Spatial variation of biomass of seaweed assemblages in the temperate-tropical transition zone of Baja California Peninsula, Mexico

Variación espacial de la biomasa de macroalgas en una zona de transición templado-tropical en la Península de Baja California, México

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RESUMEN

Se analizaron los cambios en la biomasa de las asociaciones de macroalgas en una zona de transición templado-tropical entre octubre de 1996 y agosto de 1997 en cuatro localidades. Las localidades con la temperatura más baja, alto índice de surgencias y mayor dominancia de sustrato duro presentaron los mayores valores de biomasa de macroalgas (El Cardoncito (7.2 kg m^{-2}) y Las Boyitas (6.2 kg m^{-2})) y la mayor cantidad de especies de afinidad templada. Por el contrario El Datilito (0.366 kg m^{-2}) en donde la temperatura fue más alta, no hay evidencia de surgencias, el sustrato es arenoso, es un área más somera y protegida, presentó el menor valor de biomasa de macroalgas y la menor proporción de algas de afinidad templada. Los análisis de componentes principales y similaridad mostraron una estrecha relación entre El Cardoncito y Las Boyitas. El Datilito se mantuvo como una localidad independiente, mientras que Chester Rock (4.3 kg m^{-2}) tuvo características intermedias de biomasa de algas. La estrecha relación entre las dos primeras localidades puede explicarse por la similaridad en términos de su alta biomasa aunado con las características fisiográficas y ambientales que presentaron. El Datilito presentó características fisiográficas y ambientales muy diferentes a las demás localidades, además de tener muy poca biomasa de macroalgas.

Palabras clave: Biomasa, Zona de transición, *Gelidium*, *Macrocystis*, fisiografía.

ABSTRACT

Biomass changes of seaweed assemblages in four locations in a temperate-tropical transition zone were analyzed between October 1996 and August 1997. Locations with lower temperature, a high index of upwelling, and high quantities of hard substrate presented the largest values of biomass of seaweed (El Cardoncito (7.2 kg m^{-2}), and Las Boyitas (6.2 kg m^{-2})) and the biggest quantity of species of temperate affinity. Conversely, El Datilito (0.366 kg m^{-2}), with a higher temperature, no evidence of upwelling, sandy substrate, and located in protected shallow waters, presented the lowest values of biomass and the lowest proportion of temperate affinity seaweed. The PCA and similarity analysis showed a close relationship between El Cardoncito and Las Boyitas. El Datilito was categorized as independent location, while Chester Rock (4.3 kg m^{-2}) displayed intermediate characteristics. The close relationship observed between the first two locations can be explained by the similarity of their high biomass and physiographic and environmental characteristics. El Datilito has very different physiographic and environmental characteristics and a very low biomass.

Keywords: Biomass, Transition zone, *Gelidium*, *Macrocystis*, physiographic.

INTRODUCTION

The temperate-tropical transition region on the Pacific coast of Baja California Peninsula is located between the California Current System, which dominates during the cool part of the year, and the northward intrusion of a branch of the tropical north equatorial current during the warm part. In this zone, the northwestern dominant winds give rise to coastal upwelling (Bakun & Nelson, 1977). When traveling parallel to the coast, these winds lead to the development of Eckman's transport that displaces water from the surface layer masses off the coast. These are then replaced by bottom water, which is colder and rich in nutrients.

In this zone many studies focusing on algal taxonomy, distribution, and ecology have been conducted on the Pacific coast of Baja California Peninsula. However, there are places that have not yet been explored, while information is scarce for others, such as the central part of Pacific coast of Baja California Peninsula (Hernández-Guerrero *et al.,* 2001). Dawson (1951, 1952) indicated that within the upwelling areas along the Pacific Baja California Peninsula, many genera and species indicative of cool northern waters occur far south of their expected latitudinal range. This author presented a list of 21 species of algae for the west part of Punta Malarrimo and 19 for Punta Eugenia. Dawson also reports the presence of tropical flora in Punta Malarrimo, and the presence of northern kelps and tropical flora across the intertidal zone at Punta Eugenia. After ten years, Dawson (1960, 1961) added some records of seaweeds for Punta Eugenia and Malarrimo.

More recent studies by Hernández-Guerrero *et al.* (2001) described the seasonality in the specific composition of subtidal seaweeds in the zone from El Cardoncito to El Datilito, Baja California Sur (B. C. S.) Mexico. In relation to seaweed-biomass information, Casas *et al.* (1985) and Hernández *et al.* (1989 a,b,1991) provided data on the standing stock of *Macrocystis pyrifera* in El Cardoncito and Chester Rock, but no studies are available about the biomass of seaweed assemblages and their relationship with local environmental factors in the temperate-tropical transition zone of Baja California Peninsula. The biomass is a value of the abundance that permits to know which seaweeds are the most important components of the assemblages. Also, how they varied among seasons and which of them have possibilities to be exploited.

Besides the fact that water temperature does exert a large influence on seaweed assemblages, there are other factors. Light, nutrients, intense heat, substratum type, substratum slope, wave height and force, degree of shelter, etc., are structuring factors, as shown by Carballo *et al.* (2002). They indicated that local assemblages are structured as a result of local influences.

The aim of this work was to determine the spatial variation of biomass and structure of seaweed assemblages in the temperate-tropical transition zone of Baja California Peninsula.

MATERIALS AND METHODS

Sampling locations were El Cardoncito (27º40' N and 114º56' W) and Las Boyitas (27º50' N and 115º04' W) on the oceanic western side of Punta Eugenia; Chester Rock (27º51' N and 115º52' W) and El Datilito (27º47' N and 114º40' W) inside the Vizcaino Bay (Fig. 1). Algal samples were collected in October 1996, March 1997, June 1997 and August 1997. Samples were collected manually from the subtidal zone by Hooka diving. At each location, 15 sampling units were distributed randomly using a random numbers chart. A $1m^2$ quadrant was used as a sampling unit to estimate algal biomass. The seaweeds collected from each sampling unit were separated for determination (Abbott & Hollenberg, 1976, Dawson, 1944, 1953, 1954, 1960, 1961, 1962, 1963a, 1963b, 1966a, 1966b, Taylor, 1945), and their weight determined to the nearest 0.0001 kg. For each identified species, and for the general analysis of wet biomass data, we used the terms seasonal biomass, seasonal relative abundance, total biomass and annual total biomass defined by Cruz *et al.* (1998).

At each quadrant, in every location, and in the four sampled dates, the following parameters were recorded: surface and bottom water temperature with a thermometer (± 0.1°C), depth with a depth-meter, and type of substratum by videotape recording. These tapes were subsequently analyzed by geologists at CICIMAR's Department of Oceanography. The seasonal variation of the upwelling index for latitudes 25.5º – 28.5º N for years 1996-1997 was obtained from the upwelling index database of Bakun (1973), which keeps records for 3° x 3° ocean quadrants. The upwelling index was expressed as $m^3 s^1 100 m^1$ of coast.

The Kolmogorov-Smirnov test showed that biomass data did not follow a normal distribution (p<0.01). Therefore a Kruskal Wallis test was performed separately on data for locations, to test whether biomass varied significantly on a spatial basis (Steel & Torrie, 1988).

The Bray-Curtis similarity classification technique (Ludwing & Reynolds, 1988), which uses data of biomass for macrophyte

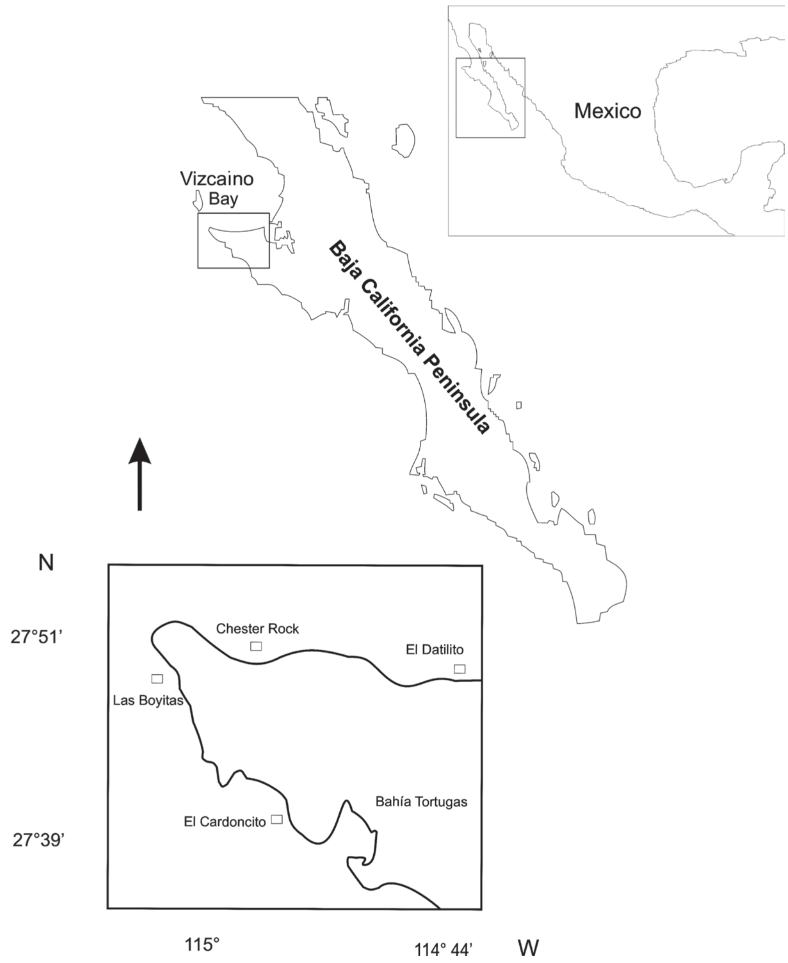

Figure 1. Location of the study area and sampling sites

species, was used to determine the degree of phyco-floristic similarity between locations. Cluster analysis was performed for the resulting matrix using the single linkage technique. Analyses were conducted using the Statistical Program (Stat Soft Inc., 2003).

A principal component analysis (PCA) was conducted using seaweed biomass, and data for environmental variables (temperature, substratum, and depth). The purpose of this analysis was to obtain a small number of linear combinations of the four variables accounting for most of the variability in the data, aiming to identify locations sharing similar characteristics (Paukert & Witting, 2002). Variables were first standardized, then the PCA was performed using the Statistical Program (Stat Soft Inc., 2003).

RESULTS

Species composition and biomass changes. The location with the highest species composition was Chester Rock (72 species) followed by El Datilito with 52, El Cardoncito with 49, and Las Boyitas with 31 species.

El Cardoncito displayed the highest seaweed biomass values (7.2 kg m^{-2}), followed by Las Boyitas (6.2 kg m^{-2}), and Chester Rock (4.3 kg m^{-2}), whereas biomass collected at El Datilito was minimal (0.366 kg m^{-2}), the latter being significantly different from all other locations ($F_{(3,211)} = 6.2523$, $p<0.05$) (Fig. 2). Table 1 includes the 45 species with biomass highest than 0.0005 kg m^2. They are classified by sampling location and by their biogeographic affinity. Nine of the 20 most abundant species were present both at El Cardoncito and Las Boyitas, while Chester Rock shared eight species with both locations. El Datilito only shared three species with the other three locations.

At El Cardoncito and Las Boyitas, perennial temperate species dominated (70% and 67%, respectively), including *Macrocystis pyrifera*, *Eisenia arborea, Gelidium robustum, Corallina vancouveriensis, Bosiella orbigniana, Prionitis cornea* and *P. australis*. The first three ones reached large sizes and hence, high biomass values. Although smaller sized, *C. vancouveriensis* and *B. orbigniana* form carpets at the base of *M. pyrifera* and *G. robustum* beds, whereas *P. cornea* and *P. australis*

Table 1. Species that presented the biggest annual average biomass (%) sampling sites and their biogeographic affinity (BA). T= template affinity; A= wide distribution; W= tropical affinity.

		El Cardoncito		Las Boyitas		Chester Rock		El Datilito	
	BA	%	kg m^{-2}	%	kg m^{-2}	%	kg m^{-2}	%	kg m^{-2}
Acrosorium venulosum (Zanardini) Kylin	A							3.04	0.010
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	A					0.18	0.008	0.95	0.003
Bossiella orbigniana (Decaisne) Silva	T	1.5	0.088	1.58	0.086	0.08	0.004		
Callophyllis violácea J. Agardh	T	0.07	0.004						
Codium sp.						0.05	0.002		
Chondracanthus canaliculatus (Harvey) Guiry	T	0.04	0.003						
Corallina officinalis Linnaeus	A	0.23	0.014	0.02	0.006	0.23	0.010	0.47	0.002
Corallina vancouveriensis Yendo	T	2.39	0.140	1.76	0.096	0.27	0.012	0.15	0.001
Cystoseira osmundacea (Turner) C. Agardh	T	0.42	0.025			0.18	0.008	6.2	0.020
Desmarestia ligulata (Stackhouse) Lamouroux	T	0.05	0.003						
Dictyopteris johnstonei Gardner	T							0.73	0.002
Dictyopteris undulata Holmes	T							2.9	0.009
Dictyota divaricata (J. Agardh) J. Agardh	W							0.34	0.001
Dictyota flabellata (Collins) Setchell & Gardner	A							0.15	0.0005
Eisenia arborea Areschoug	T	12.31	0.722	12.65	0.688	41.31	1.869	5.6	0.018
Gelidium robustum (Gardner) Hollenberg & Abbott	T	5.47	0.321	1.31	0.072	2.08	0.094		
Gelidiopsis variabilis (J. Agardh) Schmitz	T					0.07	0.003		
Gracilaria cerrosiana Taylor	T	0.27	0.016						
Gymnogongrus chiton (Howe) Silva & DeCew	A	0.05	0.003						
Gymnogongrus sp.		0.09	0.005						
Haliptilon roseum (Lamarck) Garbary & Johansen	T			0.15	0.008	0.13	0.006	3.6	0.011
Herposiphonia verticillata (Harvey) Kylin	T					0.05	0.002		
Hypnea variabilis Okamura	T			0.02	0.002				
Laurencia pacifica Kylin	A							0.55	0.001
Leptocladia binghamiae J. Agardh	A	0.13	0.008						
Macrocystis pyrifera (Linnaeus) C. Agardh	T	76	4.457	80.1	4.354	54.3	2.457		
Pachydictyon coriaceum (Holmes) Okamura	W							0.09	0.0005
Padina caulescens Thivy	W							0.09	0.0005
Padina durvillaei Bory Saint-Vincent	W							41.09	0.134
Plocamium cartilagineum (Linnaeus) Dixon	T	0.27	0.016	1.5	0.082	0.21	0.010		
Polysiphonia johnstonii Setchell & Gardner	A							0.51	0.001
Prionitis angusta (Okamura) Okamura	T			0.02	0.003				
Prionitis australis (J. Agardh) J. Agardh	T	0.21	0.012	0.45	0.025				
Prionitis cornea (Okamura) Dawson	T	0.20	0.012	0.18	0.020	0.05	0.002		
Pterocladiella capillacea (Gmelin) Santelices & Hommersand	A			0.03	0.002	0.05	0.002		
Pterosiphonia baileyi (Harvey) Falkenberg	T					0.05	0.002		
Sargassum acinacifolium Setchell & Gardner	W							6.35	0.020
Sargassum agardhianum Farlow ex J. Agardh	W							0.21	0.007
Sargassum sinicola var. *camouii* (Dawson) Norris & Yensen	W							1.16	0.003
Sargassum herporhizum Setchell & Gardner	A					0.11	0.005		
Sargassum sinicola Setchell & Garnder	W							13.96	0.045
Sargassum zacae Setchell	W							9.03	0.029
Spatoglossum howelli Setchell & Gardner	W							1.62	0.005
Spyridia filamentosa (Wulfen) Harvey	W							0.19	0.0006
Zonaria farlowii Setchell & Gardner	W							0.24	0.0008

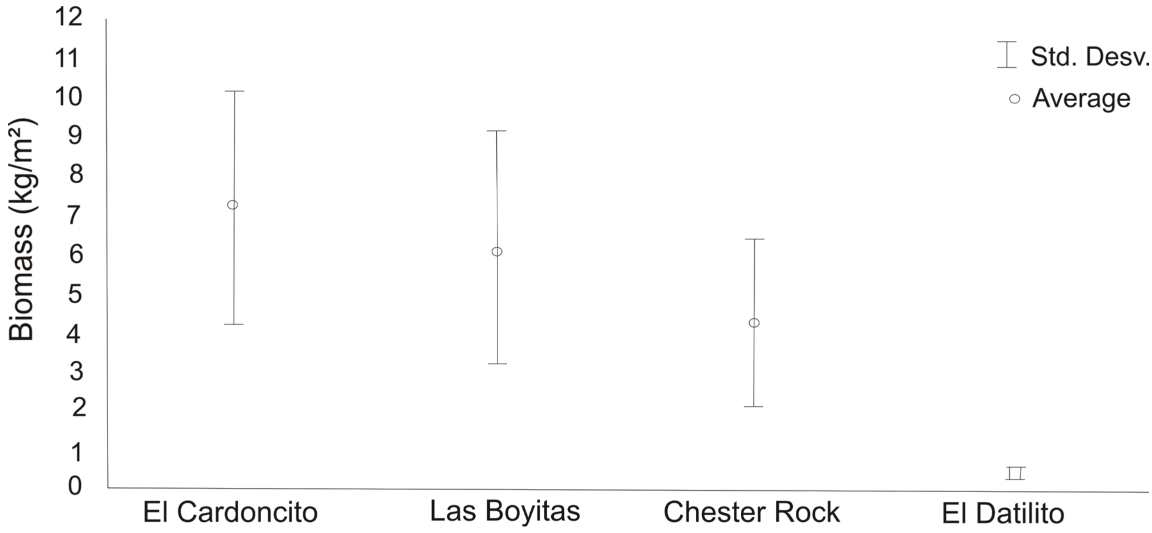

Figure 2. Variations in mean annual seaweed biomass in locations of temperate-tropical transition zone of Baja California Peninsula.

grew intermingled within *Gelidium* beds. Temperate species also dominated at Chester Rock (52%), including *M. pyrifera, E. arborea, G. robustum* and *C. vancouveriensis*. At this location, an increase in the presence of tropical (16%), and widely distributed species (32%) was observed. *M. pyrifera* attained a similar biomass in El Cardoncito and Las Boyitas (4.45 kg m^{-2} and 4.35 kg m^{-2}, respectively) with a decrease to about half this value in Chester Rock (2.45 kg m^{-2}); the opposite was true for *E. arborea*, with a similar and low average biomass in the first two locations (0.72 kg m^{-2} and 0.69 kg m^{-2}) that increased to three times this value in Chester Rock (1.87 kg m^{-2}). In the case of *G. robustum, C. vancouveriensis* and *B. orbigniana,* the biomass was higher in El Cardoncito and steadily decreased in Las Boyitas and Chester Rock. By contrast, the species with the highest biomass in El Datilito included *Padina durvillaeii*, *Sargassum sinicola* and *S. acinafolium*, all of them being annual species with a tropical affinity. In this location there was a decline in the number of temperate species that showed high biomass values in the other locations. In fact, the size and biomass of macrophyte species was lower compared to all other locations (Fig. 3a, b).

Parameters. The average annual temperature was of 18°C in El Cardoncito and Las Boyitas, 19ºC in Chester Rock and 22ºC in El Datilito. Las Boyitas was the location with the lowest temperature throughout the year, ranging between 15.1ºC in March and 20ºC in August. By contrast, El Datilito showed the highest temperature throughout the year with 20ºC in March and June and 25.4ºC in August (Fig. 4). Minimum and maximum temperatures in El Cardoncito were 16.3ºC in March and 20ºC in August. In Chester Rock these were 16.7ºC in March and 21ºC in August. The lowest temperatures occurred at Las Boyitas and El Cardoncito (18ºC). El Datilito had the highest temperature (22ºC) and Chester Rock presented intermediate values (20ºC) (Fig. 5).

The following mean depth values were recorded: El Cardoncito 5.2 m ± 0.14, Las Boyitas 5.1 m ± 0.2, Chester Rock 5.9 m ± 0.3, and El Datilito 4.0 m ± 0.3. