Research Article

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Macroalgae of the sandy cays of Alacranes Reef: Gulf of Mexico

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ABSTRACT

In the summer of 2018, a field trip to the five sandy cays on the leeward edge of the Alacranes reef was made: Pájaros Island, Chica Island, Pérez Island, Muertos or Desertora Island and Desterrada Island. The total area recorded for the 5 islands is 530,407 m^2, representing 1.7% of the reef area. In the keys, an extensive collection of macroalgae was carried out in the supralittoral zone (0-80 cm), mesolittoral (81-140 cm), and beginning of the infralittoral zone (150-330 cm). All keys have a maximum height of 3-4 m. A total of 175 species, 4 growth forms, 8 varieties, and one subspecies were recorded. The sandy cays of this reef have been recognized as important nesting areas for turtles and seabirds, hence the importance of their description for their conservation. To try to understand its dynamics, the database obtained was subjected to a divisive classification analysis considering 19 attributes including substrate, protection, reproductive status, and depth. The system reached a total diversity of 425.99 beles Ind^{-1}. The analysis presents that depth and substrate are mainly responsible for the largest drops in information in the system. The spatial analysis given by a biplot analysis shows an ecotonal continuum from the center of origin to the right, influenced by the substrate and by wave protection. This analysis gives an explained variance of 60.03% in the first three components. The high diversity of flora recorded in this work can be an important support for protecting and conserving the reef.

KEYWORDS: Algae, Reefs, Gulf of Mexico, Distribution, Sandy islands

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INTRODUCTION

In the Mexican Atlantic, the marine algae that occur are tropical, with some subtropical elements in the northern part (Joly, 1967; Garduño-Solórzano *et al.*, 2005). Many of the records of the species present belong to the intertidal and infralittoral floor, of shallow depths (Mendoza-González *et al.*, 2000; Ortegón-Aznar *et al.*, 2009). Although they colonize a varied set of habitats, the substrate, the type of coast, the coastal protection, its reproductive condition, etc. are elements that configure the distribution, establishment, and composition of this flora giving a specific identity for the elements that make up this group.

The phycological flora of the Gulf of Mexico is very diverse, although there are still areas that have not been investigated floristically or areas that, due to their size, have biotopes. The diversity of marine macroalgae of the Mexican Atlantic amounts to 754 taxa, 213 are Chlorophyta (48 genera), 85 Ochrophyta (29 genera), and 456 Rhodophyta (171 genera) (Cetz-Navarro *et al.*, 2008; Vilchis *et al.*, 2018; Pedroche & Sentíes, 2020). From the ecological point of view, in addition to the role they play in the food chain, they play fundamental relationships in the shelter of small organisms, protecting them from their predators, serving as a place of fixation and development of eggs, etc. In addition, they are potential hosts for many micros and macroalgae (Fujii *et al.*, 1996).

On the coasts of Yucatan, important contributions have been made to the knowledge of the biodiversity of seaweed, some of these works were oriented to the description of algae species such as those of Huerta-Múzquiz *et al.* (1987), Mateo-Cid (1988), Mateo-Cid and Mendoza-González (1991) and Mendoza-González and Mateo-Cid (1992), others assess specific wealth, among them we have the works of Serviere-Zaragoza *et al.* (1992), Ortegón-Aznar and González-González (2000), and others to the study of the relationships between algae associations and different aquatic environments (Collado-Vides *et al.*, 1995; Ortegón-Aznar *et al.*, 2001). Among the strategic marine ecosystems, coral reefs are of greatest interest, either for the attractiveness of the landscape and polychromies, as well as for the variety of its fauna and flora, in addition to its important ecological and systemic function, where its valuable reservoir of biodiversity supports an intricate and multi-related food chain. This ecosystem plays an indirect but significant role in fixing carbon dioxide from the atmosphere by constructing calcium carbonate scaffolds that, in many cases, act as a natural breakwater that protects adjacent coastlines from erosion (Melbourne-Thomas *et al.*, 2011; Hardisty *et al.*, 2013; Rogers *et al.*, 2014).

Alacranes is one of the largest oceanic coral reefs in Mexico, its remoteness from the coast makes it less susceptible to impacts from coastal development; however, it is not exempt from the fishing pressure in its surroundings and an incipient tourism that is increasing (CONANP, 2006; Torruco *et al.*, 2019). Despite some important contributions to the knowledge of benthic algae of Alacranes (Huerta-Múzquiz, 1960; Kim, 1964; Torruco *et al.*, 1993; Ortegón-Aznar *et al.*, 2013) that report different aspects, the scarce floristic knowledge makes it essential to update them to enhance actions that are the responsibility of the administration and conservation of this system. The present work is a contribution to the benthic macroflora of the sandy cays of the Alacranes Reef, the result of an inventory of red, green, and brown marine macroalgae, which will allow us to better understand this natural area subject to protection as a Marine Park. The main objective was to explore two facets of benthic marine algal diversity, taxonomic richness, and spatial community structure, to improve our understanding of the processes that underpin biodiversity patterns around the sandy cays on Alacranes Reef, in the understanding that it can be used for conservation actions.

MATERIALS AND METHODS

Study Area

The Alacranes reef is located between coordinates 22° 23' N, 89° 41' W 135 km off the coast of Puerto Progreso on the Yucatan Shelf, in Mexico. It is the largest and most complex of the oceanic reefs in the Gulf of Mexico and is part of the Campeche Probe series of reefs. It is a protected area as a marine park. Alacranes have an area of approximately 300 km^2 and constitute a shelf reef that rises 50 m from the seabed (Torruco *et al.*, 2019). The reef is shaped like an atoll with a north-westerly trend, due in part to winds from the east and northeast and strong currents from the east. The lagoon is filled with patches that give it a reticular pattern (Farrell *et al.*, 1983; Rezak *et al.*, 1985). There are five coarse-grained white sand cays on the leeward edge of the reef. Their shapes and dimensions can vary in the order of meters to tens of meters in short periods (Kornicker *et al.*, 1959): Pájaros Island or Blanca Island, Chica Island, Pérez Island, Muertos Island or Desertora Island, and Desterrada Island. The total area for the 5 islands is 530,407 m^2 (Logan, 1969). All Cays are very low with a maximum height of 3-4 m (Figure 1).

