POLYCHAETES BIODIVERSITY ASSOCIATED TO CORAL REEF-TYPE SEDIMENTS: A LONG-TERM STUDY

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ABSTRACT: We established a long-term monitoring program in pristine coral reef environments, targeting soft-bottom polychaetes as indicators of natural changes in their biodiversity patterns. This study allowed us to gather base-line information of richness, abundance and spatial-temporal variations of macrofaunal polychaetes, and associate these with sediment reef variables. Two sampling campaigns/year were conducted at seven stations, from 2009-2013. Sediment samples were collected near colonies of *Orbicella faveolata.* In the laboratory, macrofaunal samples were sieved, sorted, and preserved in Ethanol (70%). Sediment parameters were studied following standard laboratory protocols. All reef sediments had high content of sand and $CaCO_3$ (80-85%), which is typical for reef-type sediments. This long-term study showed that the benthic macrofauna and polychaetes associated with sediments exhibit high biodiversity, and richness but low-density values, which vary in space and time, but no seasonality. A total of 5,349 individuals belonging to 27 taxonomic groups were collected. From those, Polychaetes (representing 18%) where analyzed in further detail. 980 specimens, from 69 species (31 families) were analyzed, from which 17 are new records for Venezuela. Two families presented the highest richness and abundance: Spionidae and Syllidae (6spp, 28%, and 7 spp., 9% respectively). In terms of abundance, the spionids *Prionospio sp.* and *Prionospio cristata* were the dominant species. A significant decrease in richness and abundance of polychaetes was recorded in April-2012. Likewise, organic carbon values decreased after April-2012. These variations suggest an important change in these environments that was reflected in the polychaete community in all locations.

Key words: Polychaetes, Monitoring programs, calcareous sediments, Los Roques, Spatio-temporal variations.

RESUMEN: Se estableció un programa de monitoreo a largo plazo en arrecifes de coral del PN Archipiélago Los Roques, enfocándose en los poliquetos de sedimentos asociados al arrecife, como indicadores de cambios naturales en sus patrones de biodiversidad. Se evaluó la riqueza, abundancia de poliquetos, sus patrones de variación espacio-temporal, y se describieron variables del sedimento. Se realizaron dos campañas de muestreo/año en siete localidades, durante 2009-2013. Se recolectaron muestras cerca de colonias de *Orbicella faveolata* y en el laboratorio, se tamizaron, clasificaron y preservaron en etanol los organismos y las variables del sedimento se determinaron siguiendo protocolos estándar. Los sedimentos presentaron alto contenido de arena, y $CaCO_3$ (80-85%), típico de los sedimentos de tipo arrecifal. La macrofauna bentónica y en especial los poliquetos se caracterizaron por una alta riqueza pero baja densidad, observándose variaciones espacio-temporales, sin estacionalidad. Se recolecto un total de 5.349 individuos pertenecientes a 27 grupos taxonómicos. Los poliquetos representaron 18% del total y se identificaron 980 especímenes, 69 especies (31 familias), siendo 17 nuevos registros para Venezuela. Las dos familias mejor representadas, en riqueza y abundancia fueron Spionidae (6 spp, 28%) y Syllidae (7 spp, 9%). Las especies más abundantes fueron los espiónidos *Prionospio sp.* y *Prionospio cristata*. Se registró una disminución significativa en abril-2012 en la riqueza y abundancia de poliquetos. Asimismo, los valores de carbono orgánico disminuyeron después de abril-2012. Estas variaciones sugieren un cambio importante en estos ambientes que se vio reflejado en la comunidad de poliquetos en todas las localidades.

Palabras claves: Poliquetos, Monitoreos, Sedimentos calcáreos, Los Roques, variaciones espacio-temporales.

INTRODUCTION

Coral reefs are highly productive biodiversity hotspots that support social and economic development, making their protection to become a socioeconomic and environmental imperative. Global warming along with persistent human impacts are significant threats that have already caused substantial damage (Bastidas *et al*. 2012; Souter *et al*. 2021). However, there is considerable uncertainty about whether the current economic and social benefits provided by coral reefs can be sustained. For this reason, some emerging management strategies and monitoring programs along with a stronger protection of adjacent habitats need to be vigorously implemented to minimize the damage (Stoddart & Johannes 1978; Hughes *et al*. 2003).

Most research has focused on coral reef megafauna (e.g., corals, sponges, fishes, etc.), while the macrofauna associated with sediments of these reef environments has received relatively little attention. Sedimentary habitats, which cover extensive areas adjacent to the prominent coralline structures, are likely critical for cross-habitat exchanges of material and energy. Despite the recognition of the importance of a more integrative approach to coral reef studies, this perspective is rarely reflected in available real-world data (Schlacher *et al*. 1998; Demopoulos *et al*. 2014).

Particularly, shallow marine carbonate sediments are well known to support diverse invertebrate assemblages, being at the same time potential shelters and feeding grounds for several fish species (Jones 1984; Suchanek & Collins 1986; D'andrea & López 1997; Defelice & Parrish 2003; Ibrahim *et al*. 2006; Kim & Yu 2022; Sibaja-Cordero & Troncoso 2024). A variety of them have been identified as predators of different invertebrates who inhabits the reef-adjacent sediments. For example, large teleosts like Haemulidae (grunts), some Lutjanidae (snapper), Mullidae (mullets), Albulidae (bonefishes), elasmobranchs such as Dasyatidae (rays) and Myliobatididae are known to concentrate their feeding efforts on soft-sediment invertebrates. Jones *et al*. (1990) suggested that the abundance of these fishes may be more dependent on the surrounding soft sediments than on the reef itself and any fluctuation in the quality and quantity of these benthic organisms will directly affect the abundance of demersal fishes that are important fishery resources in the sea. It has also been suggested that the benthic fauna might be used as an integrating indicator of water and sediment quality within a particular area (Ibrahim *et al*. 2006; Gray & Elliott 2009). The macrofauna may be used as baseline information in future investigations to study the environmental changes in a specific area.

