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Macroalgae blooms, composition, abundance, and their relationship with environmental variables at a subtropical bay of the Gulf of California

Composición y abundancia de florecimientos macroalgales y su relación con variables ambientales en una bahía subtropical en el Golfo de California

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ABSTRACT

Background: In La Paz Bay macroalgae blooms have an important presence. **Goal:** Analyze the relationship of the most abundant macroalgae in algal blooms with environmental variability in a subtropical bay over two years. **Methods:** Temperature, salinity, nutrients (DIN, NT, PO_4^{-3} and PT) and macroalgae samples were taken every three months, during 2010 and 2011, at four sites with conspicuous growth of macroalgae. Total and mean biomass (wet weight) of important species was estimated by placing three transects perpendicular to the coast, divided into five equidistant points each. At each point four quadrants (0.25 m^2) were placed randomly and macroalgae were manually collected. Statistical analyzes were performed to estimate significant differences between years, months and sites of the environmental variables, nutrients, and biomass. A principal component analysis was performed, to observe the relationship between biomass and environmental variables and nutrients. **Results:** Nine macroalgae species, plus one cyanoprokaryonte showed a biomass greater than 1 g m^{-2}. *Acanthophora spicifera*, *Caulerpa verticillata* and *Spyridia filamentosa* were the most abundant species. *A. spicifera* and *G. vermiculophylla* were related with nutrient concentrations, and salinity. While *Ulva ohnoi* showed that it was not related either to environmental or nutrient concentrations. **Conclusion:** The bloom forming macroalgae *A. spicifera*, *C. verticillata* and *S. filamentosa* are consistent with genera previously reported as bloom-formers in nutrient-rich coastal waters.

Key words: biomass, environmental variability, La Paz Bay, seaweed blooms.

RESUMEN

Antecedentes: En la Bahía de La Paz los florecimientos de macroalgas tienen una presencia importante. **Objetivo:** Analizar la relación de las macroalgas más abundantes en los florecimientos algales, con la variabilidad ambiental en una bahía costera a lo largo de dos años. **Métodos:** Se tomaron muestras de temperatura, salinidad, nutrientes (DIN, NT, PO_4^{-3} y PT) y macroalgas cada tres meses, durante 2010 y 2011, en cuatro sitios con crecimiento notorio de macroalgas. La biomasa total y media (peso húmedo) de las especies abundantes se estimó colocando tres transectos perpendiculares a la costa, divididos en cinco puntos equidistantes cada uno. En cada punto se colocaron aleatoriamente cuatro cuadrantes (0.25 m^2) y se recolectaron manualmente las macroalgas. Se realizaron análisis estadísticos para estimar diferencias significativas entre años, meses y sitios de las variables ambientales, nutrientes y biomasa. Se realizó un análisis de componentes principales, con el fin de observar la relación entre la biomasa y las variables ambientales. **Resultados:** Nueve especies de macroalgas, más un cianoprocarionte presentaron una biomasa mayor a 1 g m^{-2}. *Acanthophora spicifera*, *Caulerpa verticillata* y *Spyridia filamentosa* fueron las especies más abundantes. *A. spicifera* y *G. vermiculophylla* mostraron relación con las concentraciones de nutrientes y la salinidad. Mientras que, *Ulva ohnoi* no mostró relación con las concentraciones ambientales o de nutrientes. **Conclusión:** Las macroalgas que forman florecimientos *A. spicifera*, *C. verticillata* y *S. filamentosa* coinciden con los géneros previamente reportados como formadores de florecimientos en aguas costeras ricas en nutrientes.

Palabras clave: biomasa, florecimientos macroalgales, Bahía de La Paz, variabilidad ambiental

INTRODUCTION

Macroalgae constitute a key marine community. This group embraces more than 40,000 species around the world, displaying high variability in physiology, morphology, and phylogenetic origin, as well as several key conditioning environmental and biological variables (*e.g.,* Guiry, 2012; Hurd *et al.*, 2014). Communities vary strongly along the littoral zone and with latitude, as well as with seasonal and interannual variability (Gaspar *et al.*, 2017; Cruz-Motta *et al.*, 2020; Vélez-Rubio *et al.*, 2021).

In coastal marine ecosystems, abundance estimates of different taxa are commonly made at spatial scales ranging from small (a few or hundreds of meters) to mesoscale (a few to hundreds of kilometers). At smaller spatial scales, many studies have linked community structure with variation in environmental factors (*e.g.,* local oceanographic conditions, depth, sedimentation, pollutants) and species interactions (*e.g.,* Martins *et al.*, 2013; Sangil *et al.*, 2014, 2018).

