 1996 (Villamizar 2000, Laboy-Nieves *et al.* 2001).

Coral reef studies in Venezuela have mainly focused on a point in time, in community description (*e.g.* Bone 1980, Weil 1980, Pauls 1982, Cróquer & Villamizar 1998, Zubillaga 2001, Ramírez-Villaroel 2001). Monitoring activities started thirteen years ago when the "Instituto de Tecnología y Ciencias Marinas" (INTECMAR- Universidad Simón Bolívar) joined the CARICOMP network in 1992. During four years, INTECMAR's personnel monitored the reef of Playa Caiman at the National Park of Morrocoy, however, due to the mass mortality event of 1996 at MNP, coral cover declined dramatically at Caiman (Laboy-Nieves *et al.* 2001, Bastidas *et al.* 2006), and the reef at Cayo Sombrero was substituted for Caiman in the monitoring program. Thus, the Sombrero reef has been monitored every six months, since 1996. Also, since 2002, the "Instituto de Investigaciones Marinas de Margarita" (EDIMAR) has been monitoring a coral reef in Margarita Island (Punta Ballena) as part of the CARICOMP network. In summary, from 1992 to 2002, three sites have been monitored in Venezuela (Caiman, Sombrero and only recently, Punta Ballena), but each one over a different lapse of time. Therefore, the major objective of the inclusion of the Venezuelan reefs in the Southern Tropical America Node of the Global Coral Reef Monitoring Network (STA-GCRMN) was to expand the monitoring capacities and, particularly, to incorporate reef sites from Los Roques National Park (LRNP), where the most extensive reefs in Venezuela are found. The final goal is the consolidation of a coral reef monitoring program in Venezuela for cooperating and sharing information with the other four countries of the STA-GCRMN. Data collected within this program should provide the status of Venezuelan coral reefs to incorporate them to a regional perspective.

The participation of Venezuela in the STA-GCRMN: The GCRMN was created in 1995 to encourage and compile monitoring efforts world-wide to have a better global perspective on the status of coral reef (Garzón-Ferreira *et al.* 2000). At end of 1999, Brazil, Colombia, Costa Rica, Panama and Venezuela organized the Southern Tropical America Regional Node (STA) of the GCRMN. This initiative has being coordinated by "Instituto de Investigaciones Marinas y Costeras" of Colombia (INVEMAR) with financial support of UNEP-RCU/CAR. In 2002, INVEMAR and INTECMAR signed a cooperative agreement to encourage coral monitoring in Venezuela, to improve existing monitoring programs and to expand these activities to sites of particular interest. Since 2003, INTECMAR expanded its monitoring program by adding four new sites: Madrizquí and Dos Mosquises Sur at Los Roques, and Cayo Norte and Caiman at Morrocoy National Park. In 2003 and 2004 these sites were monitored in order to evaluate the status of their benthic and fish communities. Comparisons of the benthic and fish communities between the reefs of two Parks (Los Roques and Morrocoy) were of particular interest because their oceanic and terrestrial influence, and potentiality to represent extremes of coral cover and reef conditions. Two reef sites at each park (Madrizqui, Dos Mosquises Sur, Cayo Norte and Caiman, respectively) were

used to compare: (1) the health of benthic communities and (2) the abundance and composition of fish communities.

MATERIALS AND METHODS

Description of study area: During July-August 2003 and August-September 2004 monitoring surveys were conducted at Madrizqui, Dos Mosquises Sur, Caiman and Cayo Norte. Madrizqui and Dos Mosquises reef sites were selected in view of the importance of Los Roques in terms of reef extension, development and diversity (Villamizar *et al.* 2003, Weil 2003) and also because of their relative position within the park (Fig. 1). Los Roques National Park was created in 1972 and it is an oceanic archipelago located 160km North of the Venezuelan mainland (11°44'30''-11°58'36'' N, 66°33'30''-66°57'27'' W). The park is divided into seven different management zones (i.e. integral protection, primitive, managed-natural environment, recreation, historic interest, services and special use). Both Dos Mosquises Sur and Madrizqui are fringing reefs; Dos Mosquises Sur is located at the South-Western edge of LRNP where human population is scarce (<25 permanent residents) (11º48'03'' N, 66º53'30'' W) (Fig. 1). On the contrary, Madrizqui is located close to Gran Roque Island, where the major human settlement of the archipelago is found (~1200 permanent residents) (11º56'33'' N, 66º39'38'' W). Caiman is located in the MNP <2km away from Boca Grande, a channel that communicates the inner sectors of Morrocoy national Park with the open sea (10°52' N, 69°16' W faltan más coordenadas) (Fig. 1). Morrocoy was declared a National Park in 1974 due to its importance in terms of biodiversity and richness of biotopes. Like Los Roques, the park is organized in different management zones (i.e. integral protection, primitive, managed-natural environment, area of natural recovery, recreation, services, areas for speleology, mitigation, areas of autochthon use and areas of especial use). Because data was available from 1993 to 1996 for the coral community in Caiman this reef was selected for monitoring in order to determine if there is any recovery pattern of its coral community. Contrarily, Cayo Norte is one of the few reefs that might not have been affected by the 1996 mortality event, and it may represent a reef in relatively good condition for the area of the Morrocoy National Park (10º52´ N, 68º16´ W).