The tide is 1.5 m (Torruco *et al.*, 2019). The cays are important nesting sites for white turtles *Chelonia mydas* (Linnaeus, 1758), as well as seabirds, so the Alacranes Reef is considered one of the most important breeding areas in the world for *Sula dactylatra* Lesson, 1831 bird, hence it is considered an important area for the conservation of birds in the country (AIDA, 2015). The reef is visited by fishermen who collect queen conch and other shells, lobsters, and grouper, mainly by snorkelling and harpoon diving. Despite its remoteness, tourism is increasingly frequent, especially in spring and summer (Ortegón-Aznar *et al.*, 2013). So far, this tourism has not been a relevant activity, nor has it caused a quantifiable impact. The beauty of Alacranes suggests that tourism as a business will begin to develop so that the economic value of the Alacranes Reef will be enhanced (Liceaga-Correa *et al.*, 1999).

Few human activities are carried out on the reef, which include observation of fauna and flora, both terrestrial and marine, sailing, sport fishing (harpoon and line), diving (free and autonomous), commercial fishing (nets and diving) and transit of various boats (CONANP, 2006). In addition, the reef is a refuge for fishermen during hurricanes, tropical storms, and norths. The problems presented by the reef are mainly caused by the overexploitation of fishery resources, the plundering of species under some form of protection, illegal fishing practices, fishing of closed resources, and lack of permits and authorizations for the exploitation of any resource (Liceaga-Correa *et al.*, 1999; Torruco *et al.*, 2019).

Collection

The collection of algae was done manually and sometimes with the help of a spoonbill around each of the sandy cays of the Alacranes reef. The material was collected from the littoral zone (supra and mesolittoral) to the beginning of the infralittoral zone. The material was preserved in seawater with 4% formaldehyde (Littler & Littler, 1985). The works of Taylor (1960), Joly (1967), van den Hoek (1982), Kapraun *et al.* (1983), Littler and Littler (1990, 1997), Littler *et al.* (1990) and Garduño-Solórzano *et al.* (2002) were used for identification.

Analysis

With the data obtained, a presence-absence matrix was formed, which was subjected to a second-order Information Content (CI_2) analysis (González-Solís *et al.*, 2018, 2021), to define patterns of association between the species from 19 attributes, which involved aspects of substrate, protection, depth, and reproductive condition.

The matrix was subjected to a Euclidean Biplot analysis to obtain in the same graph both species and the attributes (ter Braak, 1983). Through this technique, it is possible to reduce the dimensionality to a limited number of vectors (which can be subjected to subsequent statistical tests), in addition to detecting patterns or trends of association in the samples.

RESULTS

175 species of algae were obtained (with 4 growth forms, 8 varieties, and 1 subspecies). Of these, 63 were Chlorophyta, 36 were Ochrophyta, 71 were Rodophyta and 7 were Cyanobacteria. Table 1 presents the species recorded and the 19 attributes considered for analysis.

The Table 1 shows the percentage of species that had this characteristic. This reflects the high percentages regarding wave protection (94.1%) and depth (95.2%) shown by the algae of the sandy cays of the Alacranes reef. It is also important to mention that a significant fraction of the species was in the vegetative state (70.6%).

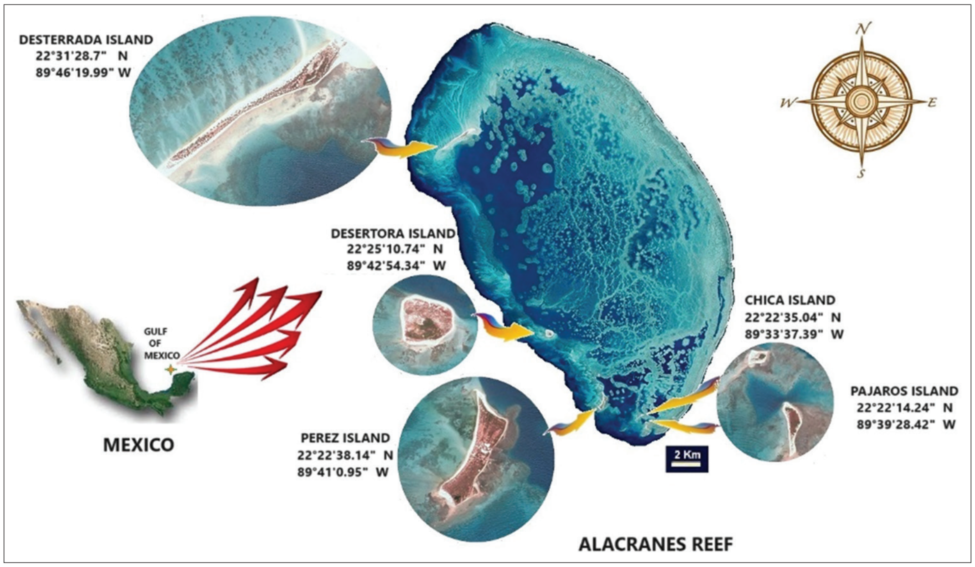

Figure 1: Location of the sandy cays of Alacranes Reef. The geographical coordinates of each key are displayed

Concerning the grouping of species, the most important attributes that define relevant falls in information are depth (littoral), substrate (epilithic, epiphyte, in shells), reproductive status (presence of spores), and protection against waves. These same characteristics are repeated at immediately lower levels (Figure 2). 28% of species, forms, and varieties did not congregate in defined groups. However, the species that showed the same attributes formed 20 groups, with a variable number of species in each, with intervals ranging from 2 to 20 species.

The biplot analysis presented a pattern where most species moved toward the second and fourth regions of the coordinate axis (right side). The first two components are the most important, as they reach 48.96% of the variance. On the right side, it is observed that the species are grouped mainly influenced by the substrate (epilithic), the depth (infralittoral), and the protection provided by the coast of the key (Figure 3). This suggests the existence of two large different phycological environments, one where species need a substrate to fix that reflects some protection towards the waves and another diverse, which includes all the others that can be epiphytic, floating, or in the sand.

