Macroalgal communities in coastal lagoons of the Yucatan Peninsula, Mexico

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1. Introduction

In coastal lagoons, habitat interactions among marine, freshwater, terrestrial and atmospheric factors (Lankford, 1977) cause stressful conditions to which the flora and fauna must ecophysiologically adapt (Day and Yañez-Arancibia, 1979). Algal communities play a very important role in these ecosystems. The phycoflora is considered to be a good bioindicator of environmental heterogeneity because species and communities respond to abrupt fluctuations as well as to gradual ones (González-González, 1992).

There are approximately 30 studies on the macroalgae of the Yucatan Peninsula, most of which were carried out on the Gulf coast or on the islands of the Mexican Caribbean. The most important are those of Taylor (1935, 1941, 1972), Humm (1952), Huerta (1958, 1961), Huerta and Garza-Barrientos (1980), Huerta *et al.* (1987), Aguilar-Rosas *et al.* (1992) and Mendoza-González and Mateo-Cid (1992).

Although coastal lagoons have been the subject of many studies due to their potential economic value, they have received little attention from the phycological point of view. Taylor (1935, 1941) and Ortegón-Aznar (1993, 1997) studied the macroalgae of Celestún lagoon and Ortegón-Aznar (1997) the macroalgae of Río Lagartos. The coastal lagoon of Nichupté has been studied intensively (Serviere *et al.*, 1992; Collado-Vides, 1992 and Collado-Vides and González-González, 1993).

We define habitat as the conjunction of species present under general environmental conditions, such as substrate, salinity, pH, transparancy and so on. Microhabitat is defined as the conjunction of species with specific ranges of environmental factors. Exclusive species are those that while they are present in only one habitat or microhabitat, are not always present there. We make use of exclusive species rather than present a typical flora because species of each habitat change in time and space depending on the conjunction of factors present at any given time.

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In this paper the macroalgal communities of three lagoons of the Yucatán Peninsula (Celestún, Río Lagartos and Nichupté) were compared with regard to species composition, distribution in the different habitats and as correlated with environmental gradients.

2. Study area

The Yucatan Peninsula is located in southeastern Mexico. The northwestern and northern coasts are on the Gulf of Mexico and the eastern coast is on the Caribbean Sea (Fig.1).

Celestún lagoon (Fig.1a) is situated at the extreme northwestern end of the state of Yucatan (20° 48' and 20° 58' N latitude, 90° 15' and 90° 25' W longitude) on the Gulf coast. It is nearly 22.5 km long and is from 2.24 km to 0.48 m wide. The climate of the region is warm with a mean temperature of 25° C and an average precipitation of 777 mm (García, 1973). The depth of the lagoon ranges from 0.5 to 2.15 m. The salinity gradient is steep between the inner (7-12‰) and the outer zones (30-36‰) of the lagoon and is variable throughout the year. Celustún lagoon is considered to be estuarine.

Río Lagartos (Fig. 1b) is located at the extreme northeastern end of the state of Yucatan (21° 38' and 21° 31' N. latitude, 87° 41' and 88° 15' W. Longitude) on the Gulf coast. The lagoon is nearly 80 km long and is between 0.5 and 4 km wide. There are three basinsin the lagoon, Río Lagartos (outer portion), Las Coloradas (middle) and El Cuyo (inner). The climate of the region is warm and dry with an annual temperature of 28° C and a precipitation of 683.9 mm (García, 1973). The depth of the lagoon ranges from 0.36 to 1.98 m. The salinity gradient is steep between El Cuyo (70-95‰) and the basin Río Lagartos (30-36‰) and is variable throughout the year. It is considered to be a hyperhaline lagoon.

Nichupté lagoon (Fig.1c) system is situated at the extreme northeastern end of the Peninsula in the state of Quintana Roo (21° 9' and 21° 1'N latitude, 86° 41' and 86° 50' W longitude) on the Caribbean coast. It too has three basins, Norte, Centro and Sur and two smaller lagoons, Bojorquez and Río Ingles. It is nearly 21 km long and 12 km wide. The climate of the region is warm and humid with an annual temperature of 26° C and a precipitation of 1150 mm (García, 1973); The depth of the lagoon ranges from 0.5 to 2.2 m. The salinity is not very variable throughout the year (29-36‰). It is considered to be a marine lagoon.

3. Methods

In Nichupté the samples were obtained from habitats, not sampling stations. The samples collected by Collado-Vides (Collado-Vides, 1992) in Nichupté were compared with those collected by Ortegón-Aznar in Celestún and Río Lagartos (Ortegón-Aznar, 1993, 1997). Samples were taken from all three lagoons in both dry and rainy seasons. In Celestún, 15 stations were sampled (May and September 1992). Twenty-seven stations were sampled in Río Lagartos (May and September 1995) in three different habitats, bottom, mangrove and springs. Two samples were collected per habitat. For