Studies have demonstrated that the macrofauna associated with coral reef sediments exhibit high diversity and variable densities across both time and space. Polychaetes are one of the most important groups within this macrofauna, serving as a significant food source for many marine organisms, particularly fishes (Dean 2008; Kim & Yu 2022). Riddle (1988) reported a diverse fauna associated with coralline sediments in the Australian Great Barrier Reef, where polychaetes were the dominant group. Furthermore, polychaete assemblages are extensively studied in environmental monitoring because these mostly sessile organisms readily integrate the effects of pollutants (Dean 2008). They represent the most diverse and species-rich invertebrate group in sediments, exhibiting a variety of feeding, motility, and reproductive strategies. These characteristics provide valuable insights into the ecological conditions of specific habitats (Gray & Elliott 2009; Mikac *et al*. 2020; Kim & Yu 2022)

Several macrofauna inventories are known for reef-type sediments. We found reports from Madagascar (Thomassin 1978), Polinesia (Salvat 1967, 1970, 1972), the Great Barrier Reef (Jones *et al*. 1990; Skilleter 1991; Skilleter & Underwood 1993), Fiji islands (Schlacher *et al*. 1998), Gulf of Mexico (Demopoulos *et al*. 2014), South Korea (Kim & Yu 2022) very few for the Caribbean (Aller & Dodge 1974), and recent work in two reef-type environments in Venezuela (Bone & San Martín 2003; Chollett & Bone 2007; Martínez *et al*. 2014; Diaz *et al*. 2014, 2015, 2016a, 2016b).

There are few studies on polychaetes associated with coral reefs or as indicators of natural biodiversity associated with corals. Recent studies include Giangrande *et al*. (2020), who consider polychaetes as

habitat formers in both hard and sedimentary bottoms. In the first case, they refer to the importance of sabellarids and serpulids as formers of biogenic structures that serve as refuge for numerous species of marine invertebrates, in addition to the polychaetes themselves. These authors considered the temporal variations of biogenic structures and discuss that the sensitivity and changes in the community structure of polychaetes could contribute to decision-making on protection and management measures for coastal ecosystems. Petrocelly (2022) and Afkar *et al*. (2024), who analyzed the association of *Spirobranchus giganteus* and *Spirobranchus* spp. (Serpulidae) with coral health and determined the impact of their presence on the coral reef ecosystem of Moorea, French Polynesia and Indonesia, respectively. Yañez & Aspe (2024) reported the presence of 750 species of polychaetes associated with the coral reefs of the Coral Triangle, which consists of oceanic territories of Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands, and Timor-Leste, emphasizing the importance of understanding biodiversity for the successful implementation of management and conservation policies, but also pointing out that polychaetes constitute a valuable resource for an in-depth analysis of marine biodiversity in the Coral Triangle, because this group, although very diverse in the area, continues to be underestimated, which accentuates the importance of this biotic component in any regional analysis of marine biodiversity and thus be able to improve our understanding of benthic processes and provide information that allows us to base conservation decisions in this biologically important and environmentally threatened region.

Most of these studies, however, are short-term and lack the spatial and temporal consistency needed to establish potential biodiversity patterns or to facilitate comparisons under conditions where disturbances of various origins may cause changes. Given the increasing likelihood of impacts on reef environments from both natural and human activities—such as oceanographic anomalies, offshore oil and gas exploration, overfishing, and rising tourism—long-term studies on benthic macrofauna are essential.

In 2009, we established a long-term monitoring program in a pristine coral reef at the Los Roques Archipelago National Park. A component of this program focuses on polychaetes inhabiting soft-bottom areas near the reef, using them as indicators of natural changes in biodiversity patterns. This biodiversity information is critical, as the park has faced continuous threats in recent years. Through this study, we were able to gather baseline data on the richness and abundance of macrofaunal polychaetes, identify patterns of spatial and temporal variation, and associate these patterns with sediment variables in the Los Roques Archipelago National Park.

MATERIALS AND METHODS

Study area

Collection of polychaetes associated with the sediment were sampled from National Park Archipelago Los Roques (NPALR) which is part of a large monitoring program for pristine reef environments that included many other aspects. Los Roques is located 130 km offshore from the Venezuelan coast (11° 58’ 36” - 11° 44’ 26” N and 66° 57’ 26” - 66° 36’ 25” W). The survey program was conducted from 2009 to 2013, with two sampling campaigns/year (February-March and August-September) at seven shallow (< 10 m. deep) reef stations, all with calcareous sediments: Gran Roque (GR), Madrisquí (MDQ), Boca del Medio (BM), Rabusquí (RBQ), Sebastopol (SB), Cayo de Agua (CA) Dos Mosquises Sur (DMS) (Fig.1). Five sediment samples for macrofaunal analyses were taken at each station per campaigns, with a PVC corer, pushed side-wise in the sediments (0.01 m^2), being bagged and fixed with formaldehyde solution (10%). Three additional samples for sediment analyses were also taken at each station, bagged, and placed into coolers. All samples were taken near large colonies of *Orbicella faveolata*, the dominant species at Los Roques reefs, in order to keep the same criteria for all stations. In the laboratory, macrofaunal samples were sieved through a 1 mm mesh, and preserved in ethanol at 70%. The polychaetes were sorted under a stereo microscope, identified to species level using specialized literature (Fauchald 1970; Uebelacker 1984; de León-González *et al*. 2009), and quantified for further calculations. Sediment samples were analyzed for granulometry and sediment parameters:

organic matter, organic carbon content, and $CaCO_3$ content were estimated following standard laboratory sieving protocols (Folk & Ward 1957; Jackson 1964; Gross 1971).