However, Figure 3 shows the presence of an ecotonal continuum between them, without showing an obvious mixing zone. However, on the first axis, two groups can be distinguished, where to the right side are most of the species and to the left a smaller number. This last group is closer to the origin of the axes and presents a certain influence on the fixation in bivalve shells. Two species are presented that do not show influence of any of the 19 attributes considered, *Acanthophora spicifera* (1), which seems that the important thing is the protection from the waves, and *Ganonema farinosum* (80), both are separated decisively from any grouping.

DISCUSSION

Plant communities have a very important influence on the characteristics of marine environments since they fix the substrate, modify the dynamics of the surrounding water, and help the sedimentation of particulate matter, decreasing its mobility (Littler & Littler, 2000; Sánchez-Molina *et al.*, 2007; Chávez *et al.*, 2007; Dawes & Mathieson, 2008). Seaweeds have developed various strategies to take advantage of each environment and on different time scales balances are established between organisms within plant communities (Ellison & Farnwort, 1996; Monrand & Merceron, 2005). Seaweeds are of particular importance since, in addition to participating in the establishment of balances conducive to aquatic biota, they are in themselves a biotic resource that can be exploited (Concepción-Alonso *et al.*, 2001).

The importance of knowing the taxonomic composition of species in the area and the relationships they have between them at the level of a biotic community lies in the fact that this knowledge is the basis on which other studies of relationships between species and environmental conditions can be initiated and from there infer causes or effects of environmental alterations of anthropogenic and/or natural origin. This knowledge can also establish ways of exploiting algal resources either from a perspective of direct use as food or source of extraction of useful or valuable products (Díaz-Piferrer, 1979; Chapman & Chapman, 1980; Robledo *et al.*, 2014). From the perspective of use based on the conservation or induction of the presence of biotic communities either for engineering purposes that take advantage of our physical, chemical, and biological knowledge of nature from a sustainable possibility. The Conservation and Management Program of the Alacranes Reef National Park (CONANP, 2006) mentions that there are records of 386 species of algae only for Isla Pérez, with a greater coverage between 3 and

Table 1: List of macroalgae species from the sandy cays of Alacranes Reef. The percentage of species that represented each attribute is shown

PHYLA		SPECIES	ATTRIBUTES																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Rhodophyta	1	*Acanthophora spicifera* (M. Vahl) Borgesen, 1910		1	1										1	1		1			1
Rhodophyta	2	*Aglaothamnion halliae* (Collins) Aponte, DL. Ballantine & JN. Norris, 1997		1				1										1			1
Rhodophyta	3	*Amphiroa beauvoisii* JV. Lamouroux, 1816	1	1				1										1			1
Rhodophyta	4	*Amphiroa fragilissima* (Linnaeus) JV. Lamouroux, 1816	1	1				1										1			1
Rhodophyta	5	*Amphiroa rigida* JV. Lamouroux, 1816	1	1				1										1			1
Rhodophyta	6	*Amphiroa tribulus* (J. Ellis & Solander) JV. Lamouroux, 1816	1	1														1			1
Cyanobacyteria	7	*Anabana oscillarioides* Bory ex Bornet & Flahualt, 1886	1					1										1			1
Rhodophyta	8	*Anotrichium tenue* (C. Agardh) Nägeli, 1862	1												1			1			1
Cyanobacyteria	9	*Aphanothece stagnina* (Sprengel) A. Braun, 1963	1					1										1			1
Cyanobacyteria	10	*Arthrospira miniata* Gomont, 1892	1					1										1			1
Rhodophyta	11	*Asparagopsis taxiformis* (Delile) Trevisan de Saint-León, 1845	1						1									1			1
Chlorophyta	12	*Avrainvillea longicaulis* (Kützing) G. Murray & Boodle, 1889					1	1									1	1			1
Chlorophyta	13	*Avrainvillea nigricans* Decaisne, 1842					1	1										1			1
Chlorophyta	14	*Blidingia minima* (Nägeli ex Kützing) Kylin, 1947		1				1									1				1
Chlorophyta	15	*Bryopsis pennata* JV. Lamouroux, 1809		1				1										1			1
Ochrophyta	16	*Canistrocarpus cervicornis* (Kützing) De Paula & De Clerck, 2006		1	1				1								1	1		1	1
Chlorophyta	17	*Caulerpa chemnitzia* (Esper) JV. Lamouroux, 1809		1			1	1									1	1			1
Chlorophyta	18	*Caulerpa cupressoides* (Vahl) C. Agardh, 1817			1		1	1										1			1
Chlorophyta	19	*Caulerpa cupressoides* V. *mamilosa* (Montagne) Weber-van Bosse, 1898			1		1	1										1			1
Chlorophyta	20	*Caulerpa cupressoides* V. *turneri* Weber -van Bosse, 1998					1	1										1			1
Chlorophyta	21	*Caulerpa fastigiata* Montagne, 1837					1	1										1			1
Chlorophyta	22	*Caulerpa mexicana* Sonder ex Kützing, 1849			1		1	1										1			1
Chlorophyta	23	*Caulerpa prolifera* (Forsskal) JV. Lamouroux, 1809					1	1										1			1
Chlorophyta	24	*Caulerpa racemosa* (Forsshal) J. Agardh, 1873		1				1									1		1		
Chlorophyta	25	*Caulerpa racemosa* V. *macrophysa* (Sonder ex Kützing) WR. Taylor, 1928		1	1			1									1	1		1	1
Chlorophyta	26	*Caulerpa sertularoides* (SG. Gmelin) M. Howe, 1905					1	1										1			1
Chlorophyta	27	*Caulerpa sertularoides* F. *brevipes* (J. Agardh) Svedelius, 1906					1	1										1			1
Chlorophyta	28	*Caulerpa sertularoides* F. *longiseta* (Bory) Svedelius, 1906					1	1										1			1
Chlorophyta	29	*Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817					1	1										1			1
Chlorophyta	30	*Caulerpa verticillata* J, Agardf, 1847		1				1										1			1
Chlorophyta	31	*Caulerpa vickersiae* V. *lujosos* WR. Taylor, 1928				1		1										1			1
Rhodophyta	32	*Centroceras clavulatum* (C. Agardh) Montagne, 1846	1												1	1		1			1
Rhodophyta	33	*Ceramium cimbricum* HE. Petersen, 1924	1												1			1			1
Rhodophyta	34	*Ceramium diaphanum* (Lightfoot) Roth, 1806	1												1			1			1
Rhodophyta	35	*Ceramium nitens* (C. Agrdh) J. Agardh, 1851		1											1			1			1
Chlorophyta	36	*Chaetomorpha antennina* (Bory) Kützing, 1847		1				1									1			1	
Chlorophyta	37	*Chaetomorpha brachygona* Harvey, 1858		1				1										1			1
Chlorophyta	38	*Chaetomorpha linum* (OF. Müller) Kützing, 1845				1		1										1			1
Chlorophyta	39	*Chaetomorpha minima* Collins & Hervey, 1917	1					1										1			1
Rhodophyta	40	*Champia parvula* (C. Agardh) Harvey, 1853	1					1								1		1			1
Rhodophyta	41	*Champia salicomoides* Harvey, 1853	1					1										1			1
Rhodophyta	42	*Chondria curvilineata* FS. Collins & Harvey, 1917		1				1										1			1
Rhodophyta	43	*Chondria dasyphylla* (Woodward) C. Agardh, 1817			1			1										1			1
Rhodophyta	44	*Chondria floridana* (FS. Collins) MA. Howe, 1928	1	1				1										1			1
Rhodophyta	45	*Chondria littoralis* Harvey, 1853			1		1								1		1			1	
Rhodophyta	46	*Chondria polyrhiza* FS. Collins & Harvey, 1917	1					1										1			1
Rhodophyta	47	*Chondria sedifolia* Harvey, 1853		1				1									1			1	
Rhodophyta	48	*Chroodactylon ornatum* (C. Agardh) Basson, 1979	1					1										1			1
Chlorophyta	49	*Cladophora albida* (Ness) Kützing, 1843	1					1										1			
Chlorophyta	50	*Cladophora dalmatica* Kützing, 1843					1									1		1			
Chlorophyta	51	*Cladophora brasiliana* G. Martens, 1866	1					1										1			1