At each site, the benthic community was described by evaluating the cover of live coral (massive, encrusting, branching, foliose and plate-like), algae (turf, fleshy, calcareous, encrusting algae and cyanobacteria), octocorals

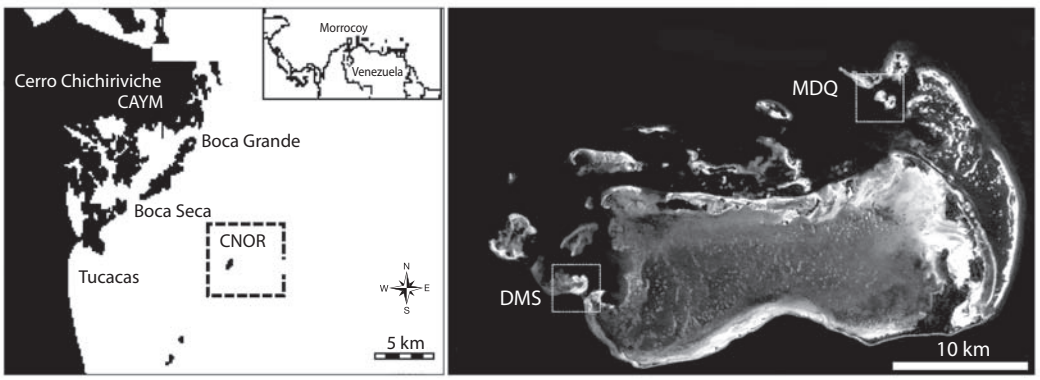

Fig. 1. Geographic position of four monitoring reef sites in Venezuela; A =Morrocoy National Park and B Los Roques National Park. A1 = Caiman. A2 = Cayo Norte. B1 = Madrizqui . B2 = Dos Mosquises Sur. Scale bar for Los Roques National Park = 15 km. Satellite images courtesy of Institute for Marine Remote Sensing.

(erect or encrusting), sponge (massive, encrusting or erect) and other non-living substrate (gaps, rock, boulder, rubble and sand). For this, 10 transects at each site were surveyed following the CARICOMP protocol. Trained observers surveyed the fish community of these reefs by visual censuses, using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) fish protocol (Version 3.1) with a modified list of 70 fish species. For this, 10 replicates consisting of belt-transects of 30m x 2m were surveyed at each site. Belt-transects for the fish and the benthic evaluation were in the same habitat and depth at each site.

Data analysis and sampling design: In order to test the effect of spatial scales on the benthic community structure (cover of different substrata), a two-way (Site-within Park) nested ANOVA with 10 transects (replicates) per site and two replicate sites per park (Madrizqui-Dos Mosquises Sur at Los Roques, and Caiman-Cayo Norte at Morrocoy) was performed. A Least Significant Difference analysis (LSD) was applied to compare the benthic community in all sites and a Bray-Curtis dissimilarity index was used to evaluate differences in the benthic community among sites. We also tested differences in the benthic community cover between years (2003-2004) with a one-way repeated measure ANOVA for each of six summary variables (coral, octocoral, sponges, algae, sand and other substrates). Also, normality and homogeneity of variances was tested with the Shapiro-Wilks and Levene tests, respectively. Both site and parks were also grouped by comparing the cover of all substrate categories (benthic community) and the abundance of major fish guilds with a Principal Component Analysis (PCA).

RESULTS

Hard coral communities and species composition: While 23 species of hard corals were identified in Los Roques only 12 species were found in Morrocoy (Table 1). *Montastraea faveolata* was the dominant coral species in all sites, especially at Cayo Norte and Dos Mosquises where its relative cover was 73.62% and 51.84%, respectively. At these two sites *M. faveolata* and *M. annularis* form a massive framework that extends down to 15m depth. The species *M. annularis* (6.84-15.73%), *Colpophyllia natans* (5.33-14.13%), *M. franksi* (3.96-10.36%), *Madracis mirabilis* (0.38-5.56%) and *Agaricia agaricites* (0.28-4.75%) were also conspicuous at all sites (Table 1).

Abundance of major substrate categories: At all sites, massive hard coral species were more abundant (1.5-46% of mean cover) than branching (0.04-3.9%), encrusting (0.15-0.87%), and foliose or plate-like forms of coral growth (0.32-2.1%) (Fig. 2a). Contrarily to all other sites, encrusting gorgonians dominated the octocoral cover in Caiman where dead hard corals were frequently overgrown by *Erytropodium caribaeorum* and *Briareum asbestinun* (Fig. 2b). Erect forms dominated the sponge cover at all sites, especially at Madrizqui where this group reached a maximum of 3% cover (Fig. 2c). Also, at all sites, turf algae were more abundant (24-37%) than any other algal guild; and this category together with fleshy algae, had the largest cover at Caiman (Fig. 2d). Sand was the predominant non-living substratum (0.25-3%), followed by rubble (0.9-2%) and gaps (0.27-1.9%) (Fig. 2e).