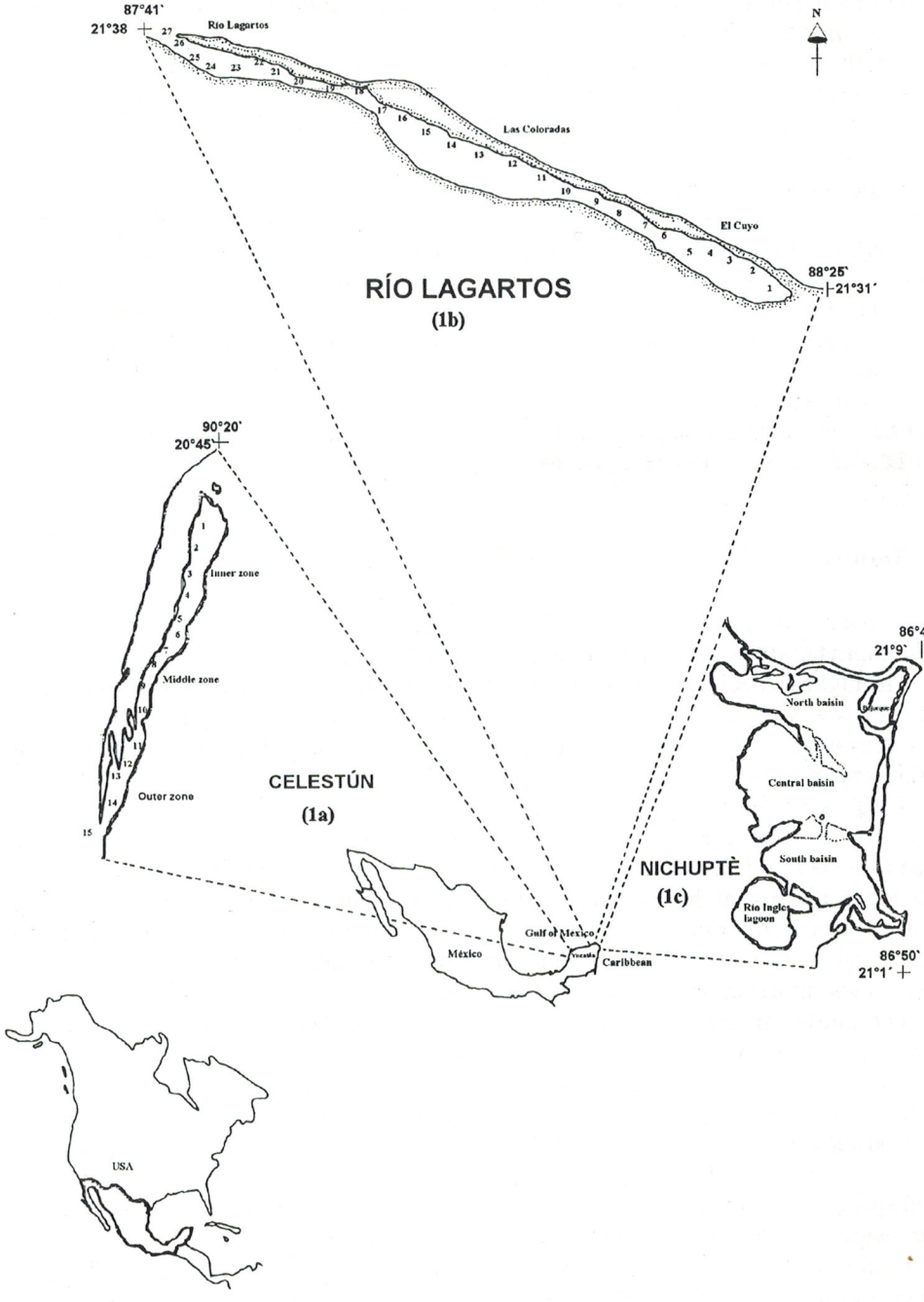

Fig. 1. Map of Mexico and localization of the study area.

sampling the bottom, a 0.25 m^2 quadrant was placed at random; in the mangrove and springs, intertidal algae were collected.

Depth, transparency, temperature, pH and salinity were recorded at all the stations. A Secchi disk was used to measure depth; a field thermometer (scale of 0-100° C) for temperature, a field refractometer for salinity and electric field equipment (Checkmate) for pH. The material was fixed in 4(%) formaldehyde.

Algal specimens were identified to species with keys in Joly (1957), Taylor (1960), Edwards (1976) and Woelkerling (1976), For *Bostrychia* spp. King and Puttock (1989) was followed and for *Polysiphonia* spp. Kapraun and Norris (1982) and Kapraun *et al.*(1983) was used. Algal genus and species names were assigned according to the catalog of Silva *et al.* (1987) and the check list of Wynne (1986). The specimens were deposited in the herbarium of the Science Faculty (FCME) of the Universidad Nacional Autónoma de Mexico.

To correlate species and environmental factors, and to find similarities between habitats and between lagoons, cluster analysis and the Multi Dimensional Scaling (MDS) of the STATISTICA package were used.

4. Results

A total of 110 species was found for the three lagoons (Table I), 64 belonging to Rhodophyta, 40 to Chlorophyta and 6 to Phaeophyta.

The highest species richness was found in Nichupté with 85 species (45 were found in the dry season and 73 in the rainy season) followed by Río Lagartos with 48 (39 dry season and 34 rainy). Celestún had 25 species (19 in the dry season and 13 for rainy season) (Table 1).

We found higher numbers of species in Nichupté in rainy season than in the dry, but this could be due to a more intense study of the former than of the latter. Río Lagartos had more species in the dry season than in rainy, perhaps because during the latter a hurricane hit the coast of Yucatan. Celestún had more species in the dry season than in the rainy season, perhaps because the increase in salinity in the lagoon during the dry season turned brackish water into marine, allowing a larger number of species intolerant to low salinity to grow.

