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DIVERSITY OF BROWN ALGAE (OCHROPHYTA, PHAEOPHYCEAE) OF SIAN KA´AN RESERVE BIOSPHERE, MEXICAN CARIBBEAN

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Abstract

The Biosphere Reserve of Sian Ka'an located in the Mexican Caribbean, where greatest diversity of seaweeds has been recorded. Despite of diversity and species richness there are limited phycological studies in the study area, suggesting that species diversity is not completely known. We reported species that complement previous reports of brown algae collected from the study area. In addition, brown algae recorded in the literature and the species present in the herbaria for the Biosphere Reserve of Sian Ka'an were also included, and data obtained from sampling at eleven localities during 2009 to 2012 were added. In all 50 infrageneric taxa are reported. Families Dictyotaceae and Sargassaceae comprised the most species richness. The presence of 11 species of Phaeophyceae is reported for the first time for the study area. Of them, *Symphyocarpus strangulans* is a new record for the Mexican Atlantic; eight species are new records for study area and two for Quintana Roo. The highest number of species was recorded for Punta Xoquem and Pulticub, while the lowest number of taxa was in Cayo Valencia. The highest number of species was found in summer rains, the lowest in winter rains. The obtained data highlights the high specific richness of Phaeophyceae indicating that the Sian Ka'an Reserve should be considered a priority area due to its great biodiversity. Moreover, these results will be a basis for future ecological, utilization and conservation studies.

Key words: Brown Algae, Ochrophyta, Phaeophyceae, Mexican Caribbean

Introduction

The Phaeophyceae (brown algae) commonly dominate rocky shores in cold and temperate waters throughout the world. Tropical waters have fewer species of brown algae, although genera such as *Sargassum* and *Turbinaria* dominate in some areas to form small-scale forests (Lee, 2008). Mexican Caribbean is one of the littoral areas having greatest brown seaweeds diversity in Mexico (Cetz-Navarro *et al.,* 2008); nevertheless, the area has not been well explored, suggesting that species diversity is not completely known. The seaweed flora around of the Sian Ka´an Biosphere Reserve (SKBR) had been investigated mainly during 1989-1992 and the last contribution was thirteen years ago. At present, 39 species of brown marine algae are reported (Taylor 1960; Aguilar-Rosas *et al*., 1989; Aguilar-Rosas 1990; Aguilar-Rosas *et al*., 1992; Aguilar-Rosas *et al*., 1998; Diaz-Martin & Espinoza-Avalos, 2000; Valadez-Cruz *et al*., 2014). Now, the marine life of SKBR is endangered due to the overexploitation of natural resources, urbanization and the other anthropogenic activities: Felipe Carrillo Puerto and Tulum (Espejel-Montes, 1983; Convención Relativa a los Humedales de Importancia Internacional (RAMSAR), 2003). In this context, the use of marine algae as ecological indicators is essential in monitoring the reserve. However, its application is still not possible due to the absence of a reliable and updated list (Cepeda-González *et al*., 2007). Therefore, the goal of this study is to integrate the previous records of brown algae (Ochrophyta, Phaeophyceae) with new records of and to update the information of this group in the SKBR, with additional information as seasonality, distribution, epiphytism and reproduction.

Materials and Methods

Materials and methods and description of the study area in the present paper are the same as described by Acosta-Calderón *et al*., (2016). Collections were made from depths of 0-3 m, data on the GPS coordinates of the localities, type of substrate, and months and year of collection in which organisms were recorded (Table 1). New records for the SKRB and for Mexico are indicated in the table 2. Species names are according to Wynne (2017) and Guiry & Guiry (2018).

