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Marine algae from the Gulf of Santa Clara, Sonora, México

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Abstract

Four sites in the Gulf of Santa Clara, northwestern coast of Sonora, Mexico, were sampled seasonally during 1995–1996. A total of 43 species of marine algae were determined, which are recorded for the first time for the area of study. The families with best representation are: Gracilariaceae and Cladophoraceae, each with 5 species; and Corallinaceae, Rhodomelaceae, and Ulvaceae, each with 3. The highest diversity was found in autumn, the lowest in summer. The sites with the low diversity were Piedras del Burro with 7 species and El Tornillal with 18. These places are broad beaches, composed of sand and with few pebbles. The higher diversity was found at Punta Gorda with 34 species and Piedras de La Salina with 26. These localities are characterized by relatively stable rocky substrates, with some intertidal pools. The most common species regardless to distribution and occurrence over time were: *Spyridia filamentosa, Dictyota flabellata, Struveopsis robusta, Cladophora microcladioides* and *Enteromorpha linza*. *Rosenvingea antillarum* and *Cladophora vagabunda* represent new records for the Gulf of California. Nine epiphytic species were identified, which were frequently observed on *Gelidium crinale*, *Spyridia filamentosa* and *Dictyota flabellata*.

Introduction

The northern Gulf of California, including the northeast coast of Baja California and northern coast of Sonora, has few published records of marine algae (Pacheco-Ruíz & Zertuche-González, 1996a,b; Aguilar-Rosas et al., 2000). Our study area, the Gulf of Santa Clara, is a fishing village located in the northern part of Sonora and is part of the Biosphere Reserve of the upper Gulf of California and River Delta created in 1993 by the National Institute of Ecology (INE), a division within the Secretariat of Environment, Natural Resources, and Fisheries (SEMARNAP), in which the reduction in river discharge has caused dramatic increases in salinity and changes in the distribution of nutrients (Alvarez-Borrego et al., 1975, Hernandez-Ayon et al., 1993), and no seasonal floristic studies on algae have been done.

Literature reviews of Norris (1975, 1976) and Espinoza-Avalos (1993) for the Gulf of California, included research on floristic and distribution studies as well as taxonomy. The contributions of Setchell & Gardner (1924), and those of Dawson between 1944 and 1966 stand out. Studies not included in these reviews, but deserving mention, are those by Hollenberg & Norris (1977), Stewart & Norris (1981), Littler & Littler (1981), Mendoza-González & Mateo-Cid (1986), Riosmena-Rodríguez & Siqueiros-Beltrones (1995), Pacheco-Ruíz & Zertuche-González (*op. cit*), and Aguilar-Rosas et al. (*op. cit*.)

Daniel T. MacDougal, who visited the Bay of San Felipe, Baja California in February of 1904, made the first collection of marine algae (*Cladophora*) from northern Gulf of California (Howe, 1911), and the earliest specimens of marine algae (*Sargassum* and *Codium*) collected on the coast of Sonora was

made also by MacDougal, in 1923 in Puerto Libertad (Dawson, 1966). Other papers in the adjacent areas showed that seasonal sampling could be increased the number of records of marine algae (Wynne & Norris, 1976; Littler & Littler, *op. cit*; Aguilar-Rosas, *op. cit*). Therefore, we planned our project to include collecting during all seasons.

The northern region of the Gulf of California is characterized by extreme variations in sea-surface temperature, 15 °C in winter and approximately 29 °C in summer (Alvarez-Borrego 1983) and by a broad intertidal zone which shows a great diversity of environments such as rocky zones, sandy pools and beaches, allowing the development of a distinctive marine flora (Norris, 1975).

In this study, we examined the occurrence and seasonal distribution of marine algae in the Gulf of Santa Clara, Sonora, northern Gulf of California. A list of species from the area is also presented.