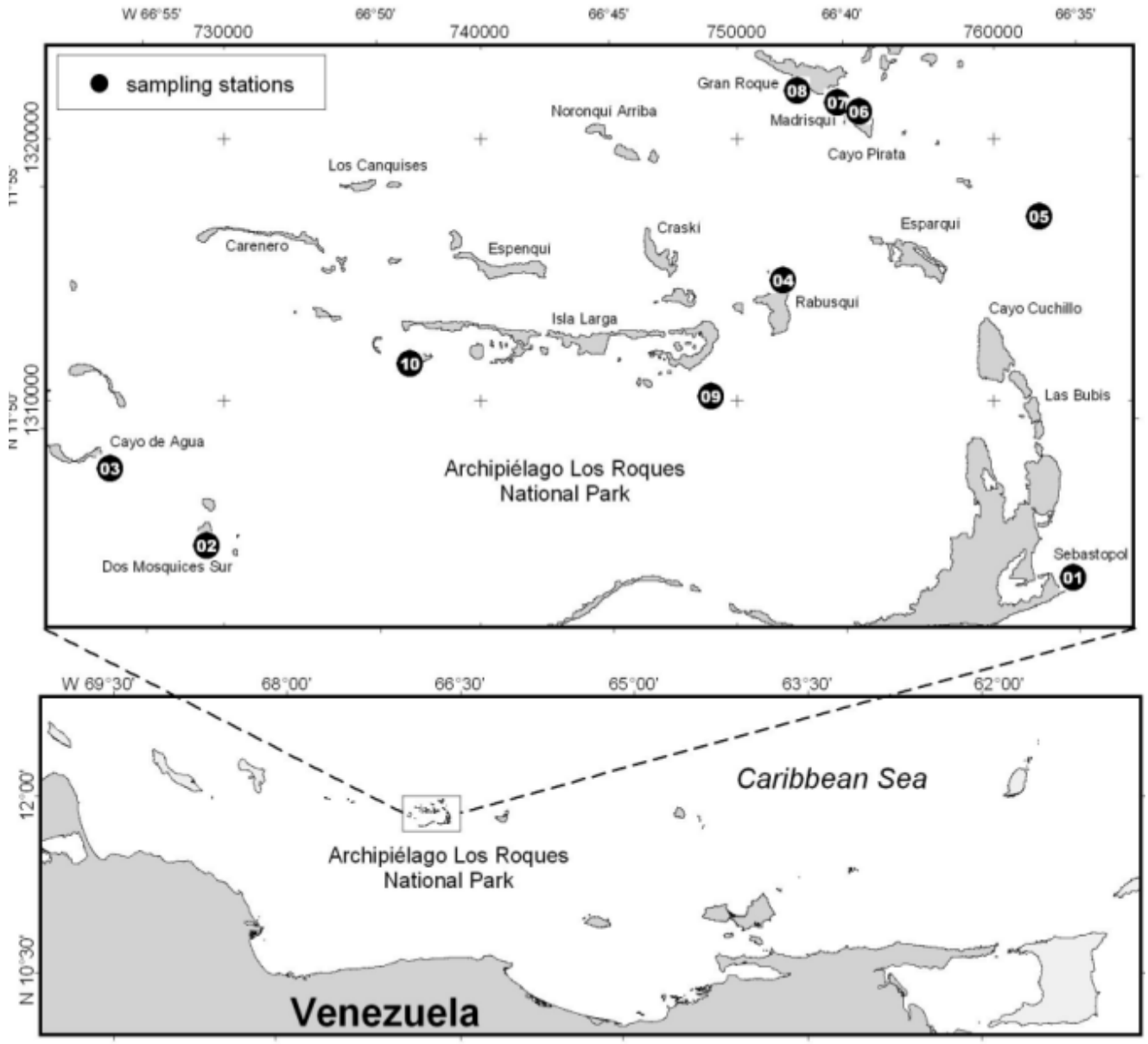


Figure 1. Sampling localities at Los Roques Archipelago National Park. 1) Sebastopol (SB). 2) Dos Mosquises Sur (DMS), 3) Cayo de Agua (CA), 4) Rabusquí (RBQ), 5) Boca del Medio (BM), 6) Madrisquí (MDQ), 7) Gran Roque (GR).

Data Analysis

Sediment samples were analyzed using a Principal Component Analysis. Spatial/temporal patterns variations of polychaete families were evaluated by non-Metric Multidimensional Scaling (nMDS) based on centroids, calculated from the Bray-Curtis similarity matrix, previously, the original abundance data were transformed by the square root. Differences in polychaeta assemblages between stations and sampling dates were tested using permutation-based multivariate analysis of variance PERMANOVA, (Clarke & Gorley 2006), based on the Bray-Curtis similarity index and using 9,000 randomizations using locations and sampling as fixed factors. BIOENV analysis was used to identify the most important environmental factors determining macrofaunal distribution patterns. All the analyses were performed with PRIMER v.6.0.