The cluster analysis showed very low similarity between lagoons. Celestún and Río Lagartos showed a 23 % similarity and no similarity with Nichupté (Fig. 2); therefore we treated each lagoon separately. Using environmental factors measured at different stations during the dry and rainy seasons, the MDS analysis divided Celestún lagoon into four zones: inner, middle, outer and springs (Fig.3, Table 2), and Río Lagartos into four zones: El Cuyo basin, Las Coloradas basin, Río Lagartos basin and springs (Fig.4, Table 3). For the Nichupté lagoon system the environmental factors were recorded from habitats, not sampling stations.

Using the species distribution and environmental factors from the three lagoons, three habitats were identified, mangrove, bottom and springs. In the mangroves, 75 species was found, 27 of them exclusive. The bottom habitat had 78 species, 32 of them exclusive. In the springs, 14 species were found, three of them exclusive. According to the MDS analysis each habitat is different, with no similarity between

Table 1. Algal species found in three Yucatan lagoons, distributed by season.

	Nichupté		Río Lagartos		Celestún	
	Dry	Rainy	Dry	Rainy	Dry	Rainy
CHLOROPHYTA						
Acetabularia crenulata	X	X	X	X		
Acetabularia stellata	X	X				
Avrainvillea longicaulis		X				
Avrainvillea nigricans		X				
Batophora oerstedi	X	X	X	X	X	X
Boodleopsis pusilla	X	X				
Caulerpa fastigiata	X	X		X		
Caulerpa prolifera		X	X	X		
Caulerpa sertularioides	X	X				
Caulerpa verticillata	X	X				
Chaetomorpha linum		X		X	X	X
Chara fibrosa					X	X
Cladophora conferta	X	X				
Cladophora crispata				X		
Cladophora crystallina	X	X				
Cladophora montagneana	X	X				
Cladophora pellucicoidea		X				
Cladophora submarina		X				
Cladophora vagabunda	X	X				
Cladophoropsis macromeres	X	X				
Cladophoropsis membranacea	X	X	X	X		
Derbesia marina			X			
Enteromorpha chaetomorphoides			X			
Enteromorpha flexuosa			X		X	
Enteromorpha lingulata			X			
Enteromorpha prolifera					X	
Halimeda incrassata	X	X	X			
Halimeda simulans		X				
Halimeda tuna		X				
Penicillus capitatus		X	X			
Penicillus lamourouxii	X					
Penicillus pyriformis	X					
Rhipocephalus phoenix		X				
Rhizoclonium africanum		X	X		X	X
Rhizoclonium crassipellitum		X			X	X
Rhizoclonium riparium	X	X	X	X		
Udotea flabellum	X	X	X			
Udotea occidentalis	X					
Ulothrix flaca		X				
Ulva lactuca			X			
PHAEOPHYTA						
Dictyota cervicornis						X
Dictyota dichotoma	X	X			X	
Ectocarpus rhodochortonoides		X				
Humia onusta		X				
Padina gymnospora			X			
Sargassum hystrix				X		
RHODOPHYTA						
Acantophora spicifera	X	X	X	X	X	

Table 1. Continued.

	Nichupté		Río Lagartos		Celestún	
	Dry	Rainy	Dry	Rainy	Dry	Rainy
Amphiroa fragilissima			X			
Anotrichium tenue	X	X				
Asparagopsis taxiformis	X	X				
Bostrychia calliptera	X		X			
Bostrychia montagnei	X		X			
Bostrychia moritziana			X			
Bostrychia pilulifera			X	X		
Bostrychia scorpioides	X		X	X		
Bostrychia tenella			X		X	X
Bostrychia radicans					X	X
Caloglossa leprieurii			X		X	X
Catenella caespitosa					X	X
Centroceras clavulatum	X	X	X		X	X
Ceramium brevizonatum var. caraibicum		X				
Ceramium flaccidum	X	X	X	X	X	
Ceramium codii		X				
Ceramium cruciatum			X			
Ceramium fastigiatum	X	X				
Ceramium leptozonum	X	X				
Ceramium leutzelburgii	X					
Champia parvula	X	X	X	X	X	
Chondria baileyana		X				
Chondria collinsiana	X	X				
Chondria dasyphylla			X			
Chondria littoralis	X	X				
Chondria polyrhiza	X					
Dasya rigidula		X				
Dasya ramosissima		X				
Digenea simplex	X	X				
Erytrocladia subintegra		X				
Erytrotrichia carnea	X	X				
Herposiphonia pecte-veneris	X	X				
Herposiphonia pecte-veneris var. laxa		X				
Herposiphonia secunda	X	X	X	X		
Herposiphonia secunda f.tenella				X		
Heterosiphonia gibbesii	X					
Heterosiphonia crispella var. laxa	X					
Hypnea spinella	X	X	X	X	X	
Jania adhaerens	X	X				
Jania pumila				X		
Laurencia sp.		X	X			X
Laurencia chondrioides	X					
Laurencia gemmifera	X	X				
Laurencia microcladia		X				
Laurencia papillosa	X	X	X	X		
Laurencia poiteaui				X		
Polysiphonia sp.		X	X		X	X
Polysiphonia atlantica	X	X	X			
Polysiphonia binneyi	X	X		X		
Polysiphonia eastwoodae	X	X	X			

Table 1. Continued.