Spatial and temporal patterns of living cover: The benthic community varied greatly among sites (Nested ANOVA, $p< 0.05$), nevertheless there were no major differences across the parks. While the benthic community of Caiman and Cayo Norte, both in Morrocoy; was 68% dissimilar, Cayo Norte and Dos Mosquises Sur, which are from different parks only, differed in 34% (Table 2). Five out of the six pairwise comparisons indicated that the cover of massive corals had the most influential contribution to the dissimilarity between sites. Encrusting gorgonians was the second most important type of substrata contributing approximately with 16% of the differences

TABLE 1

List and relative abundance (%) of hard coral species found at the monitoring sites of Los Roques (DMS = Dos Mosquises Sur; MDQ = Madrizquí) and Morrocoy (CNOR = Cayo Norte, CAYM = Playa Caimán)

	Los Roques		Morrocoy	
	DMS	MDQ	CNOR	CAY
Phylum Cnidaria				
Class Hydrozoa				
Order Milleporina				
Family Milleporidae				
Millepora alcicornis	0.48	7.65	2.19	48.59
Millepora complanata	0.04	0.43	0.46	
Class Anthozoa				
Order Scleratinia				
Family Astrocoenidae				
Stephanocoenia intersepta		2.61		
Family Pocilloporidae				
Madracis decactis	0.32	0.08		
Madracis mirabilis	5.56	0.38		
Madracis spp.		0.05		
Family Agariciidae				
Agaricia agaricites	0.28	3.09	1.81	4.75
Agaricia carinata		0.35		
Agaricia danai		10.49	1.5	
Agaricia lamarcki	0.26			
Agaricia purpurea	0.44		0.06	
Agaricia tenuifolia			0.16	
Family Siderastreidae				
Siderastrea sidera	2.76	3.06		
Family Poritidae				
Porites astreoides	1.8	1.86	0.02	24.67
Porites porites	1.35	2.89		
Family Faviidae				
Colpophyllia natans	14.13	9.38	5.33	
Diploria labyrinthiformis	0.45			
Diploria strigosa	0.24	0.98	0.21	0.45
Montastraea annularis	15.46	15.73	14.54	6.84
Montastraea faveolata	51.84	30.21	73.62	14.71
Montastraea franksi	3.96	10.36		
Montastraea cavernosa	0.54			
Family Mussidae				
Mycetophyllia aliciae		0.15		
Family Caryophyllidae				
Eusmilia fastigiata	0.08	0.28		
Tubastrea aurea			0.08	
Total species	18	19	12	6

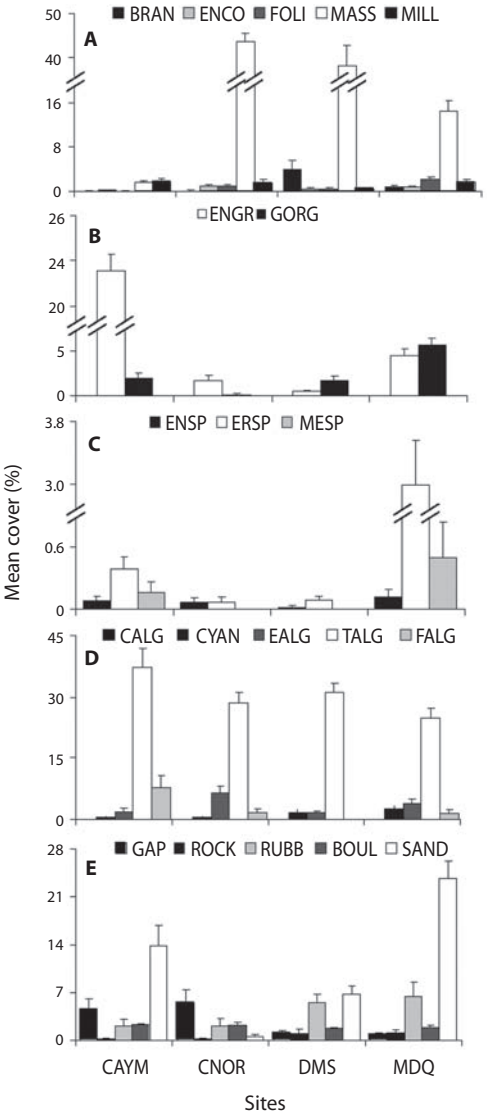

Fig. 2. Cover of biotic (a, b, c, d) and abiotic (e) substrata (mean % and standard deviation) across sites (data pooled for 2003 and 2004). Substrate abbreviations as in caption of Table 2.