RESULTS

Sediments

In general, all reef sediments showed a consistent pattern at each station and sampling date, with high sand and $CaCO_3$ content (>85% and 70% respectively) and little variation, which is typical for reef-type sediments (TABLE 1). This low variability is shown in Fig. 2, were the PCA analysis indicates that only the data for the last sampling date (oct-13) clearly separates from the rest. This result is due to high Organic Matter content and low Organic Carbon values. Detailed temporal variations show how Organic Carbon values clearly drop after April-2012, and Organic Matter content increased in the last sampling (Fig. 3).

TABLE 1. Granulometric results for sediment analyses for all years/ sampling dates (F: February, O: October, S: September, A: April).

Year	Month	Gravel (%)	Sand (%)	Mud (%)	$CaCO_3$ (%)
2009	F	5.55 ± 4.00	90.85 ± 4.57	3.60 ± 1.20	80.79 ± 6.09
	O	7.92 ± 4.99	85.04 ± 6.31	7.04 ± 4.88	80.40 ± 6.34
2010	F	6.74 ± 6.50	86.56 ± 7.11	6.70 ± 4.04	82.94 ± 2.83
	O	5.92 ± 5.71	88.33 ± 8.11	5.75 ± 6.47	80.24 ± 5.06
2011	F	4.22 ± 3.08	89.19 ± 5.33	6.59 ± 3.54	84.13 ± 5.21
	S	4.55 ± 3.65	87.13 ± 4.73	8.32 ± 2.41	82.94 ± 5.35
2012	A	6.36 ± 5.04	87.25 ± 6.06	6.37 ± 5.08	83.41 ± 3.27
	S	4.65 ± 2.60	85.32 ± 4.93	10.04 ± 5.33	80.69 ± 4.59
2013	F	6.01 ± 5.62	88.16 ± 4.56	5.82 ± 3.26	
	O	3.75 ± 3.40	91.64 ± 4.11	4.61 ± 2.08	

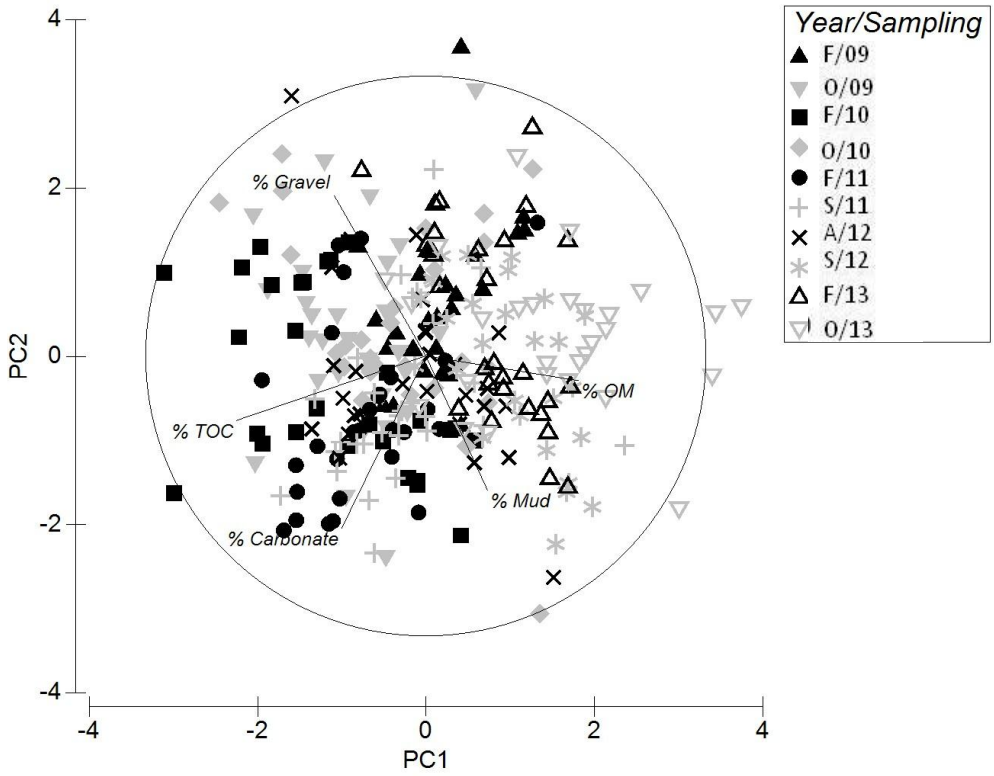


Figure 2. Principal Component Analysis results based on sediment variables for all years/sampling dates (Black symbols corresponding to first sampling/year: F: February and A: April, Grey symbols corresponding to second sampling/year: O: October, S: September).