Field and laboratory work: A total of 75 samples was collected from 11 localities: Punta Pelicanos, Hualapich, Punta Xoquem, Cayo Valencia, Hualastok, Punta Sacrificios, Punta Herrero, El Faro, Punta Mosquitero, Playa Dei and Pulticub (Fig. 1). Algal samples were preserved in a 5% formalin/sea water solution. Small fragments were cut manually with a double-edged blade, and stained with aniline blue and iodine green for anatomical observations and dimensions. All specimens of brown macroalgae were carefully checked under the microscope for epiphytes using a stereoscopic microscope Zeigen HG571405 and an optical microscope ZEISS 2273. Epiphytic algae were found growing on macroalgae as *Padina, Turbinaria* and *Sargassum*. Thalli were thoroughly examined from the base to the apical portion locating filamentous epiphytes. Subsequently that using a double- edged blade, longitudinal rasps of 2 cm of each thallus were made in order to detect microscopic algae (Mendoza-González *et al.,* 2017).

Semi-permanent slides were prepared using corn syrup/water 1:1 with a trace of phenol added to prevent fungal growth (Mateo-Cid *et al*., 2013). The

identification at the specific level was based mainly on Taylor (1960), Fletcher (1987), Schneider & Searles (1991), Littler & Littler (2000) and Dawes & Mathieson (2008). The determined specimens are housed in the herbarium ENCB of Instituto Politécnico Nacional (IPN). The classification of Wynne (2017) was mainly followed; in addition to that of Guiry & Guiry (2018) for the nomenclatural update. The floristic list comprises information on the seasonality, distribution, epiphytism and new records of marine brown algae. Also, the number of species is indicated according to location and climatic season.

Results

Floristic: Fifty infrageneric taxa of marine brown seaweeds (48 species and two varieties) were determined from the collection and bibliographic references, belonging to five Orders and six families; families with the highest number of species were: Dictyotaceae with 26 species and Sargassaceae, with 12. The more diverse genera regardless the specific richness were: *Dictyota* with 15 species and *Sargassum* with 10 species. Eleven taxa are new records for RBSK, whereas *Symphyocarpus strangulans* is new record for the Mexican Atlantic and *Canistrocarpus crispatus* (J.V. Lamouroux) De Paula & De Clerck and *Myrionema strangulans* Greville are recorded for the first time in the Mexican Caribbean. Besides eight species are new records for the Biosphere Reserve of Sian Ka'an some of them are *Dictyota friabilis* Setchell, *D. guajirae* Hörnig, Schnetter & J.M. Over, *D. implexa* (Desfontaines) J.V. Lamouroux and *Herponema tortugense* (W.R. Taylor) W.R. Taylor, among others (Table 2).

Discussion

Floristic composition: Fifty species of Phaeophyceae algae recorded herein are common in the waters of the Mexican Caribbean. We report the presence of 11 unrecorded brown marine algae in the study area, one of them; *Symphyocarpus strangulans* is a new record for the Atlantic coast of Mexico. The total number of species increases to 50 including the recently published reports of species from Biosphere Reserve of Sian Ka'an (SKBR) (Valadez-Cruz *et al*., 2014). This represents an increment of 22% from the number published in the recent article by Valadez-Cruz *et al*., (2014), who based their analyses on reports in the literature and recent collections by these authors. When analyzing the different taxonomic groups (Table 2), our survey resulted in a significant increase in the number of Dictyotaceae and Ectocarpales epiphytes (36.3%) each.

Diaz-Martin & Espinoza-Avalos (2000) reported 35 species of brown seaweeds from 72 localities of the Yucatan peninsula; however, these authors did not locate 28 species previously recorded by other authors in the study area. When comparing our data of 50 taxa, with those obtained by these authors it is evident that there is similarity in species richness between Caribbean (eastern Quintana Roo) and Reserve Biosphere Sian Ka'an, 58 vs 50 species respectively. On the other hand, Mateo-Cid and Mendoza-González (2007) reported 47 taxa of Phaeophyceae in Cozumel Island, these authors found that better represented families were Dictyotaceae (22 taxa) and Sargassaceae (11). Such data clearly indicate the Reserve Biosphere of Sian Ka'an as a region of high diversity of brown algae.

Table 1. Location of sampling sites, substrate, depth and collection dates.