Changes in the macroalgae community can be derived from changes in temperature, salinity, and light (Sangil *et al.,* 2018) and changes in nutrient concentrations (Piñón-Gimate *et al.*, 2012). Some green macroalgae such as *Ulva* and *Caulerpa* species, and red macroalgae such as *Gracilaria* spp. and *Acanthophora spicifera* (M. Vahl) Børgesen (Russell, 1992; McGlathery, 2001; Lapointe & Bedford, 2007), can grow inordinately in response to excessive anthropogenic derived nutrients (Valiela *et al.*, 1997; Morand & Merceron, 2005), especially when water temperature conditions are favorable to their growth. Higher nutrient loads benefit opportunistic benthic algae and drift algae; besides soft-tissue filamentous algae are capable of quick uptake of nutrients and subsequent rapid increase in biomass, which leads to their domination in eutrophic systems (Pedersen & Borum, 1997; Valiela *et al.*, 1997; Nelson *et al.*, 2008). This has resulted in the formation of macroalgae blooms and green-tide events which have been reported in many parts of the world including Europe, North America, South America, Japan, and Australia (Fletcher, 1996; Morand & Briand, 1996; Hiraoka *et al.*, 2004; Morand & Merceron, 2005; Merceron *et al.*, 2007). Typically, macroalgae blooms are characterized by choking off waterways in the immediate area of the bloom and subsequently local wind and tide drives senescent algae to the shore, that can change coastal marine habitats through eutrophication (Valiela *et al.*, 1997) and can cause economic losses to marine industries (*e.g.,* fisheries and tourism) (Nelson *et al.*, 2008; Liu *et al.*, 2013).

The Gulf of California (GC) is a semi-enclosed sea on the Pacific coast of Mexico and one of the most biologically diverse marine areas in the world. In La Paz Bay, South Baja California, changes were reported depending on site and seasons for example, *Sargassum* species and *Spyridia filamentosa* (Wulfen) Harvey were the most abundant species during spring, and one of the sites with the highest biomass was El Malecón during winter and Punta León during summer (Casas-Valdez *et al.*, 1997); while Cruz-Ayala *et al.* (1998) reported that species from the genus *Sargassum*, *Spyridia filamentosa*, *Caulerpa sertularioides* (S. G. Gmelin) M. Howe, *Padina durvillei* Bory, and *Hydroclathrus clathratus* (C. Agardh) M. Howe, were the most abundant species and in total represented 75% during an annual cycle. In a latter study in the same bay, high biomasses of *Ulva* species were found; in some areas and especially in the waterfront of La Paz City, the biomass of this taxon showed an important increased after a hurricane event, where the biomass collected in the beach ranged from 350 to 540 g m^{-2}. The peaks

in biomass were attributed to the runoff from rainfall which carried nutrient rich waters and to the increase of pebbles due to water motion after the hurricane (Aguila-Ramírez *et al.*, 2005).

In a recent study, changes in macroalgae biomass during a one-year period, in different sites of La Paz Bay, were presented along with the evaluation of the trophic state, that was mostly oligotrophic, while macroalgae biomass was reported below 200 g m^{-2} wet weight for the important species found (Antonio-Robles *et al.*, 2021). The aim of the present study was to identify the macroalgae species that contribute the most to the biomass of macroalgae blooms of La Paz Bay at different sites and to identify if their abundance was related to some physicochemical parameters in different sites of the bay with different characteristics in a two- year cycle.

MATERIALS AND METHODS

Study area

La Paz Bay is the largest water body in the eastern coast of the Baja California peninsula, in the Gulf of California, with an approximate surface of 1200 km^2. It is located at 24º06' and 24º47' N, 110º18' and 110º45' W. Its approximate dimensions are of 80 km long and 35 km wide, it is separated from the gulf by a narrow peninsula, projected to the north and the insular complex Espiritu-Santo-La Partida. Therefore, the connection with the gulf occurs trough two openings, la Boca Grande which is deep, located to the north, and the San Lorenzo Channel narrow and shallower, located east. The bay presents a bathymetric gradient with depths of 10 m to the south, to 450 m in the north portion, where the Cuenca Alfonso is located.

Ensenada de La Paz (24°06' - 24°11' N, 110°19' - 110°26' W), is the lagoon formed by the very large sand spit at the southern end of the La Paz Bay (Fig. 1). The inlet is 1.2 km wide, 4 km long and 7 m deep. At mean sea level, the surface area of the lagoon is approximately 45 km^2. The lagoon is shallower than the inlet; with depths from 2 to 6 m. The tide regimen is a mixed semidiurnal type (Obeso-Nieblas *et al.*, 1993).

The climate is arid dry (BWh), the annual evaporation (215 mm) exceeds annual precipitation (180 mm); the maximum rainfall in the bay occurs between July and October, associated with southeast winds, tropical storms, and hurricanes (Obeso-Nieblas *et al.*, 2008); but dominant winds come from the northwest from November to March. The annual average temperature is 24.6°C; the minimum average temperature is 14.8°C that occurs in winter and the maximum is 32.6°C in summer (INEGI, 2017).