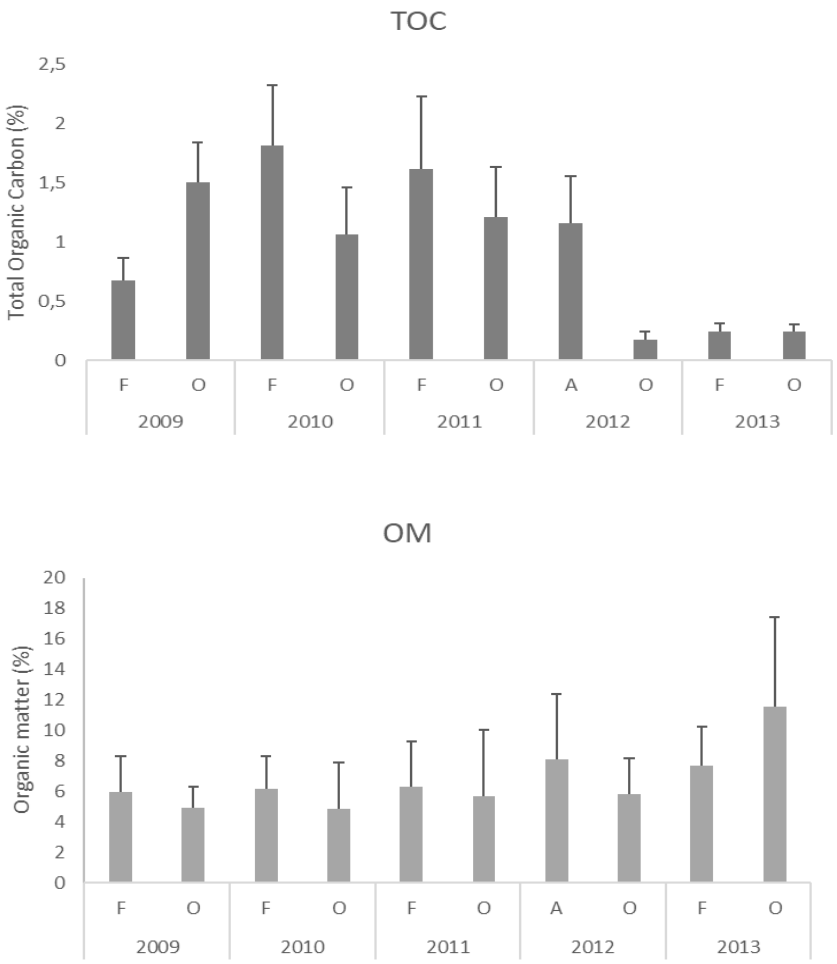


Figure 3. Temporal variations for A) Organic Carbon (OC) and B) Organic Matter (OM) during all the sampling periods.

TABLE 2. Total (number of individuals) and relative abundance (%) for all benthic macrofaunal taxonomical groups.

Groups	Total abundance (N)	Relative abundance (%)
Crustaceans	1727	32.29
Molluscs	1208	22.58
Polychaetes	980	18.32
Nematods	863	16.13
Sipunculids	221	4.13
Echinoderms	135	2.52
Cnidarians	67	1.25
Cephalochordates	36	0.67
Nemerteans	24	0.45
Oligochaetes	59	1.10
Picnogonids	7	0.13
Equiurans	17	0.32
Others	5	0.09
Total	5349	100

Benthic Macrofauna

A total of 5349 individuals belonging to 27 taxonomic groups were collected during the whole sampling period, which stresses the high macrofaunal biodiversity associated with these reef-type sediments. Crustaceans were the most abundant invertebrate group (32%), followed by Molluscs (23%) and Polychaetes (18%). However, the first ones only were present in a few localities in specific samplings. Only Polychaetes were consistent in time and space. Some other groups were also identified but their overall relative abundance was low, representing less than 16% each (TABLE 2).

Polychaetes

980 specimens were analyzed, represented by 69 species belonging to 31 families, from which 17 are new records for Venezuela (TABLE 3). This group was analyzed in further detail as it showed the best presence/absence pattern for all stations and sampling dates of all groups. Two families had a higher abundance and richness: Spionidae and Syllidae (6spp, 28%, and 7 spp, 9% respectively). Within Spionidae, *Prionospio* sp. and *Prionospio cristata* were the most abundant, whereas for Syllidae, *Syllis* sp. and *Syllis gerlachi* were the best represented species. The rest of the families were present in lower richness and abundance (TABLE 3).

The polychaetes assemblage structure showed significant differences between stations and sampling dates (PERMANOVA, p= 0.001). In terms of spatial variation, the mean number of species for all stations was 36.5±3.5 species, with a mean abundance value of 132.7±30.3 ind. The lowest richness and abundance values were found at Rabusqui (31 spp., 91 ind.) whereas the highest values were reported for Gran Roque (41 spp.) and Madrisqui (181 ind.), all of them located at the northeastern side of the archipelago. Spatial distribution patterns showed large variation (TABLE 3). Twenty seven species (39%) were present at 6 or more stations (12 were sampled at all stations), showing large range distribution pattern, 14 species, (20%) showed an intermediate distribution pattern (present in 5 or 4 stations), and 28 species (40%) exhibit a short distribution pattern, restricted to 1 or 2 stations, and in very low numbers (1 or 2 ind.).

In terms of temporal variation, mean richness value for all sampling dates was 22.3±6.2 species/ date, with the highest value in the last sampling date (33 species). Mean abundance was 86±46.4 ind., with a maximum in March 2011 (147 ind.), and the second highest values in last sampling date, September 2013 (131 ind.). The lowest values for both variables were found in the same sampling date, April 2012 (TABLE 3). In terms of frequency, eleven species were present at 70% or more of the sampling dates (high frequency, hf), fourteen between 69 and 30% (intermediate frequency, if), and the majority, 44 species, had less than 30% low frequency (lf). In terms of abundance, the spionids *Prionospio sp.* and *Prionospio cristata* were the dominant species, followed by *Glycera sphyrabrancha, Orbinia americana, Aricidea simplex* and *Armandia maculata*, representing all together more than 40% of the total abundance (TABLE 3). These species, together with *Kinberonuphis simony, Syllis* sp.*, Lysidice* cf. *hebes, Sthenelais setosa* and *Linopherus canariensis* were the best represented at the reef-type sediments of Los Roques.