(*Contd...*)

Table 1: (*Continued*)

PHYLA		SPECIES	ATTRIBUTES																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Chlorophyta	52	*Cladophora catenata* Kützing, 1843		1				1										1			1
Chlorophyta	53	*Cladophora coelotrix* Kützing, 1843		1				1										1			1
Chlorophyta	54	*Cladophora constricta* FS. Collins, 1909	1					1										1			1
Chlorophyta	55	*Cladophora corallicola* Borgesen, 1913			1			1										1			
Chlorophyta	56	*Cladophora intertexta* Collins, 1901					1	1										1			1
Chlorophyta	57	*Cladophora lehmanniana* (Lindenberg) Kützing, 1843	1	1				1										1			
Chlorophyta	58	*Cladophora vagabunda* (Linnaeus) Hoek, 1963	1	1		1		1									1	1		1	
Chlorophyta	59	*Cladophoropsis membranacea* (Hofman Bang ex C. Agardh) Borgesen, 1905		1				1									1	1		1	
Ochrophyta	60	*Cladosiphon zosterae* (J. Agradh) Kylin, 1940	1						1	1								1			1
Chlorophyta	61	*Codium taylorii* PC. Silva, 1960		1				1										1			1
Rhodophyta	62	*Contarina magdae* Weber Bosse, 1916		1				1										1			1
Rhodophyta	63	*Dasya collinseana* M. Howe, 1918	1					1										1			1
Chlorophyta	64	*Derbesia vaucheriiformis* (Harvey) J. Agardh, 1887				1			1									1			1
Ochrophyta	65	*Dictyopteris delicatula* JV. Lamouroux, 1809		1	1			1										1			1
Chlorophyta	66	*Dictyosphaeria cavernosa* (Forsskal) Borgesen, 1932	1	1				1										1			
Ochrophyta	67	*Dictyota bartayresiana* JV. Lamouroux, 1809		1	1				1									1		1	1
Ochrophyta	68	*Dictyota dichotoma* (Hudson) JV. Lamouroux, 1809		1	1			1	1									1		1	1
Ochrophyta	69	*Dictyota guineënsis* (Kputzing) P. Crouan & H. Crouan, 1878		1	1			1									1		1	1	1
Ochrophyta	70	*Dictyota implexa* (Desfontaines) JV. Lamorouroux, 1809		1	1				1									1			1
Ochrophyta	71	*Dictyota mertensii* (C. Martius) Kützing, 1859		1				1									1	1			1
Rhodophyta	72	*Digenea simplex* (Wulfen) C. Agardh, 1822		1											1		1			1	
Ochrophyta	73	*Ectocarpus breviarticulatus* J. Agardh, 1847	1	1							1							1			1
Ochrophyta	74	*Ectocarpus comensalis* Setchell & NL. Gardner, 1922	1								1							1			1
Ochrophyta	75	*Ectocarpus siliculosus* V. *dasycarpus* (Kuckuck) Gallardo, 1992	1								1							1			1
Cyanobacyteria	76	*Entophysalis conferta* (Kützing) Drouet & Daily, 1948	1					1										1			1
Rhodophyta	77	*Erythrotrichia carnea* (Dillwyn) J. Agardh, 1883	1					1										1			1
Ochrophyta	78	*Feldmannia mitchelliae* (Harvey) HS. Kim, 2010	1	1							1							1			1
Rhodophyta	79	*Galaxaura rugosa* (J. Ellis & Solander) JV. Lamouroux, 1816		1	1			1										1			1
Rhodophyta	80	*Ganonema farinosum* (JV. Lamouroux) KC. Fan & YC Wang, 1974			1					1								1			1
Rhodophyta	81	*Ganonema megagynum* (Borgesen) Huisman, 2002		1	1					1								1			1
Rhodophyta	82	*Gayliella mazoyerae* T.O.Cho, Fredericq & Hommersand, 2008	1												1	1		1			1
Rhodophyta	83	*Gelidiella acerosa* (Forsskal) Fieldman & Hamel, 1934		1	1				1								1	1			1
Rhodophyta	84	*Gelidium crinale* (Here ex turner) Gaillon, 1828		1					1								1				1
Rhodophyta	85	*Gelidium pusillum* (Stakhouse) Le Jolis, 1863		1	1				1								1				1
Rhodophyta	86	*Gloiocallis dendroidea* (P. Crouan & H. Crouan) Showe M. Lin, Huisman & DL. Ballantine, 2014		1	1			1										1			1
Rhodophyta	87	*Gracilaria cylindrica* Borgesen, 1920		1												1		1			1
Rhodophyta	88	*Gymnothamnion elegans* (Schousboe ex C. Agardh) J. Agardh, 1892	1					1									1			1	
Chlorophyta	89	*Halimeda discoidea* Decaisne, 1842		1				1										1		1	
Chlorophyta	90	*Halimeda goreaui* WR. Taylor, 1962		1				1										1			1
Chlorophyta	91	*Halimeda incrassata* (j. Ellis) JV. Lamouroux, 1816					1			1								1			1
Chlorophyta	92	*Halimeda monile* (J. Ellis & Solander) JV. Lamouroux, 1816					1	1										1			1
Chlorophyta	93	*Halimeda opuntia* (Linnaeus) JV. Lamouroux, 1816		1				1										1			1
Chlorophyta	94	*Halimeda scabra* MA. Howe, 1905			1		1	1										1			1
Chlorophyta	95	*Halimeda simulans* MA. Howe, 1907		1				1										1			
Chlorophyta	96	*Halimeda tuna* (J. Ellis & Solander) JV. Lamouroux, 1816		1				1										1			1
Rhodophyta	97	*Herposiphonia secunda* (C. Agardh) Ambronn, 1880	1	1											1	1		1			1
Rhodophyta	98	*Herposiphonia tenella* (C. Agardh) Ambronn, 1880	1	1											1	1		1			1
Rhodophyta	99	*Hydrolithon farinosum* (JV. Lamouroux) Penrose & YM. Chamberlain, 1993	1												1			1			1