In the bay, in a previous field trip (2009), all the shallow areas of the bay were visited, and four sampling locations were chosen considering excessive presence of some benthic macroalgae species near the shore that were then considered as one macroalgae bloom. Each site presented different characteristics (Fig. 1). Site Playa Conchalito (**Co**): this site is located south of the ensenada and of the other sites. It is in the vicinity of the city and at the time of the sampling period it had no influence from anthropogenic activities; however, a drain presumably for rainfall waters discharges directly at this site. The bottom sediment consists mainly of sand and some pebbles, also some rocks and shells that serve as substratum for macroalgae. Average depth for this site is 0.5 m. when there are dead tides. Site Plaza Vista Coral (**VC**): it is located at one side of the Marina Cortez, despite of being in proximity

of the marina at the time of the sampling period it had no influence directly from the restaurants or water activities at this site. The bottom is characterized by the presence of rocks as substratum and soft sediments that sometimes had bad odor. At this site we could also find seagrasses that serve as a substratum and anchoring for some of the *Ulva* species. Average depth for this site when the tides are dead is 1m. Site Casa del Marino (**CM**): this site is located at the north of the ensenada, adjacent to the tidal channel in front of the city of La Paz. It is protected and shallow and has a soft surge. Since this location has been affected by anthropogenic activities, the natural substratum has been modified and inorganic and organic material has been added. The sandy bottoms are covered in part by some boulders, shells, and coral remains. A rock breakwater was built to further moderate the surge. Average depth when dead tide is 1.5 m. Site Enfermeria (**En**): this site is located across the highway and the mangrove, its influenced by the bay waters, it is located near a crossroad, this beach is visited regularly by local people. This is a very shallow beach with sandy bottom with boulders. Average depth when dead tide is less than 0.5 m. These sites were sampled one time during two years at each of the following months: February, April, June and October of 2010 and February, April, July and October of 2011.

Environmental variables

At each site or macroalgae bloom, water samples were taken in the middle of the bloom and close to the edges during low and high tides. Temperature and salinity were determined in the field using a handheld multi-probe meter (YSI 556-Rickly Hydrological, YSI, Yellow Springs, USA) (ns4). Water samples (3 replicates) were frozen and taken back to the laboratory for further determination of nutrients: dissolved inorganic nitrogen (DIN), TN, DP, and total phosphorus (TP). Techniques used were those recommended by Strickland & Parsons (1972) and Grasshoff *et al.* (1983). Finally, the N:P ratio was obtained. Normality (Kolmogorov-Smirnov test) and variance homogeneity (Cochran's test) were tested. A MANOVA analysis model was used to determine significant differences in seawater temperature, salinity and nutrients using date and site as independent variables. Means comparisons were carried out using Tukey's test only when there was a significant effect of the interaction ($P<0.05$) (Zar, 1984).
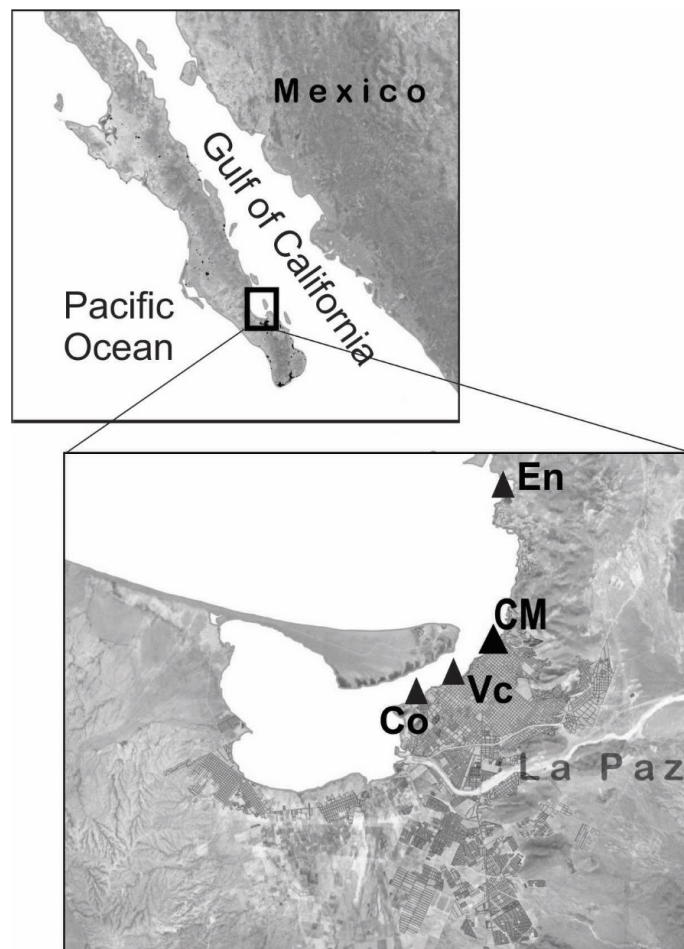

Figure 1. Study Area. Co=Conchalito, VC= Vista Coral, CM= Casa del Marino and En=Enfermería.

Macroalgae biomass

At each site or macroalgae bloom, to obtain macroalgae biomass, replicate transects were laid out perpendicular to the coast according to the area covered by the bloom, with one transect at each end and the other in the middle of the bloom. In total, there were three transects through each bloom in each season of the year. For each transect, five equidistant points were defined (since the area covered by the bloom was very extensive), with end points at the shoreline and at the far edge of the bloom. At each point, macroalgae were collected from four, non-overlapping, randomly placed quadrants (0.25 m^2) to estimate a square meter at each point. Samples were washed in the field with water from the lagoon and the species were separated by hand. Only species with biomasses >1 g m^{-2} were weighed with a digital balance (0.5 g). However, only species that contributed with more than 1% of the biomass were considered bloom forming and designated as "important" species, which were considered for analyses of species composition and temporal changes. A sample of each species was fixed with 4% formaldehyde-seawater solution for further determination at species level in the laboratory using as a reference work Setchell & Gardner (1924), Abott & Hollenberg (1976) and Chávez-Sánchez *et al.* (2019). Species names were revised in Guiry & Guiry (2022).