Locality	GPS coordinates	Substrate	Depth of collection	Collection dates
1. Punta Pelicanos	19°59′38′′N 87°27′55′′W	Rocks and coral skeletons	0-3 m	January 2011, April, August and December 2012
2. Hualapich	19°52′44′′N 87°27′40′′W	Rocks	0-2 m	January 2011, April and August 2012
3. Punta Xoquem	19°49′38′′N 87°27′08′′W	Rocks and coral skeletons	0-2 m	January and December 2011, April and August 2012
4. Cayo Valencia	19°42′19′′N 87°28′37”W	Rocks	0-1 m	March 2009, August 2012
5. Hualastok	19°39′53"N 87°26′51” W	Rocks and coral skeletons	0-2 m	April and August 2012
6. Punta Sacrificios	19°28′06′′N 87°26′38′′W	Rocks and coral skeletons	0-3 m	January and December 2011, April and September 2012
7. Punta Herrero	19°19′32′′N 87°26′56′′W	Rocks	0-1 m	April and September 2012
8. El Faro	19°18′08′′N 87°28′21′′W	Rocks	0-2 m	March 2009, April and September 2012,
9. Punta Mosquitero	19°14′12′′N 87°31′02′′W	Rocks and coral skeletons	0-2 m	April and September 2012
10. Playa Dei	19°10′55′′N 87°32′25′′ W	Rocks and coral skeletons	0-2 m	April and September 2012
11. Pulticub	19°05′17′′N 87°33′03′′W	Rocks and coral skeletons	0-3 m	December 2011, April, August and September 2012

Table 2. Marine brown algae in the coast of Reserve Biosphere of Sian Ka´an, Quintana Roo (The abbreviations are explained at the end of the table).

	Species	Loc.	Season	Rep.	Subs.	Ref	Obs.	ENCB herbarium number
	OCHROPHYTA							
	Phaeophyceae							
	Dictyotales							
	Dictyotaceae							
1.	*Canistrocarpus cervicornis* (Kützing) De Paula & De Clerck	3, 4, 5, 6, 10	W, M	♂ Es	R	A,D		23463 23464
2.	*C. crispatus* (J.V. Lamouroux) De Paula & De Clerck	2, 3, 6	W, S	Ve ♂	R	A	NRQ	23465 23547
3.	*Dictyopteris delicatula* J.V. Lamouroux				R	B, D		
4.	*D. jamaicensis* W.R. Taylor				R	C, D		
5.	*D. justii* J.V. Lamouroux	9	S	Es	R	A		20322
6.	*Dictyota. bartayresiana* J.V. Lamouroux	1, 3, 6, 8, 11	W, S, M	Es, Ve Ve	R Epi	A		23466 23549 23550 23551 213552
7.	*D. caribaea* Hörnig & Schnetter	2, 3, 8, 11	W, S, M	Es ♀ Ve	R	A, D		23467 23553 23554 23555 23556
8.	*D. ciliolata* Sonder ex Kützing	1, 2, 3, 8	W, S, M	Es, ♀ Ve	R	A, D		23469 23470 23471 23557
9.	*D. crenulata* J. Agardh	2, 3	M	Ve	R	A, D		23472 23559
10.	*D. dichotoma* (Hudson) J.V. Lamouroux	6	W	Ve	R	A, D		23654
11.	*D. dichotoma* var. *intricata* (C. Agardh) Greville	1	M	Ve	R	A, D		23560
12.	*D. friabilis* Setchell	11	W	Es	R	A	NRS	23561
13.	*D. guajirae* Hörnig, Schnetter & J.M. Over.	1	W	Es	R Epi	A	NRS	23562
14.	*D. guineënsis* (Kützing) P. Crouan & H. Crouan.	1, 2, 3, 6, 11	W, S, M	♂, Es Ve	R	A, D		23564 23566 23568 23571 23572
15.	*D. implexa* (Desfontaines) J.V. Lamouroux	3, 8, 11	M	Es	R Epi	A	NRS	23573 23574 23656
16.	*D. menstrualis* (Hoyt) Schnetter, Hörning & Weber-Peukert				R	D		
17.	*D. mertensii* (C. Martius) Kützing	3, 5, 6, 8	W, S, M	Es, Es Ve	R	A, D		23575 23575 23576 23579 23580
18.	*D. pinnatifida* Kützing	1, 2, 3, 8, 11	W, S, M	Es, ♀♂, ♂	R	A, D		23582 23584 23586 23587
19.	*D. pulchella* Hörnig & Schnetter	3, 8	M	Es, ♂	Epi	A, D		23588 23589
20.	*Lobophora variegata* (J.V. Lamouroux) Womersley ex E.C. Oliveira	1, 5, 6, 7, 8, 11	W, S, M	Es, Ve, Ve	R Epi	A, D		23592 23593 23594 23595 23596 23597 23664
21.	*Padina boergesenii* Allender & Kraft	9	S	Es	R	A, D		23602
22.	*P. gymnospora* (Kützing) Sonder)				R	B, D		
23.	*P. haitiensis* Thivy	8	S	♀	R	A, D		ENCB/10-B
24.	*P. sanctae-crucis* Børgesen	1, 2, 3, 6, 9, 10, 11	W, S, M	Es, Es, Es	R	A, D		23607 23608 23609 23610 23611 23616 23658 23659
25.	*Spatoglossum schroederii* (C. Agardh) Kützing	8, 11	S, M	Es, Ve	R	A, D		23614 23616 23617
26.	*Stypopodium zonale* (J.V. Lamouroux) Papenfuss	8, 11	S, M	Es Es	R	A, D		23620