Fig. 4 shows a MDS ordination analysis for the spatial and temporal variation of polychaetes abundance. On a spatial scale, the presence of two groups could be observed, one made up of the samples from DMS and CA and the second made up of the rest of the stations. The largest group, with a similar composition of species, but dominated by *Prionospio cristata,* and a second and smaller group dominated by *Glycera spyrabranchia*. Only one station stands out individually from the rest (MDQ), defined by the presence of *Prionospio* sp. and *Orbinia americana* in all sampling campaigns (Fig. 4-A).

When analyzing temporal variability (Fig. 4-B), Oct-10 and April-12 samplings formed a separated group, characterized by low richness and abundance. No seasonality was observed, only a decrease in richness from 2009 (44sps.) to 2012 (28sps.) and a subsequent recovery in 2013 (39sps.). In this last year, a change in composition was observed, reporting 15 species that had not been reported in previous samples, of which 4 were new records. It is important to highlight that the decrease in richness and abundance was very pronounced during April 2012 in all locations (Total: 14 species, 21 individuals), reporting significant differences (PERMANOVA, $p > 0.05$) with respect to the other samplings.

TABLE 3. Richness and total abundance for all polychaete species collected at Los Roques. SB: Sebastopol, BM; Boca del Medio, MDQ: Madrisqui, GR: Gran Roque, DMS; Dos Mosquises Sur, CA: Cayo de Agua, 1: March-April, 2: October. (*) new records for Venezuela.

Species	Sites							Years/Sampling										Total	Relative abundance (%)
	SB	BM	MDQ	GR	RQ	DMS	CA	2009		2010		2011		2012		2013			
								1	2	1	2	1	2	1	2	1	2		
Prionospio sp.	5	14	33	9	8	7	7	6	6	9	1	23	10	2	26			83	8.93
Prionospio cristata	14	5	15	10	10	14	5	28	22	9	2		12					73	7.86
*Glycera sphyrabrancha**	1	2	4	6	3	22	24		8	8	3	12	5	2	6	10	8	62	6.67
Orbinia americana	1	1	30	2	7	11	3		6	1	3	29	7		7	2		55	5.92
Aricidea (Acmira) simplex	4	3	3	4	1	16	14	11	4		1	11	4		4		10	45	4.84
Armandia maculata	8	4	13	6	2	5	4	1	1	9	2	2	4		9	4	10	42	4.52
Prionospio sp 1	6	11		10	3	5	7									10	32	42	4.52
*Kinbergonuphis simoni**	3		2	5	1	10	17		6	7	2	12	5	1	1		4	38	4.09
Axiothella sp.		4	22	5		2	2	2	7	5		3			17		1	35	3.77
Syllis sp.	3	10	2	6	5	4	2	2		6	9	5	2	1		6	1	32	3.44
Lysideice cf. *hebes*	1	2	7	7	4	1	6	2	10	2	2	5	2	1		1	3	28	3.01
Nereididae sp. A	2	12	6		1	5	2	9	2	2	2	3	4	1	3		2	28	3.01
*Sthenelais setosa **	1	2	2	5	1	3	8			3		2	4	2	6		5	22	2.37
Linopherus canariensis	1	3	4	4	5	2	2			5	2	4	2	4	4			21	2.26
Caulleriella sp.	2	3	3	1	2	4	6	4	1		4	3			2	5	2	21	2.26
Paradialychone farringtonae	3		7	5	2	1	1	2		3		1	1	2	2	3	5	19	2.05
Dasybranchus lumbricoides	4	2	1	1	2	1	5		1	6		1			4		4	16	1.72
Rashgua lobatus	4		1	3	5	1	2		2				1	1	4	2	6	16	1.72
Prionospio sp *2*	1	2	2			2	7	13					1					14	1.51
Kinbergonuphis. pygidialis	4					4	4									8	4	12	1.29
Naineris setosa		1	1	3	5	2						4			2	6		12	1.29
Syllis gerlachi	2	1		3	4		1	1				7	1	1			1	11	1.18
*Scyphoproctus guadalupensis **	1	1	1	5		2	1	3					1			6	1	11	1.18
Pista sp.	1	1		1	2	5	1	1	3	3	2		2					11	1.18
Lumbrineris sp.	3	2	2		1		1	6	1						1		1	9	0.97
Saccocirrus sp.	9												1	1	7			9	0.97
Laonice sp.	1	3		1	2	1	1	6	2			1						9	0.97
*Heteropodarke formalis**	4		2	1	1				4			2			2			8	0.86
*Magelona uebelackerae**			1	1	1	1	4	1		1		2	2		1		1	8	0.86