To describe the occurrence of "important" species during the surveys, total biomass was obtained as the sum of the biomass sampled. Relative abundance (*RA*) was obtained as the percentage of the biomass (*B*) contribution of each species (*j*) to the total biomass of the species sampled (*j =1* to *s*).

$$RA_j = \frac{B_j}{\sum_{j=1}^{s} B} x100$$

For each sampling trip, the mean biomass of each species (*MBj*) was calculated as the sum of the biomass per square meter (*b=1 to 15*) and divided by the total number of points sampled (*p = 15*) at each macroalgae bloom.

$$MB_j = \frac{\sum_{b=1}^{15} j}{p}$$

The mean biomass of each species at each site was expressed as g m^{-2} of wet weight (WW) and plotted monthly for each macroalgae bloom. For each month, biomass data was used to describe changes within and between macroalgae blooms.

The relationships between environmental parameters and "important" species biomass with the highest presence were analyzed by principal component analysis (PCA) (Sfriso & Marcomini, 1997). The significance criterion for each component was the eigenvalue (1). The greatest absolute values were selected from the correlation matrix. If there were two or more values in the same column, there was a correlation, if the signs were the same there was a direct relation, and if the signs were different there was an inverse correlation (Ballesteros-Grijalva *et al.*, 1996). All analyses were carried out using the program STATISTICA (StatSoft, 2004).

RESULTS

Environmental variables

Temperature showed significant differences during the sampling period with the lowest temperature at **Co** during February 2011 (17.5° C) and the highest at **En** during June 2011 (32.7° C), an annual pattern could be observed (Fig. 2a). Salinity showed little variation, but significant higher values (p < 0.05) were recorded during February (38.5 to 40.5) and April (38.5 to 40.0) at the four sites during 2011 (Fig. 2b).

Nutrient concentrations were variable along the study period, between years, months, and sites. For the DIN significant differences were found (p < 0.05), the highest DIN was recorded during 2011 at sites **VC** and **Co** during June, no clear seasonal pattern could be observed (4.2, 3.8 and 3.6 µM l^{-1}; respectively; Fig. 3a). Total nitrogen concentrations between years, months, and sites, were also variable but with no significant differences; however, the highest concentration was observed during 2010 at **VC** during February (52.4 µM l^{-1}, Fig. 3b). For the PO$_4$$^{-3}$ no clear seasonal patterns could be observed (Fig. 3c). The TP concentrations were variable but were very low, only during 2010 the highest concentration was observed at **En** in February (2.8 µM l^{-1}); however, no clear seasonal patterns could be observed (Fig. 3d).

Biomass

During the two-year sampling period 9 macroalgae species were identified as "important": 4 species belonging to the Phylum Rhodophyta, 5 species belonging to the Phylum Chlorophyta, plus one unidentified cyanoprokaryotic species (Table1). In general, during the study the highest biomass found corresponded to the red species *Acanthophora spicifera*, followed by the green *Caulerpa verticillata* J. Agardh and the red *Spyridia filamentosa* (Table 1).

Differences in species presence and biomass were found between years, months, and sites. At site **Co**, the contribution of the biomass was made by four out of ten "important" species. Depending on the year and month biomass, composition changes were observed for this site. The most abundant alga for this site was the cyanoprokaryotic species in October 2010 (131.8 g m^{-2}; Fig. 4). For site **VC**, nine out of ten "important" species were found. The species *A. spicifera* was the most important in 2010 and 2011, during June and October its biomass was higher than the rest of the species (Fig. 4). At **CM** we also found a high species composition (nine out of ten species) as well as the highest biomass. The species *A. spicifera* showed the highest biomass during the time the surveys lasted. During 2010 the highest biomass of *A. spicifera* was found during February and June (612.18 and 565.59 g m^{-2}, respectively), while during 2011 the highest biomass was found during April (350.52 g m^{-2}; Fig. 4). *Caulerpa verticillata* was found only at this site, its biomass was higher during June 2011 (266.17 g m^{-2}; Fig. 4). At **En** only four species and the cyanoprokaryote were found. The species *S. filamentosa* was the most important during both years, its highest biomass was found during June 2010 and October 2011 (139.9 and 187.32 g m^{-2}; Fig. 4).