Materials and methods

The Gulf of Santa Clara is located on the northwest coast of the state of Sonora (northern Gulf of California) between 31° 37′ 28″ N, 114° 23′ 18″ W (Piedras del Burro) and 31° 29′ 43″ N, 114° 09′ 16″ W (Piedras de La Salina). Marine algae were collected from 4 sites in the intertidal zone (Fig. 1) which show the following characteristics:

- Piedras del Burro: (31° 37′ 28″ N, 114° 23′ 18″ W). This site comprises a sandy beach with few intertidal rocks and pebble aggregates.
- El Tornillal: (31° 33′ 18″ N, 114° 17′ 34″ W). At this site, a sandy beach predominates with pebbles of limestone and clay dispersed in the upper part of the intertidal zone.
- Punta Gorda: (31° 30′ 32″ N, 114° 11′ 59″ W). This site is a sandy beach, with limestone and clay dispersed in the middle and upper part of the intertidal zone. During low tide, some pools are present.
- Piedras de La Salina: (31° 29′ 43″ N, 114° 09′ 16″ W). This is a sandy beach with rocky areas in middle and lower part of the intertidal zone. During low tide, small and large pools are exposed.

In general, all the sites of the study area comprise broad sandy beaches, with deposits of limestone-clay, and with a few rocky zones formed mainly of pebbles. The slope is gradual, exposing a broad intertidal zone. The two high-diversity sites have more stable substrates such as pebbles of various sizes, terraces, and more intertidal pools.

Sixteen collections were made in February and October of 1995 and May and July of 1996. Algae were preserved according to the techniques established by Abbott & Dawson (1978). Phycological material was analyzed and species were determined using Setchell & Gardner (1924), Dawson (1944, 1949a,b, 1950, 1953, 1954, 1960a,b, 1961, 1963, 1966), Taylor (1945), Hollenberg & Dawson (1961), Hollenberg & Norris (1977), Abbott & Hollenberg (1976), and Norris & Johansen (1981).

The classification adopted was the one from Silva et al. (1996). A reference collection was placed at the Faculty of Marine Sciences (Facultad de Ciencias Marinas) herbarium (CMMEX) from the Autonomous University of Baja California (Universidad Autónoma de Baja California) in Ensenada and at the National School of Biological Sciences (Escuela Nacional de Ciencias Biológicas) herbarium (ENCB) from the National Polytechnic Institute (Instituto Politécnico Nacional).

Results and discussion

Floristic

Forty three species were determined, where 3 are Cyanophyceae, 24 belong to the class Rhodophyceae, 7 to the Phaeophyceae and 9 to the Chlorophyceae. The best represented families were: Gracilariaceae and Cladophoraceae, each one with 5 sp, besides Corallinaceae, Rhodomelaceae and Ulvaceae, each one with 3. All these are new records for the Gulf of Santa Clara, Sonora. The Gulf of California has been divided into three sections on base to oceanographic and climatic differences (Roden & Groves, 1959) (Fig. 1). Most of the plants that we found (>90%) correspond to the typical flora of the north and central sections.

This study reports two new records for the northern Gulf of California: *Rosenvingea antillarum*, previously reported at Santa María del Mar on the Pacific coast of Oaxaca (Mateo-Cid & Mendoza-González, 1997) and *Cladophora vagabunda*, previously reported at Playa Guayabitos and Las Peñas on the Pacific coast of Nayarit (Mateo Cid & Mendoza González, 1992), Lag. Juluapan in Colima (Mateo Cid & Mendoza González, 1991) and Playa del Almacén in Guerrero (Chávez, 1972, as *C. expansa*).