(*Contd...*)

Table 1: (*Continued*)

PHYLA		SPECIES	ATTRIBUTES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ochrophyta	100	*Hydroclathrus clathratus* (C. Agardh) M. Howe, 1920		1				1										1			1
Rhodophyta	101	*Hypnea cervicornis* J. Agardh, 1851	1	1											1	1		1			1
Rhodophyta	102	*Hypnea musciformis* (Wulfen) JV. Lamouroux, 1813	1	1											1	1		1			1
Rhodophyta	103	*Hypnea spinella* (C. Agardh) Kützing, 1847	1					1									1			1	
Rhodophyta	104	*Jania adherens* JV Lamouroux 1816	1					1										1			1
Rhodophyta	105	*Jania capillacea* Harvey, 1853	1	1				1										1			1
Rhodophyta	106	*Jania rubens* (Linnaeus) Lamouroux, 1816	1	1				1										1			1
Ochrophyta	107	*Kuetzingiella elachistaeformis* (Heydrich) M. Balakrishnan & Kinkar, 1981	1								1							1			1
Ochrophyta	108	*Kummia onusta* (Kützing) J. Fiore, 1975	1								1							1			1
Rhodophyta	109	*Laurencia microcladia* Kützning, 1865		1	1										1			1			1
Rhodophyta	110	*Laurencia obtusa* (Hudson) JV. Lamouroux, 1813	1	1											1			1			1
Rhodophyta	111	*Liagora ceranoides* JV. Lamouroux, 1816		1	1				1									1			1
Rhodophyta	112	*Liagora pinnata* Harvey, 1853	1	1					1									1			1
Rhodophyta	113	*Lithophyllum kaiseri* (Heydrich) Heydrich, 1897		1										1			1				1
Ochrophyta	114	*Lobophora variegata* (J.V. Lamouroux) Womersley ex EC. Oliveira, 1977	1		1			1										1			1
Rhodophyta	115	*Lophosiphonia cristata* Falkenberg, 1901		1				1										1			1
Rhodophyta	116	*Lophosiphonia oscura* (C. Agardh) Falkenberg, 1897		1				1										1			1
Rhodophyta	117	*Melanothamnus sphaerocarpus* (Borgesen) Díaz-Tapia & Maggs, 2017	1	1											1	1		1			1
Cyanobacyteria	118	*Microcoleus lyngbyaceus* Kützing ex Forti, 1907	1	1				1						1				1			1
Rhodophyta	119	*Neogoniolithon affine* (Foslie & MA. Howe) Setchell & LR. Mason, 1943		1			1											1			1
Rhodophyta	120	*Neogoniolithon strictum* (Foslie) Setchell & LR. Mason, 1943					1	1										1			1
Chlorophyta	121	*Neomeris annulata* Dickie, 1874		1	1					1						1		1			
Ochrophyta	122	*Neoralfsia expansa* (J. Agardh) PE. Lim & H. Kawai ex Cormaci & G. Furnari, 2012		1					1								1		1		1
Ochrophyta	123	*Padina gymnospora* Sonder, 1871	1	1	1			1	1									1			1
Ochrophyta	124	*Padina sanctae-crucis* Borgesen, 1914	1	1					1									1			1
Rhodophyta	125	*Palisada corallopsis* (Montagne) Senties, Fuji & Díaz-Larrea, 2008	1	1				1										1			1
Rhodophyta	126	*Palisada perforata* (Bory) KW. Nam, 2007		1	1										1			1			1
Chlorophyta	127	*Pedobesia simplex* (Meneghini ex Kützing) MJ. Wynne & F. Leliaert, 2001		1					1									1			1
Chlorophyta	128	*Penicillus capitatus* Lamarck, 1813					1	1										1			1
Chlorophyta	129	*Penicillus pyriformis* A. Gepp & ES. Gepp, 1905					1	1										1			1
Chlorophyta	130	*Phaeophila dendroides* (P. Crouan & H. Crouan) Rebozados, 1902	1					1										1			1
Chlorophyta	131	*Phyllodictyon anastomosans* Kraft & MJ Wynne, 1996				1		1										1			1
Rhodophyta	132	*Pleonosporium* sp. Nägeli, 1862		1				1										1			1
Rhodophyta	133	*Pneophyllum fragil* Kützing, 1843	1												1			1			1
Rhodophyta	134	*Polysiphonia macrocarpa* (C. Agardh) Sprengel, 1827	1	1											1	1		1			1
Rhodophyta	135	*Polysiphonia saccorhiza* (Collins & Harvey) Hollenberg, 1968	1					1										1			1
Chlorophyta	136	*Pseudendoclonium marinum* (Reinke) Aleem & E. Schulz, 1952	1					1										1			1
Rhodophyta	137	*Pterocladiella bartlettii* (WR. Taylor) Santelices, 1998		1	1				1									1			1
Rhodophyta	138	*Pterocladiella sanctarum* (Fieldmann & Hamel) Santelices, 2007							1								1	1			1
Chlorophyta	139	*Ripocephalus phoenix* (J. Ellis & Solander) Kützing, 1843					1	1										1			1
Chlorophyta	140	*Ripocephalus phoenix F. longifolius* A. Gepp & E. Gepp, 1911					1	1										1			1
Rhodophyta	141	*Sahlingia subintegra* (Rosenvinge) Kormmann, 1989	1					1										1			1
Ochrophyta	142	*Sargassum fluitans* (Borgesen) Borgesen, 1914					1	1									1				
Ochrophyta	143	*Sargassum hystrix* J. Agardh, 1847		1				1									1			1	
Ochrophyta	144	*Sargassum hystrix* V. *buxifolium* (Chauvin) MJ. Wynne, 2011		1				1										1			1
Ochrophyta	145	*Sargassum natans* (Linnaeus) Gaillon, 1828					1	1									1				
Ochrophyta	146	*Sargassum polyceratium* Montagne, 1837		1	1			1										1			1