	Nichupté		Río Lagartos		Celestún	
	Dry	Rainy	Dry	Rainy	Dry	Rainy
Polysiphonia exilis		X				
Polysiphonia ferulacea	X					
Polysiphonia setuarioides	X	X				
Polysiphonia fracta		X				
Polysiphonia gorgoniae	X	X				
Polysiphonia havanensis		X		X		
Polysiphonia howei		X				
Polysiphonia saccorhiza			X			
Polysiphonia sphaerocarpa	X	X	X			
Polysiphonia subtillissima		X	X	X		
Polysiphonia scopulorum var. *Villum*	X					
Spyridia filamentosa	X	X		X	X	
Stylonema alsidii	X	X				

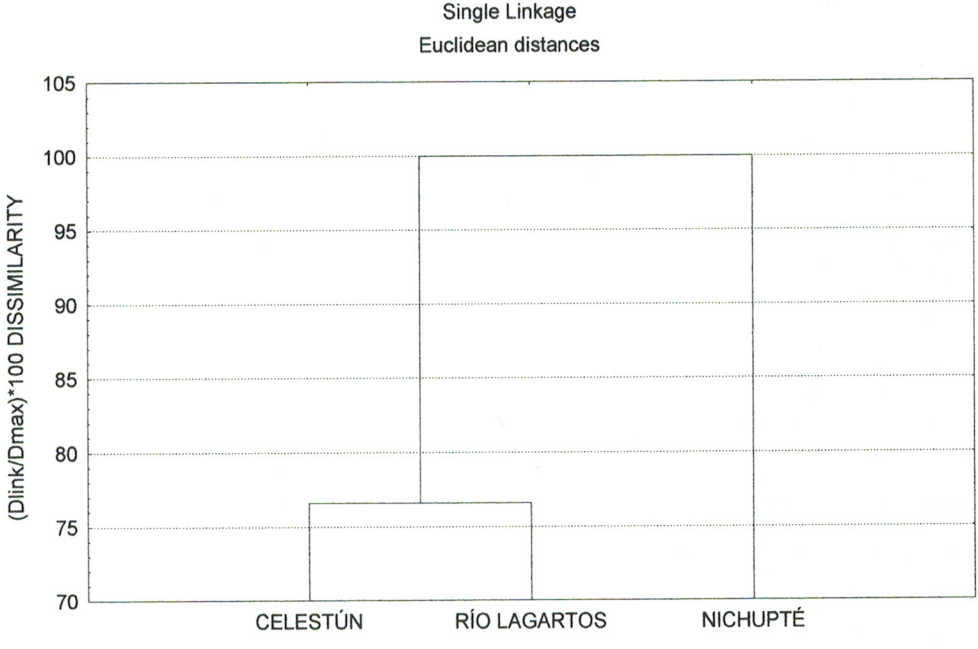

Fig. 2. Comparison of species between lagoons.

them; the mangrove and the bottom showed only a 7.5 % similarity and there was no similarity with the spring.

4.1 *Nichupté*

In the Nichupté lagoon system (Table 4), there were 61 species in the mangrove, of which 14 (23 %) were exclusive. In the bottom habitat, 68 species were found, 22 of

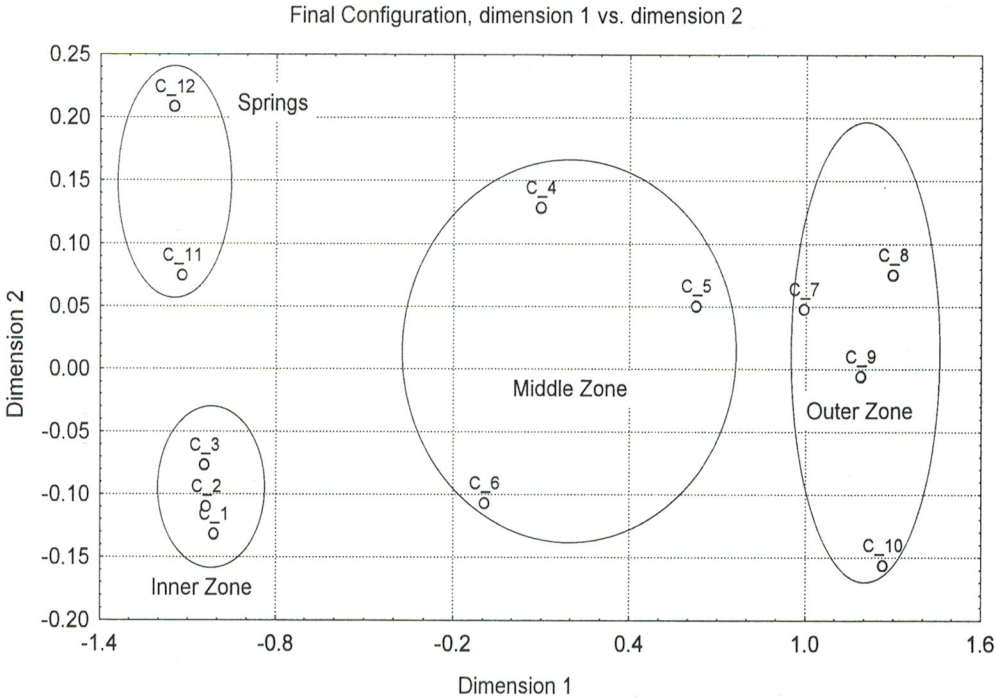

Fig. 3. Spatial division by environmental factors in Celestún lagoon.

Table 2. Distribution of environmental factors in zones and by season in Celestún lagoon. Trans denotes transparency; Temp, temperature; Sal, salinity.