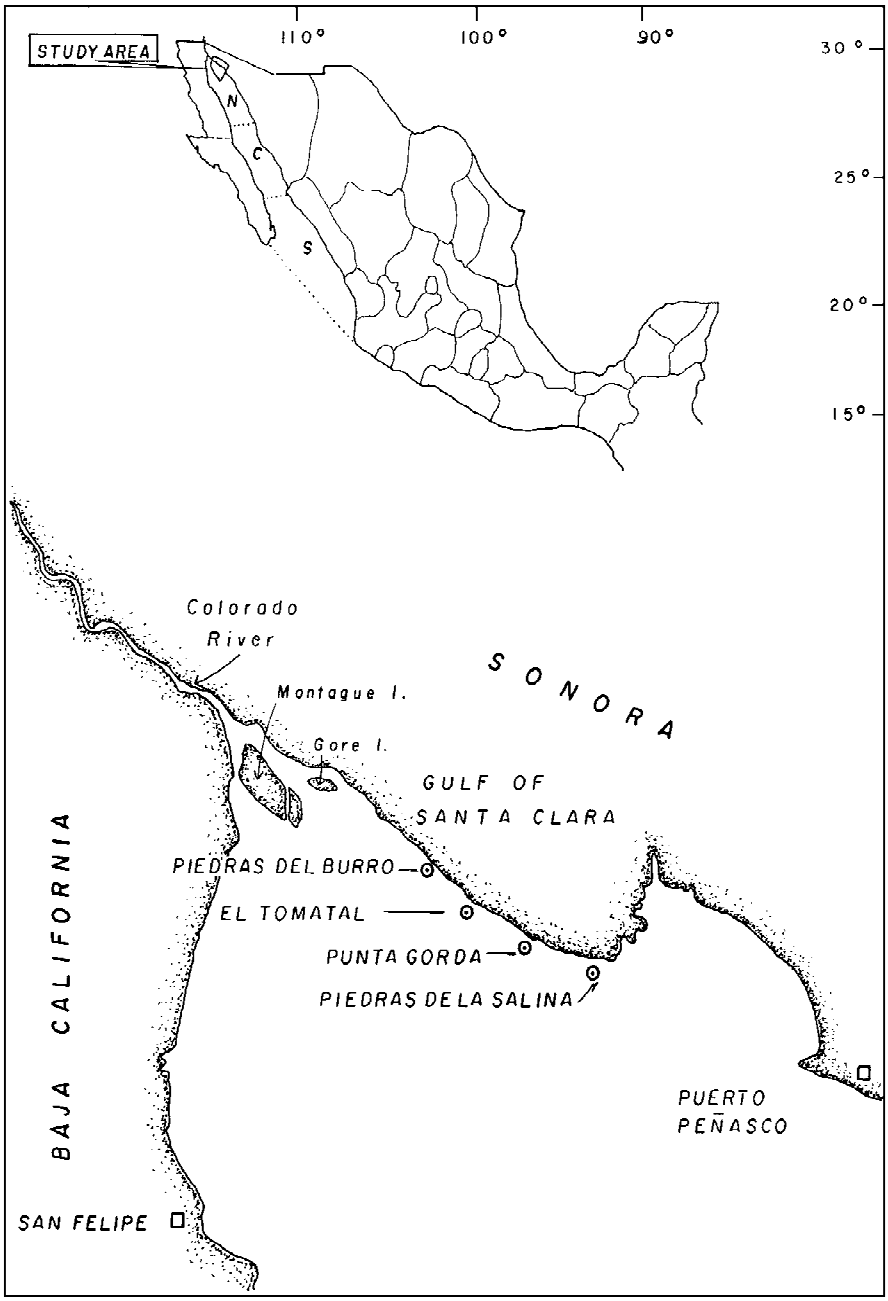

Figure 1. Location of the study area and sampling sites. Sections of the Gulf of California established by Roden & Groves (1959), North (N), central (C), and south (S).

Our collection of 43 species of marine algae have revealed low diversity when compared to other areas of the northern Gulf of California, like San Felipe with 153 species (Aguilar Rosas el al., 2000) and Puerto Peñasco with 153 (Dawson, 1966). This is remarkable since these areas have a short coastal area with a wide variety of algal environments that provide a richer and more varied flora. We observed in the study area, that the majority of specimens were poorly represented, in some cases by small size of mature plants, young thalli or scarce in occurrence.