(*Contd...*)

Table 1: (*Continued*)

PHYLA		SPECIES	ATTRIBUTES																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ochrophyta	147	*Sargassum polyceratium* V. *ovulo* (Collins) WR. Taylor, 1928		1				1										1			1
Ochrophyta	148	*Sargassum ramifolium* Kützing, 1861		1				1										1			1
Ochrophyta	149	*Sargassum vulgare* C. Agardh, 1820		1														1			1
Ochrophyta	150	*Sargassum vulgare* V. *foliossisimum* (JV. Lamouroux) C. Agardh, 1820		1													1		1		
Cyanobacyteria	151	*Schizothrix arenaria* Gomont, 1892	1															1			1
Cyanobacyteria	152	*Scytonematopsis crustacea* (Thuret ex Bornet & Flahualt) Kovàlik & Komárek, 1988	1	1														1			1
Chlorophyta	153	*Siphonocladus rigidus* M. Howe, 1905	1															1			
Ochrophyta	154	*Spatoglossum schroederi* (C. Agardh) Kützing, 1859		1													1				1
Rhodophyta	155	*Spermothamnion investens* (PL. Crouan & HM Crouan) Vickers, 1905	1												1			1			1
Rhodophyta	156	*Spermothamnion macromeros* FS. Collins & Harvey, 1917	1												1			1			1
Ochrophyta	157	*Sphacelaria brachigona* Montagne, 1843	1									1						1			1
Ochrophyta	158	*Sphacelaria fusca* (Hudson) SF. Gray, 1821	1	1								1						1			1
Ochrophyta	159	*Sphacelaria rigidula* Kützing, 1843	1	1								1						1			1
Ochrophyta	160	*Sphacelaria tribuloides* Meneghini, 1840	1									1						1			1
Ochrophyta	161	*Sporochnus pedunculatus* (Hudson) C. Agardh, 1817		1				1										1			1
Rhodophyta	162	*Spyridea filamentosa* (Wulfen) Harvey, 1833	1	1											1			1			1
Rhodophyta	163	*Spyridea hipnoides* (Bory de Saint-Vincent) Papenfuss, 1968		1				1										1			1
Rhodophyta	164	*Taenioma perpusillum* (J. Agardh) J. Agardh, 1863	1					1										1			1
Rhodophyta	165	*Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka, 1990		1	1			1										1			1
Ochrophyta	166	*Turbinaria tricostata* ES. Barton, 1891		1				1						1			1			1	
Ochrophyta	167	*Turbinaria turbinata* (Linnaeus) Kuntze, 1898		1				1									1			1	
Chlorophyta	168	*Udotea conglutinata* (J. Ellis & Solander) JV. Lamouroux, 1816					1	1										1			1
Chlorophyta	169	*Udotea occidentalis* A. Gepp & ES. Gepp, 1911					1	1										1			1
Chlorophyta	170	*Udotea spinulosa* MA. Howe, 1909					1	1										1			1
Chlorophyta	171	*Ulva chaetomorphoides* (Borgesen) HS. Hayden, biomster. Maggs, PC Silva, Stanhope & Waaland, 2003		1				1										1			1
Chlorophyta	172	*Ulva clathrata* (Roth) C. Agardh, 1811				1		1										1			1
Chlorophyta	173	*Ulva compressa* Linneo, 1753		1				1									1			1	
Chlorophyta	174	*Ulva flexuosa* Wulfen, 1803		1	1			1									1	1		1	1
Chlorophyta	175	*Ulva flexuosa subsp. Paradoxa* (C. Agardh) MJ. Wynne, 2005		1				1										1			1
Chlorophyta	176	*Ulva lactuca* Linneo, 1753		1				1									1			1	
Chlorophyta	177	*Ulva lactuca* F. *rígida* (C. Agardh) Hylmö		1				1									1		1		
Chlorophyta	178	*Ulva linza* Linneo, 1753			1			1									1				1
Chlorophyta	179	*Ulva paradoxa* C. Agardh, 1817	1					1										1		1	
Chlorophyta	180	*Ulva prolifera* (OF. Müller) J. Agardh, 1883			1			1									1	1		1	1
Chlorophyta	181	*Ulvella viridis* (Reinke) R. Nielsen, CJ O'Kelly & B Wysor, 2013	1					1										1			1
Chlorophyta	182	*Valonia ventricosa* J. Agardh, 1887	1					1										1			
Chlorophyta	183	*Willeella brachyclados* (Montagne) MJ. Wynne, 2016				1		1										1			1
Rhodophyta	184	*Wrangelia argus* (Montagne) Montagne, 1856		1											1			1		1	
Rhodophyta	185	*Yuzurua poiteaui* (JV. Lamoroux) Martin-Lescanne, 2010	1	1											1			1			1
Ochrophyta	186	*Zonaria tournefortii* (JV. Lamouroux) Montagne, 1846		1				1										1			1
		% de especies, formas y variedad	**40**	**55**	**20**	**5**	**19**	**71**	**12**	**8**	**8**	**7**	**6**	**8**	**20**	**14**	**27**	**95**	**12**	**22**	**94**