Seasons	Dry					Rainy				
Zone/factors	Depth (m)	Trans (%)	Temp (°C)	pH	Sal (‰)	Depth (m)	Trans (%)	Temp (°C)	pH	Sal ‰
Inner zone	0.81	73	29.5	8.01	20.6	0.73	100	28	7.65	10.8
Middle zone	2.14	34	30.1	7.69	30.03	1.885	69.5	30	7.84	15.36
Outer zone	1.65	32.5	30.7	8.21	34.11	1.56	47.87	30	7.95	24
Spring 1	1.5	100	29	8.23	5.32	1.5	100	27.5	7.04	5.93
Spring 2	0.5	100	29	7.63	4.06	0.5	100	27	7.3	3.44

them exclusive (32 %). In the mangrove there were more species (36) in the dry season than in the rainy (32) while in the bottom there were more species during the rainy season (50) than during the dry (38) Microhabitats were not studied in this lagoon.

Some of the species exclusive to the mangrove were *Cladophora submarina, Ectocarpus rhodochortonoides, Hummia onusta, Bostrychia montagnei, Bostrychia*

Table 3. Distribution of environmental factors in zones and by season in Río Lagartos lagoon.

Season	Dry Season					Rainy Season				
Zones	**El Cuyo**	**Las Coloradas**	**Río Lagartos**	**Spring I**	**Spring II**	**El Cuyo**	**Las Coloradas**	**Río Lagartos**	**Spring I**	**Spring II**
Depth (m)	0.56	0.54	0.91	0.52	149	0.71	1.09	1.81	0.82	1.49
Temperature (°C)	31.5	31.3	29.3	28	26.3	27	27.7	30	26.7	26.3
Transparency (%)	52.1	100	97.5	100	100	43	69	86.5	48.5	100
Salinity ($^0/_{00}$)	112.8	64.2	34.3	6	6	63	51	37.5	8	6
pH	8.02	8.46	8.2	7.7	7.8	8.2	7.8	8.2	7.2	7.8

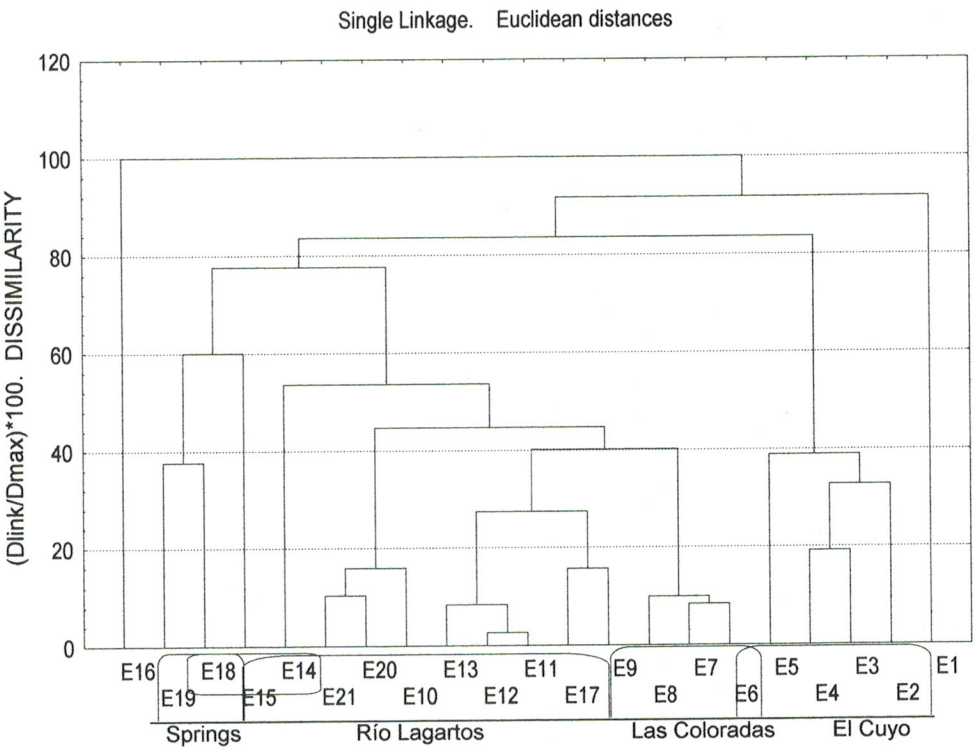

Fig. 4. Spatial division by environmental factors in Rio Lagartos lagoon.

scorpioides, Chondria polyrhiza, Dasya rigidula, Heterosiphonia crispella var. laxa, Polysiphonia exilis, Polysiphonia ferulacea, Polysiphonia fracta and *Polysiphonia scopulorum var. villum.* In the bottom habit exclusive species *Avrainvillea longicaulis, Caulerpa prolifera, Cladophora conferta, Halimeda incrassata, Halimeda simulans, Halimeda tuna, Laurencia chondrioides, Laurencia microcladia,Penicillus capitatus, Rhipocephalus phoenix, Udotea flabellum and Udotea occidentalis.*

4.2 *Río Lagartos*

In Río Lagartos 26 species were found in the mangrove habitat, 13 of them exclusive (50 %). In the bottom habitat, 25 species were found, 16 of them exclusive (64 %) and in the springs, nine species were found, five of them exclusive (55 %). In the mangrove there were more species (17) in the rainy season than in the dry (15) while on the bottom the dry season had more species (20) than the rainy (11) The number of species in the springs remained the same throughout the year.

The number of species increased from El Cuyo to the basin of Río Lagartos, both within the bottom and mangrove habitats. This is due to the high salinity in El Cuyo and Las Coloradas basins since according to Britton and Morton (1989) species number decreases from marine to hyperhaline zones.

Three microhabitats were found for the bottom (Table 5), one in the basin of El

Table 4. Distribution of species in habitats and according to environmental factors in Nichupté lagoon.