Table 1. Marine algae from Gulf of Santa Clara, northwest coast of Sonora, México

	Las Piedras del Burro				El Tornillal				Punta Gorda				Piedras de La Salina			
	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au
CYANOPHYCEAE																
Scytonemataceae																
Scytonema hofman-bangii C. Agardh	x		x		x		x									
Oscillatoriaceae																
Blennothrix lyngbyacea (Kützing) Anagnostidis & Komárek						x										
Pseudanabaenaceae																
Pseudanabaena catenata Lauterborn		x														
RHODOPHYCEAE																
Porphyridiaceae																
Stylonema alsidii (Zanardini) K. Drew								x	x	x		x				
Erythrotrichiaceae																
Erythrotrichia carnea (Dillwyn) J. Agardh										x				x		
Acrochaetiaceae																
Acrochaetium microscopicum (Nägeli ex Kützing) Nägeli				x												
Acrochaetium pacificum Kylin									x	x				mn		
Gelidiaceae																
Gelidium crinale (Turner) Gaillon										te			te	te		x
Gelidium pusillum (Stackhouse) Le Jolis										x				x		x
Gracilariaceae																
Gracilaria crispata Setchell & Gardner										ci						
Gracilaria pachydermatica Setchell & Gardner										ci						
Gracilaria subsecundata Setchell & Gardner				ci				ci		x		ci		x		ci
Gracilaria turgida Dawson										ci				ci		
Gracilariopsis lemaneiformis (Bory de Saint -Vincent) Dawson, Acleto et Foldvik					x			ci								te
Corallinaceae																
Amphiroa beauvoisii *Lamourox*																x
Hydrolithon farinosum (Lamourox) Penrose & Chamberlain												x				
Jania tenella (Kützing) Grunow									x							
Gigartinaceae																
Chondracanthus pectinatus (Dawson) L. Aguilar & R. Aguilar										x				x		
Hypneaceae																
Hypnea spinella (C. Agardh) Kützing				x				x		x		x				
Champiaceae																
Champia parvula (C. Agardh) Harvey								x				x				x

Continued on p. 235

Table 1. Continued

	Las Piedras del Burro				El Tornillal				Punta Gorda				Piedras de La Salina			
	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au
Ceramiaceae																
Antithamnionella elegans (Berthold) J. Price & John												x				
Ceramium caudatum Setchell & Gardner												te				
Spyridia filamentosa (Wulfen) Harvey								x	x	x		x		x	x	x
Dasyaceae																
Dasya sinicola (Setchell & Gardner) Dawson												x				
Rhodomelaceae																
Chondria dasyphylla (Woodward) C. Agardh										x						
Polysiphonia sertularioides (Grateloup) J. Agardh									te	te		x				
Polysiphonia paniculata Montagne									x			ci				
PHAEOPHYCEAE																
Ectocarpaceae																
Ectocarpus siliculosus (Dillwyn) Lyngbye					pl			pl	pl	pl		pl				
Sphacelariaceae																
Sphacelaria rigidula Kützing								pp								pp
Dictyotaceae																
Dictyota flabellata (Collins) Setchell & Gardner					x			x		x		x		x	x	x
Padina durvillei Bory de Saint-Vincent							x			x						
Scytosiphonaceae																
Rosenvingea antillarum (P. Crouan & H. Crouan) M. J. Wynne								x				x				
Sargassaceae																
Sargassum johnstonii Setchell & Gardner					x			x	x				gf			
Sargassum sinicola Setchell & Gardner													gf			
CHLOROPHYCEAE																
Ulvaceae																
Enteromorpha compressa (Linnaeus) Nees	x				x				x				x			
Enteromorpha flexuosa (Wulfen) J. Agardh								x				x	x			x
Enteromorpha linza (Linnaeus) J. Agardh	x			x	x			x				x	x			
Cladophoraceae																
Chaetomotpha linum (Müller) Kützing																x
Cladophora hesperia Setchell & Gardner													x			
Cladophora microcladioides Collins									x	x				x		x
Cladophora prolifera (Roth) Kützing								x		x			x			
Cladophora vagabunda (Linnaeus) Van den Hoek										x				x		
Siphonocladaceae																
Struveopsis robusta (Setchell & Gardner) Rhyne & H. Robinson									x		x	x		x		x