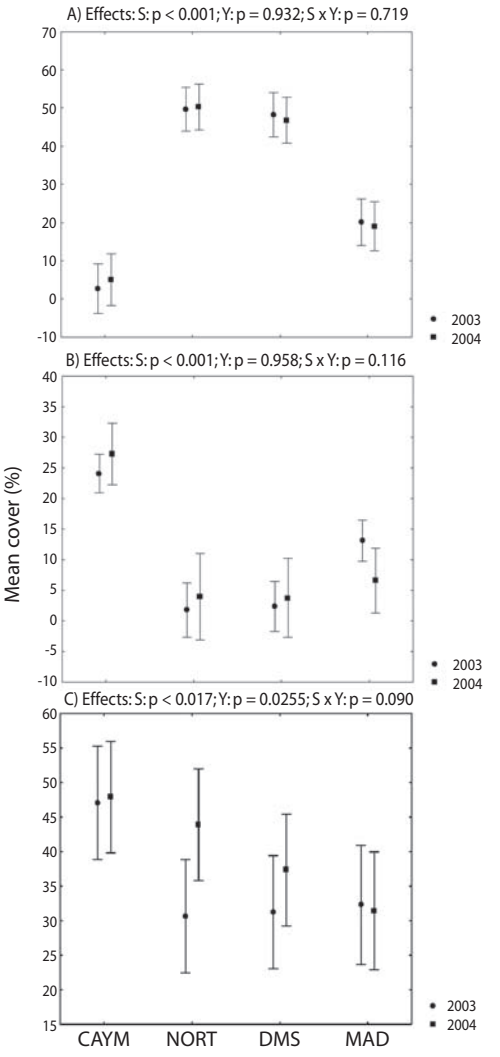

Fig. 3. Comparison of hard coral, octocoral and algal cover (%) (a, b, and c respectively) between 2003 and 2004 (repeated measure ANOVA).

found between Caiman and the other three sites (Table 2).

The cover of live benthic components varied among sites, whereas only the algal and abiotic cover changed between years (repeated measures ANOVA, $p > 0.05$) (see Fig. 3 and Fig. 4). Live coral cover was significantly higher at Cayo Norte (50.3-51%) and Dos Mosquises Sur (48-43.7%), compared to Madrizqui (20-18.2%) and Caiman (2.6-4.2%) for both years (Fig. 3a). Mean cover of sponges was highest at Madrizqui (3.5-4.8%) compared with similar values (0.5-1.8%) among Caiman, Cayo Norte and Dos Mosquises Sur (Fig.4a). As mentioned before, the mean cover of abiotic substrates

TABLE 2

Bray-Curtis dissimilarity index (%) for all pairwise comparisons between monitoring sites (CNOR = Cayo Norte, DMS = Dos Mosquises, MDQ = Madrizquí and CAYM = Playa Caiman). Dissimilarity is based on the cover (%) of 17 different substrata categories recorded in all reef sites

Substrata	Mean Cover (%)		Contribution (%)	Ac. Cont (%)	Av. Diss (%)
	CAYM	CNOR			
Mass	1.5	46.7	33.4	33.4	
Engr	23.8	1.7	16.3	49.7	
Talg	37.3	28.6	14.9	64.6	67.9
Sand	13.8	0.6	10.0	74.6	
Falg	7.8	1.7	5.9	80.5	
	CAYM	DMS			
Mass	1.5	42.6	31.5	31.5	
Engr	23.8	0.5	17.9	49.4	
Talg	37.3	31.1	15.0	64.4	62.5
Sand	13.8	6.7	9.5	73.9	
Falg	7.8	0.0	6.0	79.9	
	CAYM	MDQ			
Talg	37.3	24.9	18.7	18.7	
Engr	23.8	4.5	17.0	35.7	
Sand	13.8	23.7	15.0	50.8	
Mass	1.5	14.4	11.4	62.2	56.7
Falg	7.8	1.4	7.1	69.3	
Rubb	2.0	6.5	6.1	75.4	
Gorg	1.9	5.6	4.2	79.9	
	CNOR	DMS			
Mass	46.9	42.6	21.7	21.7	
Talg	28.6	31.1	18.2	40.0	
Sand	0.6	6.7	9.3	49.2	
Ealg	6.5	1.7	8.8	58.0	33.8
Rubb	1.7	5.4	8.6	66.6	
Gap	5.5	1.1	7.8	74.4	
Bran	0.0	3.9	5.8	80.2	
	CNOR	MDQ			
Mass	46.9	14.4	28.3	28.3	
Sand	0.6	23.7	20.1	48.4	
Talg	28.6	24.9	11.1	59.5	
Rubb	1.7	6.5	6.1	65.5	57.4
Ealg	6.5	3.9	5.5	71.0	
Gorg	0.2	5.6	4.7	75.7	
Gap	0.6	0.8	4.6	80.4	
	DMS	MDQ			
Mass	42.6	14.4	28.9	28.9	
Sand	6.6	23.7	18.8	47.7	
Talg	31.1	24.9	12.5	60.2	50.9
Rubb	5.4	6.5	7.6	67.8	
Gorg	1.7	5.6	4.4	72.2	
Engr	0.5	4.5	4.1	76.3	
Bran	3.9	0.7	4.0	80.3	

Bran = branching corals, Enco = encrusting corals, Foli = foliaceous corals, Mass = massive corals, Mill = milleporids, Engr = encrusting gorgonians, Ensp = encrusting sponges, Ersp = erect sponges, Mesp = masive sponges, Calg = calcareous algae, Cyan = cyanobacteria, Ealg = encrusting algae, Turf = turf algae, Falg = fleshy algae, Gap = gaps, overhangs and holes, Rock = bare substrata, Rbb = rubble and Sand = sand.