Attributes: 1-Epiphyte, 2-Epilithic, 3-On bivalves, 4-Floating, 5-Psammofila, 6-Vegetative, 7-Spores, 8-Gametocytes, 9-Zoidocysts, 10-Propagules, 11-Receptacles, 12-Conceptacles, 13-Tetraspores, 14-Cystocarps, 15-Littoral, 16-Infralittoral, 17-Exposed, 18-Semi-protected and 19-Protected

15 m. However, the document reports a record of 195 including varieties and forms, a value like that found in this work.

Some authors (Round, 1981; Chávez *et al.*, 2007) mention that in the intertidal zone, the Chlorophyta are the ones that are best represented, mentioning that they are plants capable of tolerating extreme environments in temperature, salinity, desiccation, exposure to rain, and winds and great light intensity. However, in the keys of Alacranes presented in this area 14 species of this type 10 species of Rhodophyta, and 10 species of

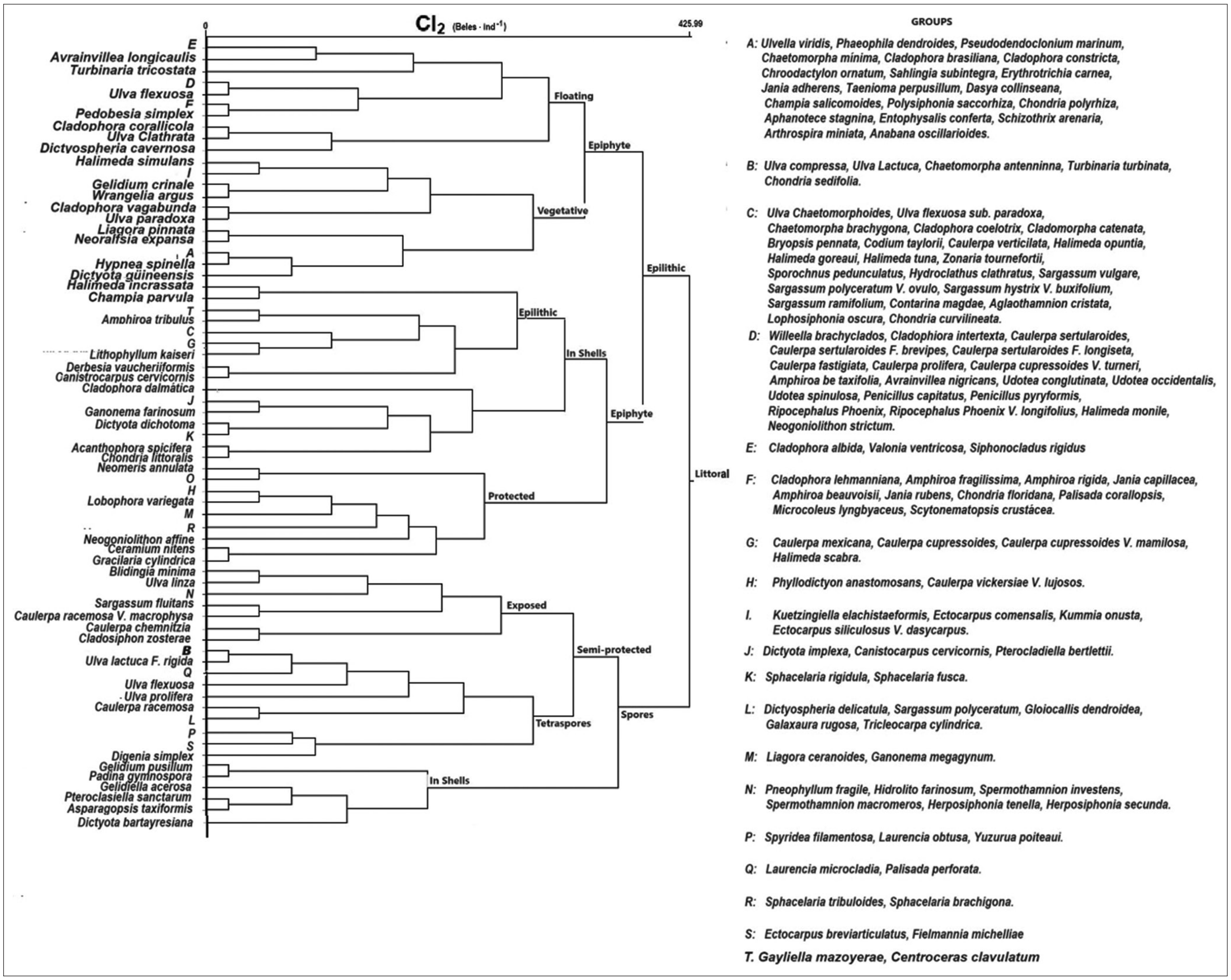

Figure 2: Dendrogram obtained with the Information Content. It shows the attributes that cause the greatest drop in information and the groups that represent more than one species

Ochrophyta, which could suppose that these three phyla have the capacity of a similar tolerance.