Reproduction:
Green algae
Brown algae
x – Vegetative
pp – Propagula
pl – Plurangia
gf – Gametangia (female)
Red algae
x – Vegetative
te – Tetrasporangia
ci – Cystocarps
mn – Monosporangia
Season:
Au – Autumn
Wi – Winter
Sp – Spring
Su – Summer

Table 2. Seasonal occurrence of marine algae in the Gulf of Santa Clara, Sonora, México

Winter	Spring	Summer	Autumn
Scytonema hofman-bangii	*Blennothrix lyngbyacea*[a]	*Scytonema hofman-bangii*	*Stylonema alsidii*
Stylonema alsidii	*Pseudanabaena catenata*[a]	*Spyridia filamentosa*	*Acrochaetium microscopicum*
Acrochaetium pacificum	*Stylonema alsidii*	*Dictyota flabellata*	*Gelidium crinale*
Gelidium crinale	*Erythrotrichia carnea*[a]	*Padina durvillei*	*Gelidium pusillum*
Gracilariopsis lemaneiformis	*Acrochaetium pacificum*	*Struveopsis robusta*	*Gracilaria subsecundata*
Jania tenella var. *tenella*	*Gelidium crinale*		*Gracilariopsis lemaneiformis*
Spyridia filamentosa	*Gelidium pusillum*		*Amphiroa beavoisii*[a]
Polysiphonia sertularioides	*Gracilaria crispata*		*Hydrolithon farinosum*[a]
Polysiphonia paniculata	*Gracilaria pachydermatica*[a]		*Hypnea spinella*
Ectocarpus siliculosus	*Gracilaria subsecundata*		*Champia parvula*[a]
Dictyota flabellata	*Gracilaria turgida*[a]		*Ceramium caudatum*
Sargassum johnstonii	*Chondracanthus pectinatus*[a]		*Spyridia filamentosa*
Sargassum sinicola	*Hypnea spinella*		*Dasya sinicola*[a]
Enteromorpha compressa[a]	*Antithamnionella elegans*[a]		*Polysiphonia sertularioides*
Enteromorpha flexuosa	*Spyridia filamentosa*		*Polysiphonia paniculata*
Enteromorpha linza	*Chondria dasyphylla*[a]		*Ectocarpus siliculosus*
Cladophora hesperia	*Polysiphonia sertularioides*		*Sphacelaria rigidula*
Cladophora microcladioides	*Ectocarpus siliculosus*		*Dictyota flabellata*
Cladophora prolifera	*Dictyota flabellata*		*Rosenvingea antillarum*
Struveopsis robusta	*Padina durvillaei*		*Sargassum johnstonii*
	Cladophora microcladioides		*Enteromorpha flexuosa*
	Cladophora prolifera		*Enteromorpha linza*
	Cladophora vagabunda[a]		*Chaetomotpha linum*[a]
	Struveopsis robusta		*Cladophora microcladioides*
			Cladophora prolifera
			Struveopsis robusta

[a]Occurrence in one season.

Seasonality

Despite the fact that seasonal samplings were carried out, we consider this report to be a fairly complete list of marine algae for the Gulf of Santa Clara (Table 1). Additional species are likely to be found with further sampling. Previous works in adjacent areas (Wynne & Norris, 1976; Aguilar-Rosas et al., 2000) indicate the same conclusion. The climatic conditions of the Gulf of California, such as the large variation of temperature from 15 °C in winter to approximately 29 °C in summer (Alvarez-Borrego, 1983), are reflected in seasonal changes in the occurrence of algal species (Pacheco-Ruíz & Zertuche-González, 1996a,b; Aguilar-Rosas, *op. cit*).