Aphelochaeta cf. *marioni*	2	2	2			2		1		3	1	2			1			8	0.86
*Fimbriosthenelais hobbsi**	3	1	3													1	6	7	0.75
Syllis riojai	1	3	1		1		1	5	1		1							7	0.75
Pectinaria gouldii	2			3	2				2							4	1	7	0.75
Schistomeringos pectinata			1	1	2	2		4		1					1			6	0.65
Exogone arenosa	2	2		1		1		4	2									6	0.65
Galathowenia oculata		1		1		2	2	1		1		4						6	0.65
Scoloplos (Leodamas) rubra		2				4											6	6	0.65
Timarete punctata		1	1		2		2	1		2	2						1	6	0.65
Eunice sp.				1	3	1						3			1	1		5	0.54
*Kinbergonuphis rubrescens**	3						2	4					1					5	0.54
Syllis corallicola	3	1		1					5									5	0.54
Poecilochaetus cf. *johnsoni*				1		4		1							2	2		5	0.54
Marphysa sp.	3			1					4									4	0.43
Exogone dispar	3			1												1	3	4	0.43
Capitella giardi		4							4									4	0.43
Streblosoma hartmanae		1				1	2		1		1	2						4	0.43
*Protodorvillea kefersteini**			1		2												3	3	0.32
Questa sp.	1		2					2	1									3	0.32
Phyllodoce madeirensis		1	1		1			1			2							3	0.32
Pisione wolfi *		1		1			1	2	1									3	0.32
Syllides sp.	3								3									3	0.32
Mesochaetopterus taylori		2	1													1	2	3	0.32
Polycirrus sp.	2			1												2	1	3	0.32
*Arabella iricolor**		1	1						2									2	0.22
*Paranaitis gardineri**			1				1										2	2	0.22
*Pseudopolydora floridensis**				1			2					2					1	3	0.32
Chloeia viridis				1												1		1	0.11
Eurythoe complanata							1							1				1	0.11
Dorvillea sociabilis			1						1									1	0.11
Polyodontes sp.						1											1	1	0.11
Chrysopetalum floridanum				1								1						1	0.11
Psamathe sp.*							1										1	1	0.11
Sigalion lewisii	1																1	1	0.11
Perkinsyllis sp.*				1				1										1	0.11
Syllis ortizi							1	1										1	0.11

*Isocirrus corallicolus**	1																		1		1	0.11
*Prionospio caribensis**				1							1										1	0.11
Piromis sp				1									1								1	0.11
Lanicola carus			1								1										1	0.11
Loimia salazari							1								1						1	0.11
Richness	40	36	36	41	31	34	38	30	29	22	18	27	21	14	23	20	33					70
Abundance	119	112	181	123	91	149	154	126	113	88	42	147	72	21	113	76	131				929	100

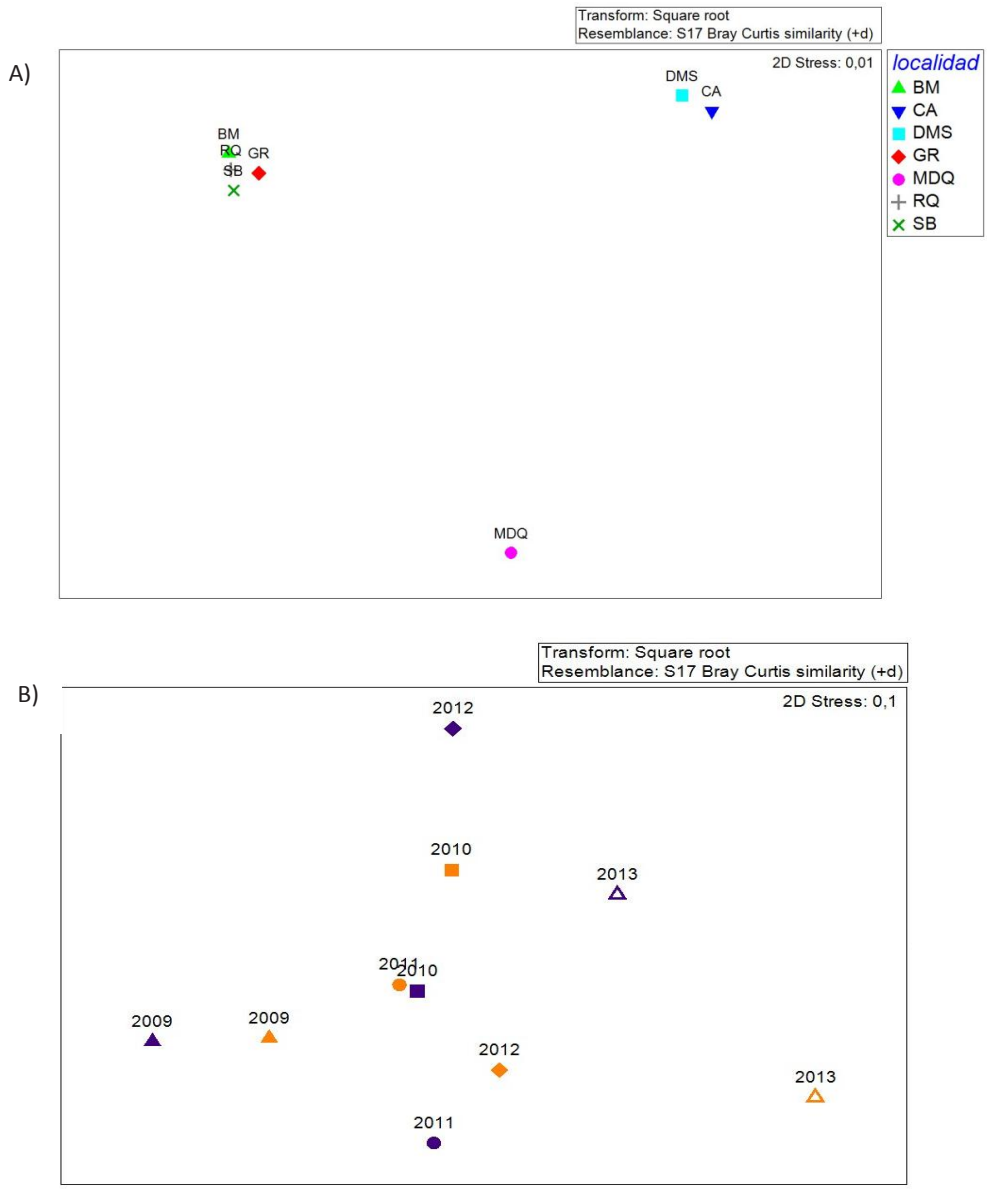


Figure 4. MDS ordination based on centroids. A) Spatial variation. SB: Sebastopol, BM; Boca del Medio, MDQ: Madrisqui, GR: Gran Roque, DMS; Dos Mosquises Sur, CA: Cayo de Agua. B) Temporal variation Blue sign corresponding February sampling and Orange sign corresponding to September/October samplings)