Biomass and environmental variables

Principal Component Analysis could only be performed with "important" species but that were also present during several months and sites. The eigenvalues showed that components 1 and 2 were the ones that could explain the correlations found (2.98 and 1, respectively). Component 1 explained 49.77%, while component 2 explained 30.11%. In component 1 it was observed that the biomass of *A. spicifera* and *G. vermiculophylla* was related with the DIN and PO$_4$$^{-3}$, and salinity. While in the component 2 *G. vermiculophylla* and *Caulerpa sertularioides* were related to TN and TP concentrations. The biomass of *Ulva ohnoi* M. Hiraoka & S. Shimada was not related to nutrient concentrations or any of the other parameters (Table 2).
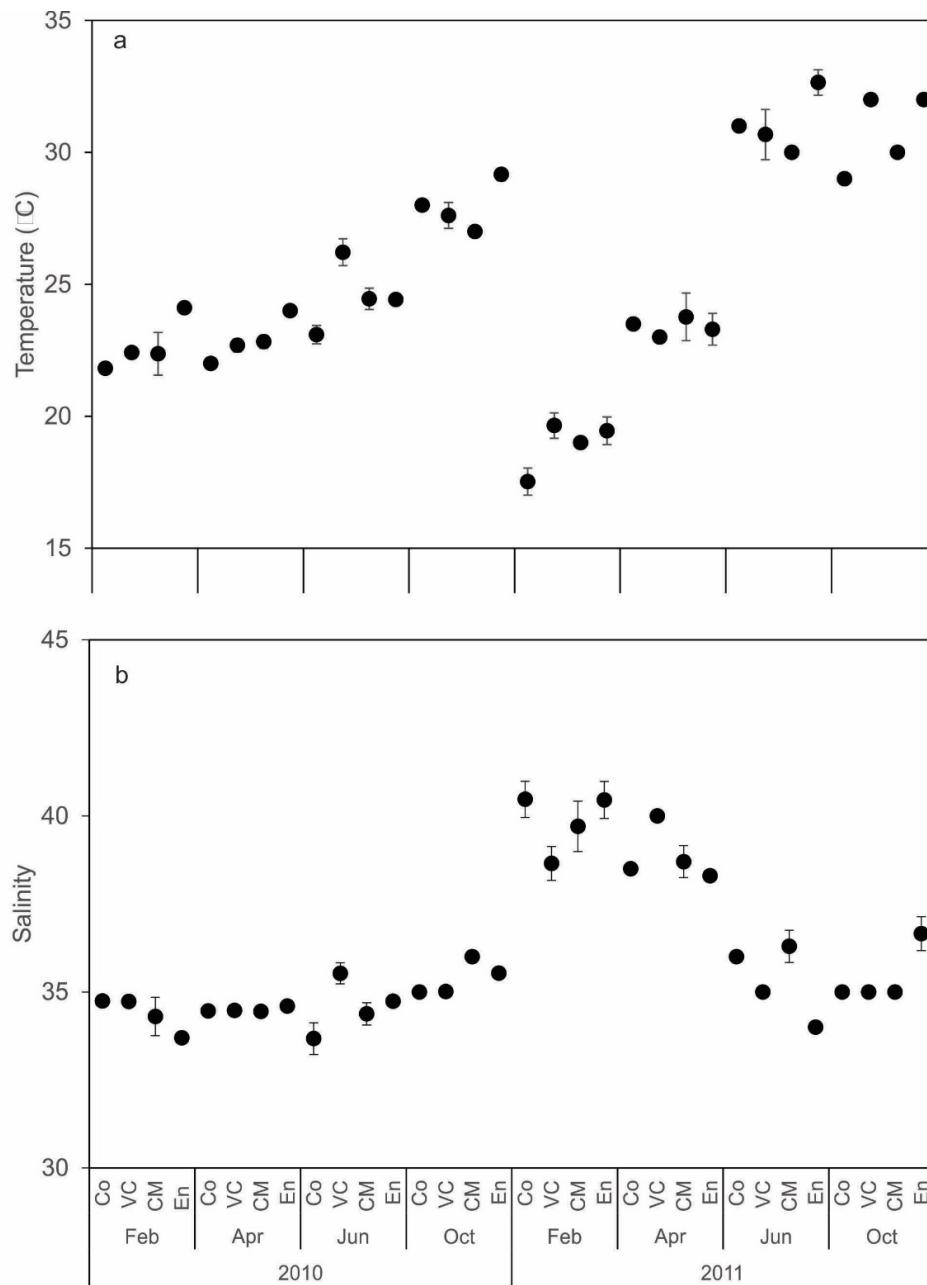
Figure 2. Environmental parameters: a) Mean temperature (±SD), b) mean salinity (±SD), by year, month, and site. Co=Conchalito, VC= Vista Coral, CM= Casa del Marino and En=Enfermería.

DISCUSSION

In La Paz Bay, 9 macroalgae species and one cyanoprokaryote were considered bloom forming species, which was like that number recordered for the southeast portion of the Gulf of California; where *C. sertularioides*, *Ulva* species, *S. filamentosa* and *Gracilaria* species were "important" macroalgae (Piñón-Gimate *et al.*, 2008). These macroalgae have the characteristic of being ephemeral species, of rapid growth as previously reported in other regions of the world where macroalgae blooms are of importance (Piñón-Gimate *et al.*, 2012). These species are also consistent with genera previously reported as bloom-formers in nutrient-rich coastal waters. Fletcher (1996) reported *Caulerpa*, *Ulva*, *Gracilaria*, and *Hypnea* as characteristic of eutrophic waters and cyanoprokaryotes under anaerobic conditions and low pH, also important components of macroalgal blooms (Lotze & Schram, 2000; McGlathery, 2001).

Table 1. Total and relative biomass of "important" species present in macroalgae blooms in La Paz Bay.