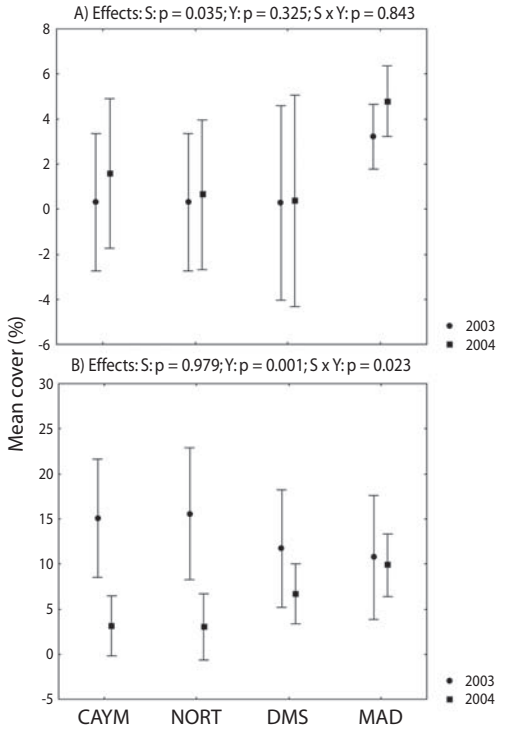

Fig. 4. Comparison of sponge and abiotic substrata (*i.e.* gaps, sand and bare substrata) cover (%) (a and b, respectively) between 2003 and 2004 (repeated measure ANOVA).

(i.e. gaps, sand and bare substrata) was significantly reduced in 2004 (repeated measures ANOVA $p < 0.05$) from 15 to 3% only at both sites of Morrocoy (Fig. 4b).

Description of fish communities; species richness and abundance of major guilds: The two sites at Los Roques had the highest numbers of fish species. In Dos Mosquises Sur, 57 species were observed out of the 70 species in the fish database (modified from the original AGRRA list). The families with higher number of species among the studied sites were Scaridae (9), Serranidae (8) and Pomacentridae (7) (Table 3). In Madrizqui and Cayo Norte, respectively, 48 and 40 fish species were observed from the AGRRA list. Caiman was the site with the least number of fish species (28) of all sites (Table 3).

Overall, the fish community at all sites was dominated by herbivorous species, comprising mostly damselfishes (Pomacentridae), parrotfishes (Scaridae) and surgeonfishes (Acanthuridae) (Table 4). Commercially important carnivores such as snappers (Lutjanidae) were more abundant at the two sites of Los Roques (Dos Mosquises and Madrizqui) (Table 4).

In Dos Mosquises, the fish community was dominated by pomacentrids. The average density of this family varied from 14.45 individuals/100m^2 in 2003, to 4.21 individuals/100m^2 in 2004. In Madrizqui, pomacentrids showed the highest relative abundance in 2003 and 2004 (46% and 37%, respectively) (Table 4), however, average densities were lower than in Dos Mosquises (10.12 and 1.25 individuals/100m^2, in 2003 and 2004 respectively).

In Cayo Norte (Morrocoy), pomacentrids also showed the highest relative abundance in both 2003 and 2004 (42% and 46%, respectively) (Table 4). However, at this site, haemulids were also abundant in both years (34% and 37%, respectively), reaching an average density of 34.8 individulas/100m^2 in 2003. Also at Morrocoy, Caiman was characterized by high abundance of pomacentrids (42-40.2 6%) and the highest abundance of acanthurids (34.92- 27.85%) compared with the other sites (Table 4).

Benthic and fish community across sites: With 85% of the total variance explained by the two first axis, the PCA showed that sites from different parks (Cayo Norte-Dos Mosquises) had in common a high cover of live hard coral, turf algae and crustose-coralline algae, but high abundance of Haemulids only in Cayo Norte (Fig. 5). In contrast, what we consider as the most disturbed reefs within each park (Caiman and Madrizqui), grouped together opposite to the other two sites. Although top carnivores were present in Madrizqui and were absent at Caiman, these "more disturbed" reefs had higher abundance of herbivores (Fig. 5).

TABLE 3

Fish species sighted in 2003 and 2004 using the AGRRA fish protocol in the monitoring sites of: Dos Mosquises (DMS), Madrizquí (MDQ), Cayo Norte (CNOR) and Playa Caiman (CAYM), Venezuela