More species were found during autumn (26) and spring (24), with lower numbers during summer (5) and winter (20) (Table 2). Most of the plants disappeared in summer and others were severely damaged. It is assumed that this pattern is caused by the extreme heat of summer, with water temperature near 29 °C. Several species were found to occur in only one season, especially spring or autumn (Table 2). This pattern of seasonality corresponds to that previously shown for the northern Gulf of California, characterized by a great variety of opportunistic organisms in a specific season or seasons (Littler & Littler, 1981, 1984).

Species diversity

The inverse correlation between temperature and species diversity has been considered a common pattern for the Gulf of California (Norris, 1975; McCourt, 1984; Huerta-Múzquiz & Mendoza-González, 1985; Mateo-Cid et al., 1993). Spring annuals are known in several places (Huerta-Múzquiz & Mendoza-González, 1985; Pacheco-Ruiz et al., 1992; Aguilar-Rosas et al., 2000).

At Punta Gorda and Piedras de La Salina, diversity reached 32 and 25 species, respectively. These sites are characterized by sandy beaches with relat-

Table 3. Epiphytic species and their hosts from Gulf of Santa Clara, northwest coast of Sonora, México

Ephiphyte	Hosts
RHODOPHYCEAE	
Stylonema alsidii	*Cladophora microcladioides, Chaetomorpha linum, Gelidium crinale*
Erythrotrichia carnea	*Gelidium crinale*
Acrochaetium microscopicum	*Gracilaria subsecundata*
Acrochaetium pacificum	*Gelidium crinale*
Antithamnionella elegans	*Dictyota flabellata*
Ceramium caudatum	*Padina durvillei*
Polysiphonia sertularioides	*Spyridia filamentosa*
PHAEOPHYCEAE	
Ectocarpus siliculosus	*Spyridia filamentosa, Rosenvingea antillarum, Dictyota flabellata*
Sphacelaria rigidula	*Sargassum johnstonii, Hypnea spinella*

ively stable substrata, including pebbles and intertidal pools, where more species could be found. A lower diversity was observed at Piedras del Burro (7 species) and El Tornillal (18 species), where sandy beaches are also broad but there are fewer rocky areas and even fewer pebble zones. Marine algae habitats in the Peninsula of Baja California and the Gulf of California are mainly related to rocky substrate. In the study area, the availability of stable substrate was crucial for the development of marine algae species since the process of sediment transport produce an instability on the substrate of the platform adjacent to the Colorado River delta, known as the Upper Gulf of California, including Sonora and Baja California (Carriquiry & Sánchez, 1999).

Epiphytism

In the study area, nine epiphytic species were identified, 7 are Rhodophyceae, and two Phaeophyceae (Table 3). They were frequently observed on *Gelidium crinale*, *Spyridia filamentosa* and *Dictyota flabellata.* Due to the instability of the substrate in the study area, characterized mainly by broad sandy beaches with few rocky areas, a semidiurnal tidal regimen and strong tidal currents (Carriquiry & Sánchez, 1999), epiphytism could be considered to be an important ecological strategy to find a 'substrate'. The high epiphytism has been observed in the Gulf of California regarding principally to filamentous algae (Mateo Cid et al., 2000; Aguilar-Rosas et al., 2000).

Reproduction

At all sites we found reproductive specimens, although the majority were vegetative (Table I). The relative number of reproductive or vegetative plants and the dominance of a particular reproductive phase vary according to the salinity, substrate, and ability of spores to survive (Nelson, 1989). In Rhodophyceae, we observed monosporic, tetrasporic, and cystocarpic plants. In the Phaeophyceae, we observed plurilocular structures only in *Ectocarpus siliculosus* and *Sphacelaria rigidula*, and in winter, some fertile plants of *Sargassum* (*S. johnstonii* and *S. sinicola*). All specimens of Chlorophyceae were vegetative, possibly because they were immature or to the fact that reproductive structures are not conspicuous. Another explanation could be that reproductive structures have a very short period of life (Santelices, 1977; Littler et al., 1983).

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