Species	Total Biomass (g)	Relative biomass (%)
Acanthophora spicifera (M. Vahl) Børgesen	60121.48	46.50
Caulerpa verticillata J. Agardh	13099.2	10.13
Spyridia filamentosa (Wulfen) Harvey	12399.8	9.59
Ulva ohnoi M. Hiraoka & S. Shimada	9153.34	7.08
Caulerpa sertularioides (S. G. Gmelin) M. Howe	7883.6	6.09
Ulva sp.1	5198.5	4.02
Halimeda discoidea Decaisne	4759.3	3.68
Gracilaria vermiculophylla (Ohmi) Papenfuss	4031.3	3.11
Cyanoprokaryotic species	*3685.9*	*2.85*
Laurencia pacifica Kylin	2681.2	2.07

In general, the mean values of monthly biomass for the important species were lower than those previously reported for species in macroalgal blooms with nutrient enrichment from anthropogenic sources (Ochoa-Izaguirre *et al.*, 2002; Scanlan *et al.*, 2007). However, they were consistent with biomass values of communities in the Gulf of California (Cruz-Ayala *et al.*, 1998; Casas-Valdez *et al.*, 2000; Carballo *et al.*, 2002).

The most abundant species was the red algae *A. spicifera*; it has been reported that this species shows high biomasses in places where it has been found as invasive, such as in the Hawaiian Islands where its biomass surpassed over the benthic communities after being introduced unintentionally (O'Doherty & Sherwood, 2007). However, *A. spicifera* had previously been reported in La Paz Bay, but it was only reported as present (Ávila *et al.*, 2012). In a recent study its presence and
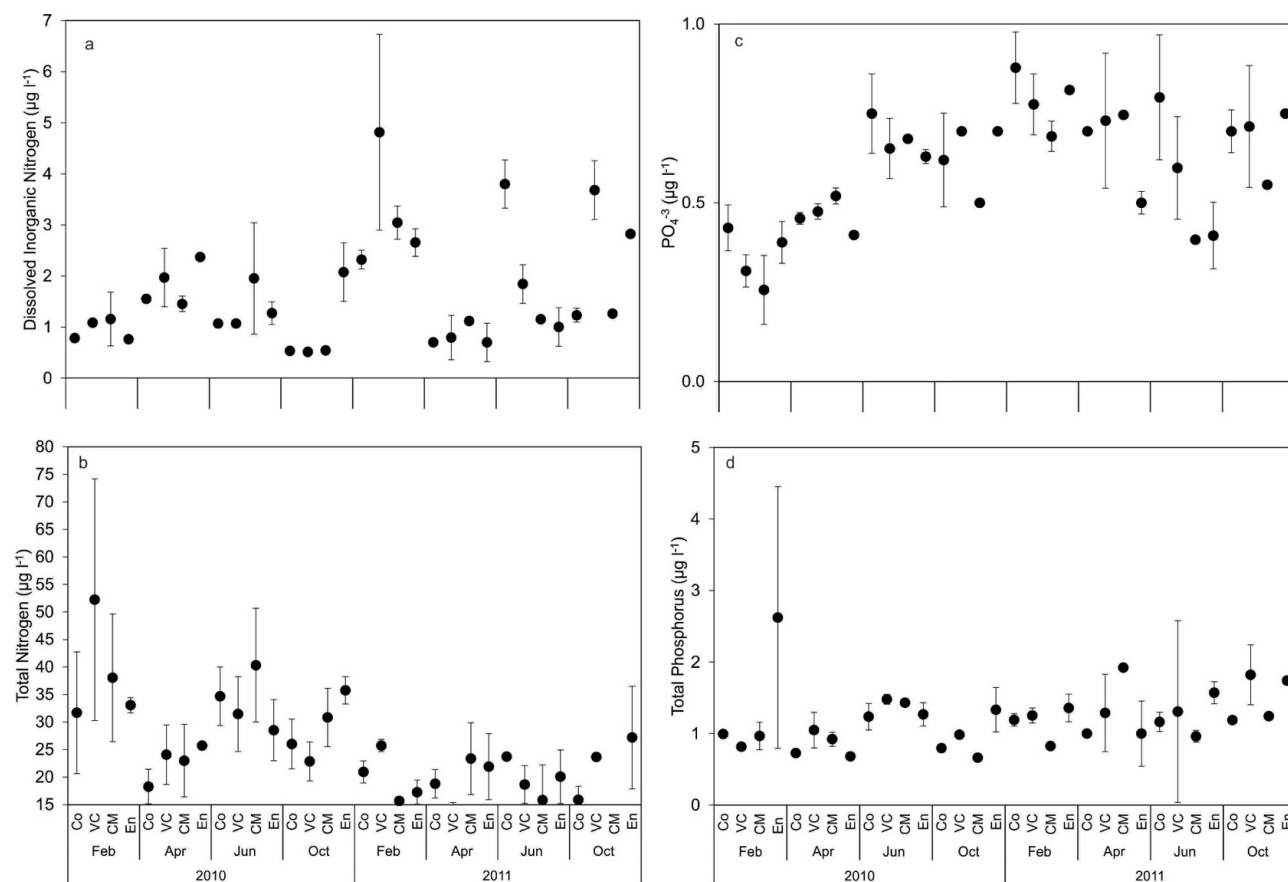