Table 2. (Cont'd.)

	Species	Loc.	Season	Rep.	Subs.	Ref	Obs.	ENCB herbarium number
	Ectocarpales							
	Acinetosporaceae							
27.	*Herponema tortugense* (W.R. Taylor) W.R. Taylor	11	M	Plu	Epi	A	NRS	23621
28.	*Feldmannia irregularis* (Kützing) G. Hamel				Epi	D		
29.	*F. mitchelliae* (Harvey) H.S. Kim				R	D		
30.	*Kuetzingiella elachistaeformis* (Heydrich) M. Balakrishnan & Kinkar	9	M	Plu	Epi	A, D		23601
	Chordariaceae							
31.	*Cladosiphon zosterae* (J. Agardh) Kylin				Epi	B, D		
32.	*Hecatonema floridanum* (W.R. Taylor) W.R. Taylor	2	S	Plu	Epi	A	NRS	23611
33.	*Myrionema strangulans* Greville	2	S	Plu	Epi	A	NRQ	23611
	Scytosiphonaceae							
34.	*Symphyocarpus strangulans* Rosenvinge	2	M	Plu	Sphy	A	NRM	ENCB/12/CA-01
	Onslowiales							
	Onslowiaceae							
35.	*Onslowia endofitica* Searles & Leister	8	S	Plu	End	A, D		ENCB/11/A
	Sphacelariales							
	Sphacelariaceae							
36.	*Sphacelaria novae-hollandiae* Sonder	10	M	Pp	Epi	A	NRS	23642
37.	*S. rigidula* Kützing	6, 9, 10, 11	W, S, M	Pp Pp Pp	Epi	A, D		23632 23633 23651 23652
38.	*S. tribuloides* Meneghini	11	M	Pp	Epi	A, D		23653
	Fucales Sargassaceae							
39.	*Sargassum buxifolium* (Chauvin) M.J. Wynne					B		
40.	*S. filipendula* C. Agardh	6	S	♀	R	A, D		20229
41.	*S. fluitans* (Børgesen) Børgesen	11	M	Ve		A, D		4153
42.	*S. hystrix* J. Agardh	1	W	♀	R	A, D		23661
43.	*S. natans* (Linnaeus) Gaillon	8	S	Ve		A, D		
44.	*S. platycarpum* Montagne	1	S	♀	R	A, D		17598
45.	*S. polyceratium* Montagne	1, 6, 7, 10, 11	W, S, M	♀♂ Ve ♀♂	R	A, D		23621 23622 23624 23627
46.	*S. polyceratium* var. *ovatum* (Collins) W.R. Taylor	3, 6, 9, 10, 11	W, S, M	♀♂ ♀♂ ♀♂	R	A	NRS	23623 23628 23631 23632 23633
47.	*S. rigidulum* Kützing	6, 8	W, M	♀♂ ♀♂	R	A	NRS	23634 23635
48.	*S. vulgare* C. Agardh	3, 8	W, S	♀ ♀♂	R	A, D		23637 23638
49.	*Turbinaria tricostata* E.S. Barton	1, 2, 3, 6, 10	W, S, M	♀♂ ♀♂ ♀♂	R	A, D		23639 23640 23641 23648 23663
50.	*T. turbinata* (Linnaeus) Kuntze	2, 3, 6, 11	W, S, M	♀♂ ♀♂ ♂	R	A, D		23646 23649 23650 23651