Family	Species	DMS	MDQ	CNOR	CAYM
Acanthuridae	*Acanthurus bahianus*	X	X	X	X
	Acanthurus chirurgus	X	X		
	Acanthurus coeruleus	X	X	X	X
	Aulostomus maculatus	X	X	X	X
Balistidae	*Balistes vetula*	X			
	Balistes capriscus				
	Cantherhines pullus			X	
	Cantherhines macrocerus				
	Cantidermis sufflamen	X			
	Melichthys niger	X			
Chaetodontidae	*Chaetodon capistratus*	X	X	X	X
	Chaetodon ocellatus	X		X	
	Chaetodon striatus	X	X	X	
Haemulidae	*Haemulon aurolineatum*		X	X	
	Haemulon chrysargyreum	X	X	X	X
	Haemulon flavolineatum	X	X	X	X
	Haemulon macrostoma	X		X	X
	Haemulon plumieri	X	X		
	Haemulon sciurus	X	X	X	X
Labridae	*Bodianus rufus*	X	X	X	X
	Clepticus parrae	X	X	X	
	Haelichoeres bivitttatus		X		
	Haelichoeres gamoti	X	X	X	
	Lachnolaimus maximus	X	X		
	Thalassoma bifasciatum	X	X	X	X
Lutjanidae	*Lutjanus analis*	X			
	Lutjanus apodus	X	X	X	X
	Lutjanus jocu	X	X	X	
	Lutjanus mahogoni	X	X	X	
	Lutjanus synagris			X	
	Ocyurus chrysurus	X	X	X	X
Mullidae	*Mulloidichthys martinicus*	X	X	X	
Otraciidae	*Laptophrys trigueter*	X		X	
Pomacentridae	*Holacanthus ciliaris*				X
	Holacanthus tricolor	X	X		X
	Pomacanthus arcuatus	X	X		
	Pomacanthus paru	X	X	X	
	Abudefduf saxatilis	X	X	X	X
	Chromis cyanea	X	X	X	X
	Chromis multilineata	X	X	X	X
	Microspathodon chrysurus	X	X	X	X
	Stegastes partitus	X	X	X	X
	Stegastes planifrons	X	X	X	X
	Stegastes variabilis	X	X	X	X

TABLE 3 (Continued)

Fish species sighted in 2003 and 2004 using the AGRRA fish protocol in the monitoring sites of: Dos Mosquises (DMS), Madrizquí (MDQ), Cayo Norte (CNOR) and Playa Caiman (CAYM), Venezuela

Family	Species	DMS	MDQ	CNOR	CAYM
Scaridae	*Scarus coeruleus*	X			
	Scarus coelestinus	X			
	Scarus guacamaia	X			
	Scarus iserti	X			
	Scarus taeniopterus	X			
	Scarus vetula	X			
	Sparisoma aurofrenatum	X			
	Sparisoma chrysopterum	X			
	Sparisoma rupripinne				
	Sparisoma viride	X			
Scombridae	*Scomberumorus regalis*	X	X		
Serranidae	*Epinephelus fulvus*	X	X		
	Epinephelus adscensionis	X	X		
	Epinephelus cruentatus	X	X		
	Epinephelus guttatus	X	X		
	Epinephelus striatus	X			
	Hypoplectrus guttavarius		X		
	Hypoplectrus nigricans		X		
	Hypoplectrus puella	X	X	X	X
	Hypoplectrus uniculor		X	X	
	Mycteroperca bonaci	X			
	Mycteroperca tigris				
	Mycteroperca interstitialis	X			
	Serranus tigrinus				
Sphyraenidae	*Sphyraena barracuda*	X			
Total species		57	48	40	28

TABLE 4

Abundance (%, calculated as per AGRRA) of selected reef fish families in the monitoring sites of: Dos Mosquises (DMS), Madrizquí (MDQ), Cayo Norte (CNOR) and Playa Caiman (CAYM), Venezuela

Sites	Herbivores						Carnivores						Corallivores	
	Acanthuridae		Scaridae		Pomacentridae		Haemulidae		Lutjanidae		Serranidae		Chaetodontidae	
Years	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
DMS	18.51	3.17	15.23	14.59	44	58.38	0.55	0.43	3.37	10.26	2.35	2.01	4.86	1.3
MDQ	3.49	8.41	27.21	17.13	46.44	37.38	3.39	7.49	3.28	8.41	4.04	2.49	2.73	4.04
CNOR	2.01	3.7	3.48	3.28	42.03	36.04	3.44	3.68	0.82	0.64	0.43	0.63	2.43	2.11
CAYM	34.92	27.85	16.66	12.48	41.75	46.26	2.06	1.23	1.11	1.05	0.63	0.5	1.42	1.23