Figure 3. Nutrient concentrations: a) Mean DIN (±SD), b) NT (±SD), c) PO$_4$$^{-3}$ (±SD), d) PT (±SD) by year, month, and site. Co=Conchalito, VC= Vista Coral, CM= Casa del Marino and En=Enfermería.

abundance were described at some sites of La Paz Bay (Antonio-Robles *et al.*, 2021), but its biomass was lower than that found in the present study (16.8 g m⁻² and 43.1 g m⁻², in 2017 and 2018, respectively). As it has been mentioned before conditions of the substratum of some of the sites, had changed over the years towards a sandier and muddier bottom (*personal observation*), hence the changes in the biomass observed trough could be explained in terms of a lack of substratum since activities remain the same such as in **CM**.

The green algae *C. sertularioides* was studied in Balandra where after a hurricane its biomass increased significantly; however, it latter disappeared from this site at La Paz Bay (Scrosati, 2001). Other studies have reported the presence of *C. sertularioides* associated with nutrient rich waters in coastal lagoons of Sinaloa in the Gulf of California (Piñón-Gimate *et al.*, 2008). In the present study *C. verticillata* was abundant, it had also been reported in another sites, Esterito and La Concha, (Pérez-Estrada *et al.*, 2013); however, in the most recent study in **CM** this species was not reported (Antonio-Robles *et al.*, 2021), probably conditions, such as lack of substratum, were not favorable for this species at this site. Although there are no obvious answers as to whether this species was no longer present at **CM**, it shows that the presence of certain species depends not also on seasonal factors but also could be related to changes in the substratum as pointed out previously.

Table 2. Factor contribution of environmental variables and species biomass. Gv= *Gracilaria vermiculophylla*, Sf= *Spyridia filamentosa*, Uo= *Ulva ohnoi*, Usp1= *Ulva* sp. 1, As= *Acanthophora spicifera*, Cs= *Caulerpa sertularioides*.

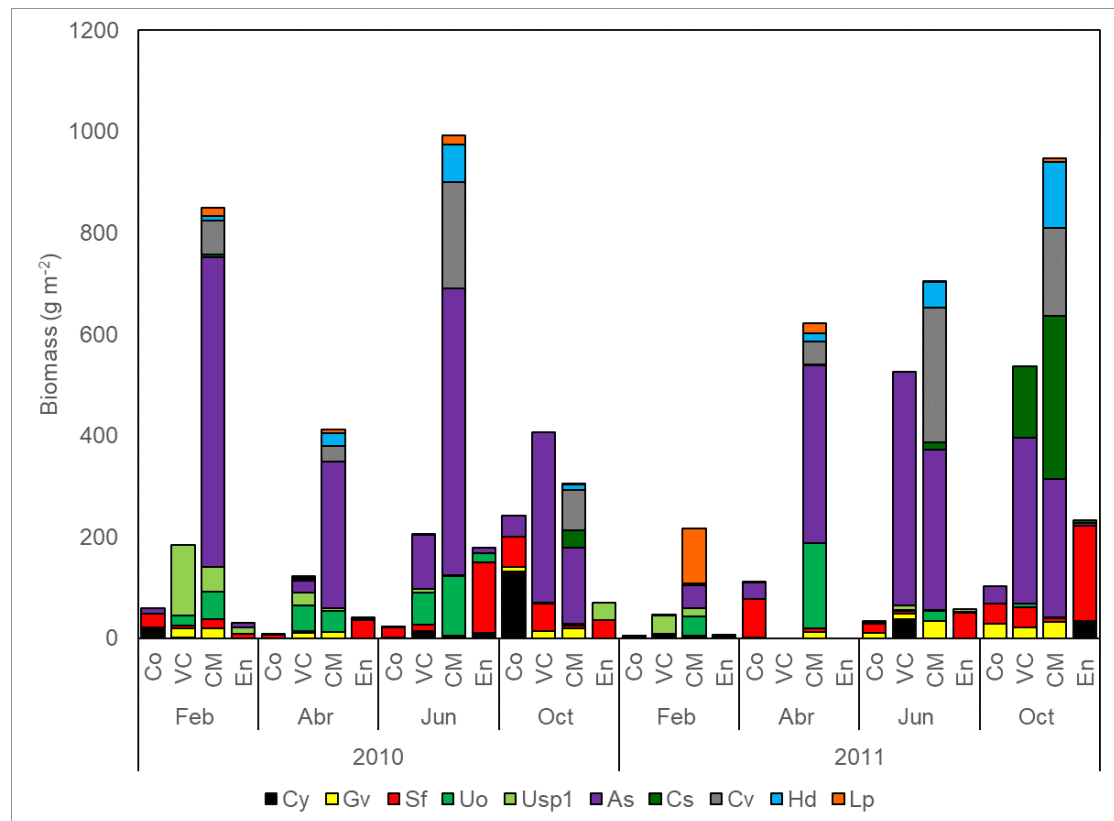|	Factor 1	Factor 2
T	**-0.594761**	-0.355900
Sal	**0.895701**	-0.210119
DIN	**0.895857**	0.412315
TN	-0.625975	0.656188
PO₄	0.635076	0.633119
TP	-0.482226	**0.796656**
*Gv	0.542017	0.775922
*Sf	0.275897	0.126783
*Uo	0.294979	**-0.949220**
*Usp1	0.150411	0.105347
*As	**0.724848**	-0.259063
*Cs	0.353115	**0.691660**