Simbols:

Localities (Loc): 1. Punta Pelicanos, 2. Hualapich, 3. Punta Xoquem, 4. Cayo Valencia, 5. Hualastok, 6. Punta Sacrificios, 7. Punta Herrero, 8. El Faro, 9. Punta Mosquitero, 10. Playa Dei, 11. Pulticub

Seasonality (Climatic Season.):W (winter rains): January, March and December, S (dry): April, M (summer rains): August and September

Reproduction (Rep.): ♀= Female (Oogonia), ♂= Male (Antheridia), Pp= Propagules, Plu= Plurilocular sporangia, Es= Sporangia, Ve= Vegetative

References (Ref. Data source): A. This study, B. Aguilar-Rosas *et al*., (1998), C. Keeney, 1999, D. Valadez-Cruz *et al*., (2014)

OBS. (Observations): NRS: New record for Reserve Biosphere of Sian Ka´an.; NRQ: New record for littoral of Quintana Roo; NRM: New record for Atlantic coast of Mexico

Substrate: R: Rocky, Epi: Epiphytic on other algae, End: Endophyte, Sphy: Semiendophyte

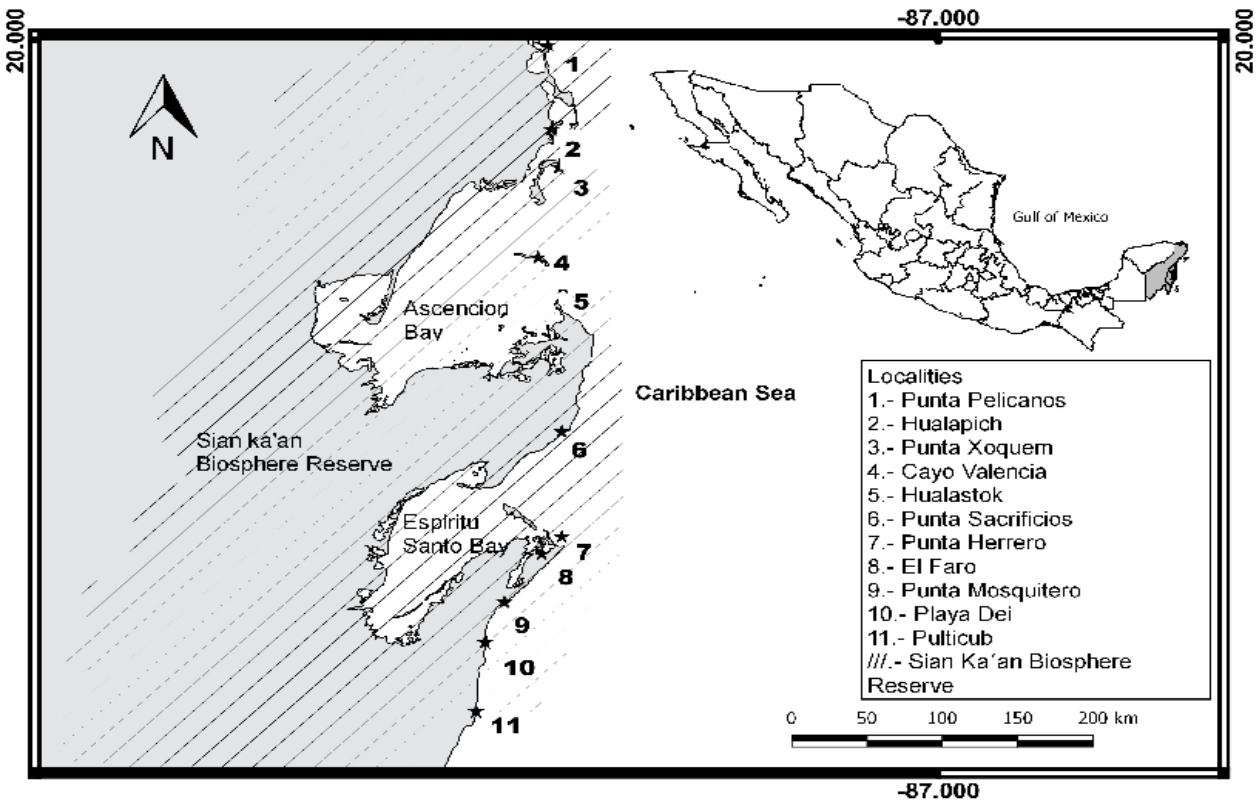

Fig. 1. Study area and Sampling localities.

Type of substrate: Most of the Phaeophyceae develop in marine rocky areas, according to our study, of the 50 species, 35 develop in rocky substrate, while 14 were located as epiphytes, and only two were endophytes or semi endophytes (Table 2). These results agreed with those of Huerta-Múzquiz *et al*., (1987), Mateo-Cid *et al*., (2013) and Mendoza-González *et al*., (2016), who indicated that brown algae were almost exclusively marine species and formed a conspicuous component in tropical rocky areas of ocean. The rocky substrate is favorable for the establishment and growth of numerous brown algae (Dictyotales, Ectocarpales and Fucales) in the tropical regions of the world.

Seasonality: Temperature and light limit the latitudinal distribution of seaweeds, and hence their geographical distribution for they also influence the composition, variation and periodicity of populations at the intertidal and subtidal levels (Santelices, 1977). In our study area summer days are 4 to 5 hours longer that in the winter. Therefore, the availability of light for seaweed is higher, which influences the species richness during the summer (rainy season), with 27 species. The lowest specific richness occurred in winter rains ("nortes") with 21 species. Finally, during the dry season 26 species of Phaeophyceae were recorded. These results were similar to the previous studies in the Mexican Atlantic who also repoted the higher species richness of algae is higher in the summer rains Aguilar-Rosas (1980); Mendoza-González & Mateo-Cid (1992); Aguilar-Rosas *et al*., (1989, 1992, 1998); Ortega *et al*., (2001); Mateo-Cid *et al*., (2013).

In the rocky zone of Punta Pelicanos, Hualapich, Punta Xoquem, Punta Sacrificios, El Faro and Pulticub number belonging to species of the families Dictyotaceae, Ectocarpaceae and Sargassaceae occurred. In Pulticub 17 taxa, Punta Xoquem 16 and El Faro 15 were found. In the all seasons *Dictyota caribaea, D. ciliolata, Lobophora variegata, Sargassum polyceratium, Turbinaria tricostata* and *T. turbinata* were common; while *Hecatonema floridanum* and *Myrionema strangulans* were present only in the winter rains. Finally, *Feldmannia irregularis, Kuetzingiella elachistaeformis* and *Symphyocarpus strangulans* were found in summer rains.

Conclusions

The coast line of Sian Ka´an Biosphere Reserve has 110 km and its an important region of the state of Quintana Roo wich has an extension of 865.2 km and in this Reserve we found 50 infrageneric taxa of brown algae, some of them have potential importance under the economic, industrial or environmental point of view for their proteins, carbohydrates, minerals, among other components, the content of phycocolloids and because they support the refuge of the marine fauna. The RBSK present a typical tropical brown algae spot of the Caribbean Sea. The results obtained in this study contributed to the knowledge of diversity of the brown marine algae incorporating new records as well as information about the distribution and occurrence of the species in RBSK. Furthermore, these results are the basis for future ecological, utilization and conservation studies in the Mexican Caribbean.

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