Factors		**Mangrove**		**Bottom**
Depth (m)	0.83-0.90	*Acetabularia crenulata*	0.83-0.94	*Acetabularia crenulata*
Temperature (°C)	28.3-29	*Anadyomene stellata*	28.4-29.8	*Anadyomene stellata*
PH	7.8-8.1	*Avranvillea nigricans*	6.9-7.7	*Avranvillea longicaulis*
Salinity (‰)	33.3-36	*Batophora oerstedi*	27.9-29.9	*Avranvillea nigricans*
Substrate	Mangrove root	*Boodleopsis pusilla*	Sand-lime	*Batophora oerstedi*
		Caulerpa sertularioides		*Boodleopsis pusilla*
		Caulerpa fastigiata		*Caulerpa fastigiata*
		Caulerpa verticillata		*Caulerpa prolifera*
		Cladophora conferta		*Caulerpa sertularioides*
		Cladophora crystallina		*Caulerpa verticillata*
		Cladophora montagneana		*Chaetomorpha linum*
		Cladophora submarina		*Cladophora conferta*
		Cladophora vagabunda		*Cladophora montagneana*
		Cladophora pellucicoidea		*Cladophora vagabunda*
		Cladophoropsis macromeres		*Cladophoropsis macromeres*
		Cladophoropsis membranacea		*Cladophoropsis membranacea*
		Penicillus lamourouxii		*Halimeda incrassata*
		Penicillus pyriformis		*Halimeda simulans*
		Rhizoclonium africanum		*Halimeda tuna*
		Rhizoclonium riparium		*Penicillus capitatus*
		Ulothrix flaca		*Penicillus lamourouxii*
		Dictyota dichotoma		*Rhipocephalus phoenix*
		Ectocarpus rhodochortonoides		*Rhizoclonium africanum*
		Hummia onusta		*Rhizoclonium crassipellitum*
		Acantophora spicifera		*Rhizoclonium riparium*
		Asparagopsis taxiformis		*Udotea flabellum*
		Anotrichium tenue		*Udotea occidentalis*
		Bostrychia montagnei		*Ulothrix flaca*
		Bostrychia scorpioides		*Dictyota dichotoma*
		Centroceras clavulatum		*Acantophora spicifera*
		Ceramium brevizonatum var. *caraibicum*		*Asparagopsis taxiformis*
		Ceramium flaccidum		*Anotrichium tenue*
		Ceramium fastigiatum		*Centroceras clavulatum*
		Ceramium leptozonum		*Ceramium brevizonatum* var. *caraibicum*
		Champia parvula		*Ceramium flaccidum*
		Chondria collinsiana		*Ceramium codii*
		Chondria polyrhiza		*Ceramium fastigiatum*
		Dasya rigidula		*Ceramium leptozonum*
		Digenea simplex		*Ceramium leutzelburgii*
		Erytrotrichia carnea		*Champia parvula*
		Herposiphonia secunda		*Chondria baileyana*
		Heterosiphonia crispella var. *laxa*		*Chondria collinsiana*
		Hypnea spinella		*Chondria littoralis*
		Jania adhaerens		*Dasya ramosissima*
		Laurencia gemmifera		*Digenea simplex*
		Laurencia papillosa		*Erytrocladia subintegra*
		Polysiphonia sp.		*Erytrotrichia carnea*
		Polysiphonia atlantica		*Herposiphonia pecten-veneris*
		Polysiphonia binneyii		*Herposiphonia pecten - veneris* var. *laxa*

Table 4. Continued.

Factors	**Mangrove**	**Bottom**
	Polysiphonia eastwoodae *Polysiphonia exilis* *Polysiphonia ferulacea* *Polysiphonia sertularioides* *Polysiphonia fracta* *Polysiphonia gorgoniae* *Polysiphonia havanensis* *Polysiphonia howei* *Polysiphonia subtillissima* *Polysiphonia scopulorum* var. *villum* *Spyridia filamentosa* *Stylonema alsidii*	*Herposiphonia secunda* *Heterosiphonia gibbesii* *Hypnea spinella* *Jania adhaerens* *Laurencia* sp. *Laurencia chondrioides* *Laurencia gemmifera* *Laurencia microcladia* *Laurencia papillosa* *Polysiphonia* sp. *Polysiphonia binneyii* *Polysiphonia eastwoodae* *Polysiphonia sertularioides* *Polysiphonia fracta* *Polysiphonia gorgoniae* *Polysiphonia sphaerocarpa* *Polysiphonia subtillissima* *Spyridia filamentosa* *Stylonema alsidii*

Cuyo (three species), one in the basin of Las Coloradas (six species) and one in the basin of Río Lagartos (16 species). *Halimeda incrassata, Ulva lactuca, Udotea flabellum, Herposiphonia secunda* f. *tenella* and *Laurencia poitei* were some of the species found exclusively in the bottom habitat.

Two microhabitats were found in the mangrove, one in the basin of El Cuyo (one species) and one in the basin of Río Lagartos (twenty-four species) (Table 6). The principal exclusive species in the mangrove habitat belonged to the genus *Bostrychia*.

In this lagoon there are two springs with similar environments except for the substratum and depth. Since their species compositions were different, each spring was considered to be a separate microhabitat (Table 7). The main exclusive species were *Enteromorpha chaetomorphoides, Enteromorpha flexuosa,* and *Enteromorpha lingulata.*

4.3 *Celestún*

In the Celestún lagoon 10 species were found in the mangrove habitat, one of them exclusive (10 %), while in the bottom habitat, 16 species were found, 10 of them exclusive (62.5 %). In the springs, nine species were found, one of them exclusive (11%). In the mangrove there were more species (9) in the dry season than in the rainy (7) but in the bottom habitat, the dry season had more species (14) than the rainy (8).