Figure 4. Seasonal variation in the mean biomass of important species at four sites. Co=Conchalito, VC= Vista Coral, CM= Casa del Marino and En=Enfermería. Cy= Cyanoprokaryote, Gv= *Gracilaria vermiculophylla*, Sf= *Spyridia filamentosa*, Uo= *Ulva ohnoi*, Usp1= *Ulva* sp.1, As= *Acanthophora spicifera*, Cs= *Caulerpa sertularioides*, Cv= *Caulerpa verticillata*, Hd= *Halimeda discoidea*, Lp= *Laurencia pacifica*.
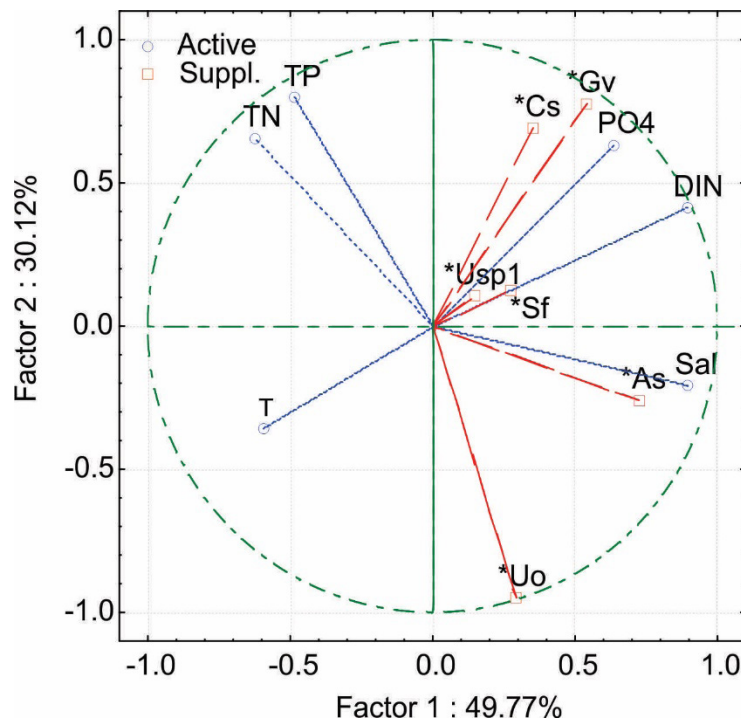
Figure 5. Principal Component Analysis (PCA) for the correlation between macroalgae biomass and environmental parameters and nutrients. T=-Temperature, Sal = Salinity, DIN= Dissolve Inorganic, TN= Total Nitrogen, PO_4^{-3}= Orthophosphates, TP= Total Phosphorus, Gv= *Gracilaria vermiculophylla*, Sf= *Spyridia filamentosa*, Uo= *Ulva ohnoi*, Usp1= *Ulva* sp.1, As= *Acanthophora spicifera*, Cs= *Caulerpa sertularioides*.

The PCA showed that the species *A. spicifera* and *G. vermiculophylla* were related with nutrient concentrations, and salinity; and in the other component *G. vermiculophylla* and *C. sertularioides* were more related with nutrient concentrations. While *U. ohnoi* showed no relation with the increases in nutrient concentrations, but also with none of the other parameters, hence its presence at this time must be related to some other factor, or the conjunction of several parameters. It has been shown that the species *C. sertularioides* was related to the ratio N:P in coastal lagoons of Sinaloa suggesting that high concentrations of nitrogen relative to low phosphorus levels favor its growth (Ochoa-Izaguirre *et al.*, 2002; Piñón-Gimate *et al.*, 2008).

In the region of the present study, *Ulva* species were the most abundant green algae in Laguna San Ignacio (Nuñez-López & Casas-Valdez, 1998). This abundance was related to the lower temperatures prevailing during the winter and to nutrient enrichment, although the authors did not measure nutrient concentrations. In La Paz Bay, other studies have found higher biomasses of *Ulva* from 351 to 537 g m⁻² (Aguila-Ramírez *et al.*, 2005), while in the present study the maximum biomass was of 138 g m⁻². Biomass of these species was found at sites where nutrient loads are considered of importance even though sources are not recorded or reported to the municipal authorities. Biomass of *Ulva* was lower than that found at coastal lagoons of Sinaloa (Piñón-Gimate *et al.*, 2008) and in general lower than *Ulva* beds of the Gulf of California (see Piñón-Gimate *et al.*, 2012). Sfriso & Marcomini (1997) reported biomass production of *Ulva* of 2.4 kg m⁻² DW in Venice lagoon, Italy in association with the nutrient loads of anthropogenic origin. The monitoring of macroalgae blooms is of importance given that continuous changes are occurring at coastal areas given the increase in population and anthropogenic activities.

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