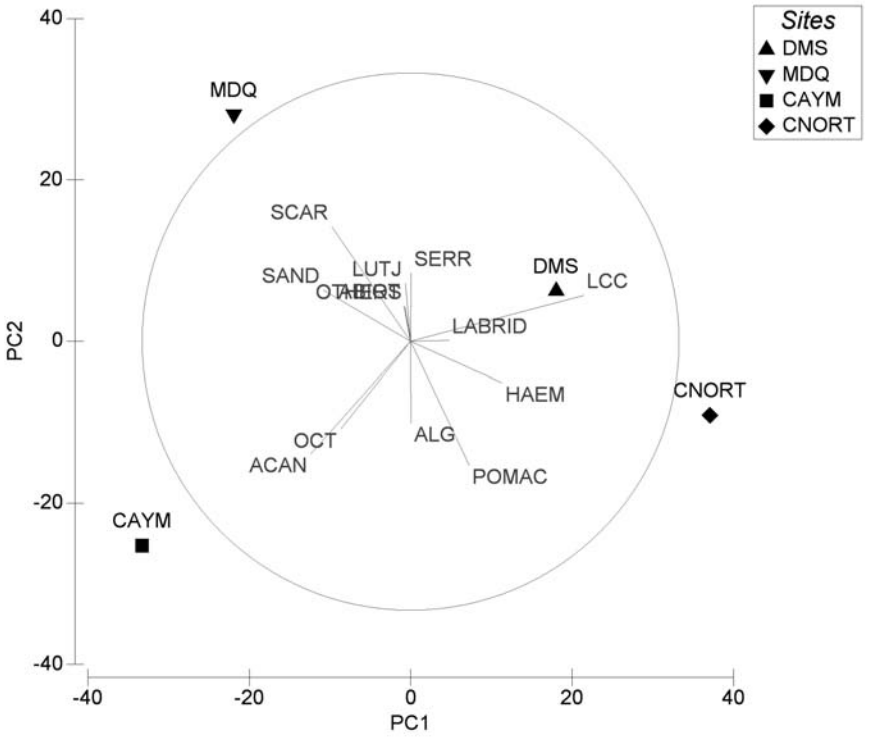

Fig. 5. Principal Components Analysis (PCA) for benthic (percentage cover) and fish (density) variables of all monitoring reef sites. Dos Mosquises (DMS), Madrizquí (MDQ), Cayo Norte (CNOR) and Playa Caiman (CAYM). LCC = live coral cover, OCT = encrusting and erect gorgonians, OTHER = other sessile organisms (sponge, zoanthids, milleporids, etc), ABIOT = abiotic substrates other than sand (rubble, gaps, etc), SAND = sand, HAEM = Haemulidae, POMAC = Pomacentrids, LABRID = Labridae, LUTJ = Lutjanidae, SCAR = Scaridae, ACAN = Achanturidae.

DISCUSSION

Considering coral communities, two reef sites (Dos Mosquises and Cayo Norte) out of four monitoring reefs that are located in oceanic and coastal areas of Venezuela are healthier in terms of live hard coral cover and abundance of major fish guilds, than many Caribbean reef sites, where coral cover rarely exceeds 20% (Ogden *et al.*1997). These two relatively healthier sites from different parks (Los Roques and Morrocoy), have live coral cover > 45%, algae cover < 15%, high fish density (230-250 indv/100m^2), and relatively high fish richness (40-57 species). On the other hand, Madrizqui had the lowest coral cover at Los Roques (16-19%), and Caiman at Morrocoy had the lowest live coral cover (<3%) and the lowest fish species richness (28) among all sites. Thus, larger differences for both benthic and fish communities were found within reef sites of Los Roques and Morrocoy than between these two national parks. This trend is well exemplified comparing Cayo Norte with Dos Mosquises; from different parks and shelf positions (<10km and >100km from mainland, respectively), and yet, similar in terms of their benthic and fish communities. Considering the similar habitat type chosen in these reef sites, the results of this study suggest that ecological processes at the spatial scales of dozens of km can be more important than those at the scale of

hundreds of km in structuring these communities. In other words, generalizations about the status of coral reefs should be taken carefully as each reef site seems subjected to different processes leading to particular benthic and fish community structures, regardless of its shelf position.

There is evidence indicating that different processes of mortality have occurred among sites, both at Los Roques and Morrocoy. For instance, the status of the coral reef at Madrizqui might be a consequence of a white plague type II (WP-II) epizootic event recorded in September 2000 (Cróquer *et al.* 2003). This event affected major coral reef builders (i.e. *Montastraea* spp. *Colpophyllia natans* and *Stephanocoenia intersepta*), reaching up to 29% of prevalence among scleractinian species. By the end of 2001, the coral cover in this site had dropped from 34% to 28% over permanent transects (Cróquer *et al.* 2005). Similar WP-II epizootics have been reported throughout the Caribbean region having significant effects on the populations of major reef-builders (i.e. partial mortality, loss of living tissues and coral cover) (Richardson *et al.* 1998, Nughes 2002). Some other factors such as eutrophication might also be affecting corals at Madrizqui as this reef is < 3km from Gran Roque, the island with the largest human population of the archipelago (~1200 people). On the contrary, the monitoring site of Dos Mosquises has not been extensively affected by white plague and this may have helped in maintaining its live coral cover above 40% in 2003 and 2004. Another example of differences in mortality process affecting all sites occurred in Caiman. In 1996, this site was severely impacted by a massive died off that affected the majority of reefs in Morrocoy (Villamizar 2000, Laboy-Nieves *et al* 2001) but had no significant effects on Cayo Norte, despite both sites are relatively close to each other.

Although in Venezuela coral reefs are usually more extensive and well-developed in some of its oceanic islands compared to highly-impacted coral reefs closer to the mainland, prevalence and frequency of epizootics events can produce severe mortality in oceanic-"pristine" reefs, both in Venezuela and other Caribbean sites (Cróquer *et al.* 2003, 2005, Weil 2003, 2004, Bruckner & Bruckner 2003). Thus, this study in Venezuela supports that both "healthy and impacted" reef can be found both at oceanic and coastal locations. However, it is possible that the relative good condition of Cayo Norte is the exception and not the rule among reef sites at Morrocoy and/or other coastal areas. Thus, it is necessary to highlight that results from this study only provide a base line of the current status of coastal and oceanic reefs in Venezuela, and it would be desirable to have more sites at each locality.