In the areas where there was a meadow of *Thalassia testudinum* König, they were areas of sandy substrate and especially semi or protected with little movement of water and in some cases with less clear waters. In this area, there was floating algae drifting or in midwater. Genera of psammophiles algae were presented as *Penicillus*, *Rhipocephalus*, *Caulerpa*, *Cladophora*, *Udotea*, *Halimeda*, *Avrainvillea*, and *Willeela* among the green algae, *Neogoniolithon*, and Chondria among the red ones, the brown algae are only represented by the genus *Sargassum*. Torruco *et al.* (1993), mention that around Isla Pérez there were associations of algae such as *Sargassum* sp. and *Turbinaria turbinata*, *Dictyota sp.* and *Lobophora veriegata* or associations between *Goniolithon sp.* and coral fragments, but also that there were areas dominated by algae such as *Halimeda incrassata*, *Laurencia* sp., *Ceramium* sp. aspects that were also presented in this work and not only in Isla Pérez but also in Desterrada. This area presented a high incidence of epiphytes, some of these genera are mentioned in the works of Jordán-Dahlgren *et al.* (1978), León-Tejera (1980), and Gómez-Pedroso (1987) for similar habitats.

In the infralittoral zone, where there were limestone rocks or coral remains, 55% of the registered species of the three phyla were presented, Cyanobacteria were not present in these areas. This area presented places exposed to waves with a lot of agitation, reef crest, channels, etc. These areas reported the presence of fouling forms such as *Hydrolithon*, *Lithophyllum* and *Neogoniolithon*. There are also calcareous algae such as *Galaxaura*, *Amphiroa*, and Jania, in addition to the brown algae genera *Padina* and *Dictyota* especially in the coral remains. This pattern was like that found by Littler and Littler (1984) and Mendoza-González *et al.* (2000) for Carrie Bow in Belize and Cozumel in the Mexican Caribbean respectively. As for epiphytes, they occurred in all areas, with a high predominance of Rhodophyta, followed by brown algae. The few Cyanobacteria presented themselves in this way.

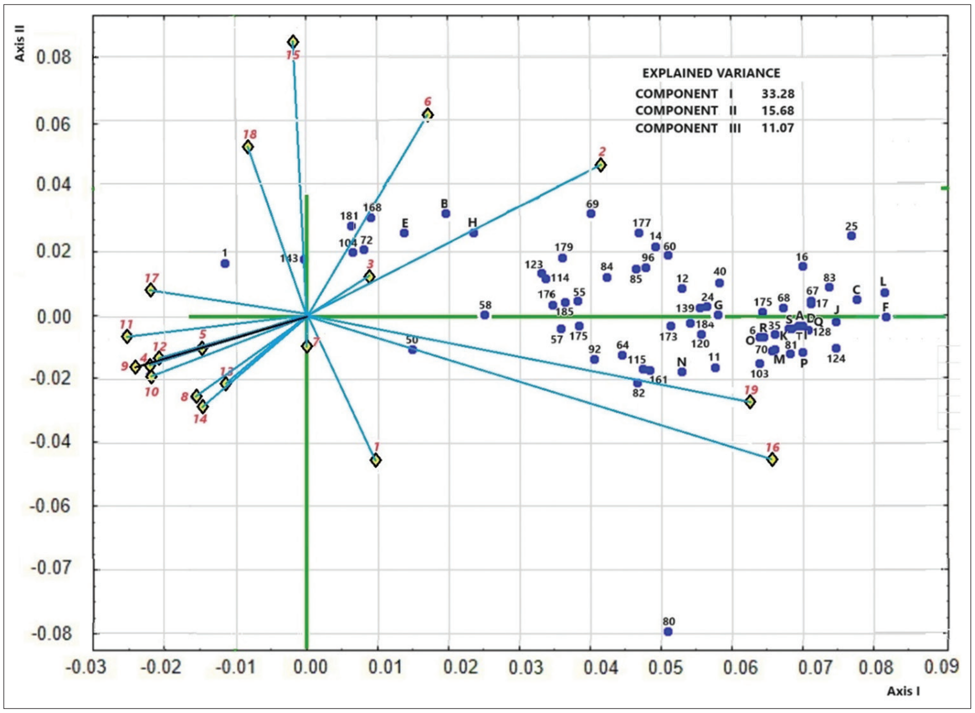

Figure 3: Representation of the BIPLOT analysis, which shows the distribution of attributes and species in n-dimensional space. The percentage of variance explained by the first three axes is shown

As a result of the analyses carried out and in the search for some pattern of attributes and preferences of the algae in the sandy cays of the Alacranes reef, we have that the substrate constitutes the determining factor and thus, it is possible to say that in phycofloristic terms two general environments can be distinguished in the study area: sandy areas and areas with hard substrate, whether biotic or not, but both are decisively influenced by depth, so that of the 51 species listed by Ballantine and Aponte (2003) as deep benthic reef algae in the Bahamas (>27 m), 18 were listed in this work.

Between these two environments, there seems to be an ecotonal continuum where each species can be presented. Few species are not limited by the substrate such as *Acanthophora spicifera* and *Ganonema farinosum*, which have other conditions that influence them more strongly. In our case, the morphological structures of some species such as rhizoids or calcified thallus do not limit their distribution in the different environments surrounding the sandy cays, as mentioned by Fujii *et al*. (1996) for Nichupté in Quintana Roo. On the other hand, the percentage of epiphytic species implies that the morphological structures of the hosts may be important and hence their presence in several areas.

Finally, even when elements have been identified that decisively influence the presence of algae, it is recommended that research involving temporality be carried out, at least in the three seasons recognized for this area (dry, rainy, and northern), together with specific records of environmental factors, to discern if some of them connect the presence and abundance of this group and enhance its importance for the conservation of this ecosystem.

CONCLUSIONS

The benthic algae of the sandy cays of the Alacranes reef are a diverse group, 178 species of 4 phyla were located. Among the 19 attributes recorded, substrate, depth, and wave protection were the most important. There appears to be an ecotonal gradient between sandy areas and between areas with rocks or coral fragments. A significant number of epiphytes were found at all sites.

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