The BIOENV results showed a low and no significant levels of correlation between the sediment variables and the polychaeta community (Rho: 0.033, p: 0.29) indicating that none of the sediment variables estimated were correlated with the polychaeta community.

DISCUSSION

The described community at Los Roques was characterized by a high richness and a low density of organisms, where some specific groups such as Polychaetes dominated the macrofaunal assemblages. The information recorded by Bone *et al*. (2005) in Morrocoy National Park has similar pattern compared to our results: high richness of species and dominance by some specific groups, where Polychaetes (80%) recorded density values >500 ind/m^2, similar to some localities and seasons observed at Los Roques. The ecology of macrofauna on the sandy bottom of oceanic islands in the tropics has rarely been studied (Sibaja-Cordero & Troncoso 2024). However, in some studies, a similar structure and composition have been observed. For example, Riddle (1988) reported a diverse fauna associated with coralline sediments in

the Australian Great Barrier Reef, where polychaetes were the dominant group, particularly, some specific families such as Syllidae, Spinioidae and Paraonidae. Other studies have been focused on particular groups, like mollusk, finding a marked diversity in these invertebrate communities (Jones *et al*. 1990; Skilleter 1991; Skilleter & Underwood1993; Schlacher *et al.* 1998).

The sandy bottoms associated with coral reef constitute important sites in terms of their diversity, although they have been studied very little. In the NPALR, 74 species of polychaetes were identified, 17 of them being new records for Venezuela, so this evaluation contributed significantly to increasing knowledge of the biodiversity of polychaetes in reef environments in Venezuela and the Southern Caribbean. The group of polychaetes associated with these habitats were characterized by being diverse, but not very abundant, with a large proportion of rare species with restricted distribution, which makes it difficult to clearly define spatial or temporal patterns.

Another remarkable feature of macrofauna assemblages assessed at Los Roques was the abundance and richness decrease occurred in April 2012 compared to other seasons, where mean densities were higher than 1000 ind/m^2. The significant decrease in the abundance and diversity of polychaetes may be indicating a possible disturbance on a large spatial scale that affected the archipelago. However, the nature of this event does not seem to be related to a change in the sediment, which remained with few variations in its granulometry. Some studies have identified seawater temperatures above 29 ^oC at Los Roques during the end of 2010 (Bastidas *et al*. 2012), causing a massive bleaching event, which could be a possible reason to affect the macrofauna communities in a long-term basis. Bastidas *et al*. (2014), found that in Los Roques, the major drivers of coral reef decline do not seem to be related to pollution, overfishing, hurricanes or other natural factors. Instead, thermal anomalies, which cause bleaching and contribute to trigger epizootic events of coral diseases seem to be responsible for this declining trend. Thermal anomalies in 2010 clearly triggered a massive and unprecedented bleaching event in Los Roques that was followed by epizootic events, both capable of removing live coral tissues and reducing coral cover very fast. Probably this major event caused declines in macrofaunal community, which is reflected some months later.

A decrease in organic carbon values was observed at all stations, however the reasons for this decline are unknown and do not appear to be directly related to or affect the polychaeta community. The association and variability usually found between benthic macrofauna and calcareous sediments are results of several biological and physical factors which probably vary with distance from the reef. Besides, coral reefs can affect nearby macrofaunal assemblages in several ways, where these soft sediments can be physically modified by the reef, altering movement of water, sediment size distribution and organic content of the sediments (Barrosa *et al.* 2001). These differences could affect the abundance and type of suspended particles, the stability of the substratum and availability of food. Furthermore, coral reefs potentially act as a source of shell to the nearby soft sandy bottom, where wave action might be concentrated around the reefs and local currents could cause the local loss of fine sediments, contributing to the dominance of coarse sediments near the reefs (Schlacher *et al.* 1998).

The macrofaunal benthic assemblages inhabiting subtidal soft-sediments close to living corals have been highly variable (Riddle 1988; Schlacher *et al.* 1998; Barrosa *et al.* 2001; DeFelice & Parrish 2003) due to a combination of different factors which affects these community structures; however, it is necessary long periods of monitoring time to determine whether there is a defined pattern corresponding to natural community fluctuations or, instead, a community disturbance result.

This study can provide a baseline for characteristics of macrofaunal assemblages associated with reef sediments, which will be useful in future marine ecological environmental monitoring. The benthic community structure associated with coral reef sediments at Los Roques showed a high diversity, with densities varying in time and space. These communities should be monitored for long periods of time to get a better understanding about the causes of these variations. Additionally, these communities are diverse and contribute to increasing knowledge of the biodiversity of macrofauna groups such as polychaetes, with

a total of 17 new species recorded for Venezuela in this study. However, in this environment it's necessary to consider other environmental variables (more than sediments) to explain in a better proportion the variability in these communities.

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