Considering fish communities, fish density was similar between sites of Morrocoy, however, at Caiman only three species of two families (*Stegastes planifroms*, *S. partitus* and *Scarus iserti*) accounted for almost 80% of fish abundance; whereas up to seven species of three families (*Haemulon aurolineatum*, *S. partitus*, *S. planifrons*, *Clepticus parrae* and *Chromis multilineata*) reached a similar abundance in Cayo Norte. Due to the lack of data of fish communities at Caiman before the drop in coral cover in 1996; it would be difficult to link the differences in fish density and composition with the changes in the benthic community alone. However, it is possible that changes in coral and benthic community, like the ones that occurred in Caiman, could affect fish assemblages, particularly those fish species most heavily dependent on live coral cover for shelter or sustenance (Lindahl *et al.* 2001, Cheal *et al*. 2002, Spalding & Jarvis 2002, Halford *et al.* 2004). Dos Mosquises, Madrizqui and Cayo Norte had similar fish communities in terms of species richness, relative family dominance and trophic composition, compared with other reefs in the Caribbean (Mejía & Garzón-Ferreira 2000, Bruckner & Bruckner 2003, Kramer *et al.* 2003) and Florida (Bohnsack & Banerot 1986).

In Los Roques, Posada *et al.* (2003) conducted AGRRA surveys in 1999 covering

different reef habitats along the archipelago. In Dos Mosquises Sur (8m depth), they recorded 36 AGRRA fish species (out of a list of 70 species) and densities of 70.8 ind./100m^2, where recorded live coral cover was 60% in the same year (Villamizar *et al.* 2003). At the same site, but covering a wider depth range (4-8m), in this study, up to 57 fish species and less live coral cover (45%), were recorded. Overall, fish densities in Dos Mosquises Sur in 2003 (234.03 ind./100m^2) and 2004 (115.83 indv/100m^2) were higher than those reported for 1999 (70.8 ind./m^2) by Posada *et al.* (2003) for the same site. However, because Posada *et al*. (2003) included only one species of Pomacentridae in their surveys, these estimates may not be comparable. Moreover, the fish community structure of DMS in 1999 was dominated by Scaridae, followed by Lutjanidae, which were two of the most abundant families, after Pomacentrids (Table 4) in the present study, which suggest that at least by the end of 2003 and 2004, the fish community structure in Dos Mosquises Sur remains similar compared to previous data.

In conclusion, major differences in both benthic and fish communities were observed among reef sites (Cayo Norte, Dos Mosquises Sur, Madrizqui and Caiman) rather than between the two parks (Los Roques and Morrocoy). This result supports the importance of local events or processes at spatial scales of few kilometers in structuring these coral reef communities. While fish communities were similar at both sites of Los Roques and at Cayo Norte, Cayman was different from these sites as only 2 families dominated the community. As expected, there were no major differences in the benthic or fish community between 2003 and 2004. The addition of Dos Mosquises, Madrizqui, and Cayo Norte and the reincorporation of Caiman as monitoring reef sites in Venezuela, have improved the capabilities for understanding our reefs.

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RESUMEN

En este estudio se describe la condición de las comunidades bentónicas e ictícolas en cuatro arrecifes que fueron monitorizados durante 2003 y 2004 en Venezuela: Dos Mosquises Sur y Madrizquí en el Parque Nacional Archipiélago Los Roques y Caimán y Cayo Norte en el Parque Nacional Morrocoy. Para ello, empleamos los protocolos de CARICOMP y AGRRA para describir la comunidad bentónica e ictícola, respectivamente. La cobertura de los cinco principales grupos bentónicos difirió entre arrecifes (ANOVA anidado, $p < 0.05$) más no entre parques. A pesar de pertenecer a diferentes parques la estructura de la comunidad bentónica entre Dos Mosquises Sur y Cayo Norte mostró un índice de similitud (Bray-Curtis) de 76%, mientras que Caiman difirió entre 57 y 68% con respecto a todos los arrecifes. Como se esperaba, la cobertura coralina, algas esponjas y octocorales no cambió entre 2003 y 2004. De forma similar, la comunidad de peces tampoco cambió en el tiempo y estuvo dominada por especies de herbívoros (Pomacentridae, Scaridae and Labridae). Sin embargo, en Los Roques los carnívoros de importancia comercial (e.g. lutjanidos y serranidos) fueron más abundantes que en Morrocoy. Aunque se esperaba encontrar diferencias en la comunidad bentónica e ictícola de Los Roques y Morrocoy, solo la de peces reflejó las diferencias, encontrándose en mejor estado de salud en Los Roques, mientras que CNOR, localizado en Morrocoy, presentó una cobertura similar o ligeramente mayor que los arrecifes localizados en Los Roques. Por lo tanto, los resultados de este estudio muestran que los arrecifes oceánicos no necesariamente se encuentran en mejor estado que los costeros. La inclusión de 3 nuevos sitios y la reincorporación de Caimán ha expandido y mejorado las capacidades de monitoreo de Venezuela y representa el primer paso hacia la creación de un sistema de monitoreo de arrecifes en el país.

Palabras clave: GCRMN, Arrecifes coralinos, organismos bentónicos, peces arrecifales, monitoreo, CARICOMP, AGRRA, Venezuela, Caribe.

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