Three microhabitats were identified for the bottom and mangrove habitats of Celestún Lagoon (Tables 8 and 9), one of each in the inner, middle and outer zones. Some of the exclusive species in the bottom were *Chara fibrosa* and *Dictyota dichotoma* while exclusive species in the mangrove were *Catenella caespitosa* and *Bostrychia* sp. The only place we found *Caloglossa-Bostrychia* was in this lagoon in one zone even though Post (1936) describes this association as 'typical' for mangroves. In both habitats

Table 5. Characteristics and species found in the three bottom microhabitats in Río Lagartos lagoon.

	El Cuyo		Las Coloradas		Río Lagartos
Factors					
Depth (m)	0.56-0.71	*Batophora oerstedi*	0.54-1.09	*Batophora oerstedi*	0.91-1.81	*Batophora oerstedi*
Transparency (%)	43-52	*Cladophora* sp	69-100	*Acetabularia crenulata*	86-97.5	*Acetabularia crenulata*
Temperature (°C)	27-31	*Cladophoropsis membranacea*	27.7- 31.3	*Cladophoropsis membranacea*	27.7-29.3	*Cladophoropsis membranacea*
$_{P}H$	8.0-8.2		7.8-8.4	*Caulerpa prolifera*	8.2	*Caulerpa prolifera*
Salinity ($^{0}/_{00}$)	63-113		51-64	*Penicillus capitatus*	34-37	*Penicillus capitatus*
Substrate	Lime		Lime-clay	*Acantophora spicifera*	Clay-sand	*Udotea flabellum Halimeda incrassata*
						Ulva lactuca
						Rhizoclonium africanum
						Acantophora spicifera
						Champia parvula
						Herposiphonia secunda
						Herposiphonia secunda f.tenella
						Laurencia papillosa
						Laurencia poiteaui
						Spyridia filamentosa

Table 6a. Physical and chemical characteristics of two mangrove microhabitats in Río Lagartos lagoon.

	El Cuyo	**Río Lagartos**
Factors		
Depth (m)	0.71	0.91-1.81
Transparency (%)	43	86-97.5
Temperature (^{0}C)	27	27.7-29.3
pH	8.2	8.2
Salinity (‰)	63	34-37
Substrate	Mangrove root	Mangrove root

Table 6b. Algal species found in two mangrove microhabitats in Río Lagartos lagoon.

El Cuyo	Río Lagartos	
Cladophora crispata	*Batophora oerstedi*	*Polysiphonia subtilissima*
	Bostrychia tenella	*Caulerpa fastigiata*
	Bostrychia calliptera	*Cladophora* sp.
	Bostrychia montagnei	*Acetabularia crenulata*
	Bostrychia moritziana	*Jania pumila*
	Bostrychia pilulifera	*Hypnea spinella*
	Bostrychia scorpioides	*Laurencia papillosa*
	Polysiphonia binneyi	*Spyridia filamentosa*
	Polysiphonia havanensis	*Ceramium flaccidum*
	Polysiphonia eastwoodae	*Ceramium cruciatum*
	Polysiphonia saccorhiza	*Herposiphonia secunda*
	Polysiphonia sphaerocarpa	*Chaetomorpha linum*

Table 7. Characteristics of two spring microhabitats in Río Lagartos lagoon.

	Spring 1		Spring 2	
Factors				
Depth (m)	1.49	*Batophora oerstedi*	0.52	*Polysiphonia subtilissima*
Transparency (%)	100	*Enteromorpha flexuosa*	100	*Enteromorpha lingulata*
Temperature (^{o}C)	26.3-28.3	*Rhizoclonium africanum*	26-28.7	*Enteromorpha flexuosa*
pH	7.8-8.2	*Enteromorpha chaetomorphoides*	7.8-8.2	*Cladophoropsis membranacea*
Salinity (‰)	6-8	*Rhizoclonium riparium*	6-13	*Polysiphonia atlantica*
Substrate	Mangrove root		PVC	

specific richness was higher in the outer zone than in the inner, due to low salinity in the latter.

Species tend to increase in number from freshwater zones to marine in estuarine ecosystems (Remane and Schlieper, 1971; Barnes, 1974; Britton and Morton, 1989). The habitat with the highest richness was the bottom. The springs showed the same number of species for both seasons.

In this lagoon also there are two springs with similar environmental factors except for the substratum and depth. Since each had a different species composition,

Table 8a. Physical and chemical characteristics of three bottom microhabitats of Celestún lagoon.

	Inner	**Middle**	**Outer**
Factors			
Depth (m)	0.73-.81	1.8-2.1	1.6-1.8
Transparency (%)	73-100	34-70	32-47
Temperature (°C)	28-29	30-30.1	30.3-30.7
$_{p}$H	7.6-8.5	7.7-7.8	7.8-8.2
Salinity (‰)	10-20	15-30	24-34
Substrate	Lime	Lime-clay	Clay-sand

Table 8b. Algal species found in bottom microhabitats of Celestún lagoon.

Inner zone	Middle zone	Outer zone
Batophora oerstedi	*Batophora oerstedi*	*Chaomorpha linum*
Chara fibrosa	*Chaetomorpha linum*	*Enteromorpha prolifera*
Rhizoclonium crasipellitum	*Rhizoclonium crasipellitum*	*Rhizoclonium crasipe*
Rhizoclonium africanum	*Rhizoclonium africanum*	*Rhizoclonium africanum*
	Acantophora spicifera	*Acantophora spicifera*
	Ceramium flaccidum	*Ceramium flaccidum*
	Centroceras clavulatum	*Centroceras clavulatum*
	Spyridia filamentosa	*Champia parvula*
		Hypnea spinella
		Polysiphonia sp.
		Spyridia filamentosa
		Dictyota cervicornis
		Dictyota dichotoma

they were considered as a separate microhabitats (Table 10). The most abundant exclusive species was *Enteromorpha* flexuosa in spring 2.

5. Conclusions

Seventy seven percent of the total number of species was found in Nichupté, 44 % were in Río Lagartos and 18 % were found in Celestún.

Thirty one percent of species were shared among the three lagoons. There was a decrease in the number of species from the eastern to the western ends of the Peninsula, because Nichupté has a greater influence from the Caribbean Sea and does not have the stressful conditions that the other lagoons do. The floristic composition of the lagoons showed no similarities, because the different combinations of microfactors in each lagoon select for a different conjunction of species.

Rhodophyta were dominant over Chlorophyta and Phaeophyta in all three lagoons, because of the high number of epiphytic algae, especially in *Polysiphonia* and *Ceramium.*

In both mangrove and bottom habitats, Rhodophyta were dominant. In the springs, Chlorophyta were dominant because the species of the latter tend to tolerate both higher and lower salinities than do the Rhodophyta and Phaeophyta.

Table 9. Characteristics and species found in three mangrove in Celestún lagoon.

	Inner zone		Middle zone		Outer zone
Factors					
Depth (m)	0.73-0.81	*Batophora oerstedi*	1.8-2.1	*Batophora oerstedi*	1.6-1.8	*Bostrychia tenella*
Transparency (%)	73-100	*Polysiphonia* sp.	34-70	*Bostrychia tenella*	32-47	*Bostrychia radicans*
Temperature (°C)	28-29		30-30.1		30.3-30.7	*Catenella caespitosa*
$_{p}$H	7.6-8.5		7.7-7.8		7.8-8.2	*Caloglossa leprieurii*
Salinity (‰)	10-20		15-30		24-34	*Chaetomorpha linum*
Substrate	Mangrove root		Mangrove root		Mangrove root	*Enteromorpha prolifera*
						Rhizoclonium crasipellitum
						Rhizoclonium africanum

Table 10. Characteristics and species found in two spring microhabitats in Celestún lagoon.

	Spring 1		Spring 2	
Factors				
Depth (m)	1.5	*Chaetomorpha linum*	0.5	*Bostrychia radicans*
Transparency (%)	100	*Bostrychia tenella*	100	*Enteromorpha prolifera*
Temperature (°C)	27.5-29	*Rhizoclonium africanum*	27-29	*Enteromorpha flexuosa*
pH	7.04-8.2	*Rhizoclonium crasipellitum*	7.3-7.6	*Polysiphonia sp*
Salinity (‰)	5.3-5.9		3.4-4.0	*Caloglossa leprieurii*
Substrate	Mangrove root		Rocky	

The spatial and temporal distribution patterns in Celestún and Río Lagartos were affected mainly by salinity, the environmental factor with the highest variation between the zones. In Nichupté no spatial or temporal distribution pattern was found.

The total number of exclusive species was higher in Nichupté than in the other lagoons, but the total number of exclusive species per habitat was roughtly equal, approximately 32 %. In Río Lagartos the number of exclusive species was lower than in Nichupté but the total number of exclusive species per habitat was higher (69%) and as well, in Celestún the total number of exclusive species per habitat was also higher (41%).

Río Lagartos had the highest number of exclusive species per habitat. Environmental factors (especially salinity) in the other lagoons cause more stressful conditions so that habitats are more restrictive.

The presence of an algal association is the result of a certain combination of specific ranges of factors that allows only them to be present. The presence or absence and permanence of each algal species in different time and space will depend on its adaptive capacity to the general and specific environmental factors.

6. Summary

The peninsula of Yucatan is located in southeastern México on the Gulf of México. Although coastal lagoons have been the subject of many studies due to their economic potential, they have received little attention from the phycological point of view.

In this paper the macroalgal communities of three lagoons of the Yucatán Peninsula (Celestún (estuarine), Río Lagartos (hyperhaline) and Nichupté (marine) are studied comparatively which regard to species composition, distribution in the different habitats and the correlation with environmental gradients.

Samples collected by Collado-Vides (Collado-Vides, 1992) in Nichupté were compared with those collected by Ortegón-Aznar in Celestún and Río Lagartos (Ortegón-Aznar, 1993, 1997). All samplings were done during both the dry and rainy seasons.

Three different habitats were sampled: bottom, mangrove and springs; two samples were collected per station. In all the sampling stations environmental factors were recorded.

The total of species found in this study was 110. Nichupté is the locality with most species (85) followed by Río Lagartos (48) and Celestún (20). Three different habitats were found, mangrove (75 species, 27 of them exclusive), bottom (78 species, 33 of them exclusive) and springs (14 species, three of them exclusive). No floristic composition was specific to any habitat; there were exclusive species present in a particular habitat when conditions allowed. Generalizations about typical floras should be in terms of associations of macroalgae related to general or specific environmental factors, because communities of macroalgae change with environmental factors.

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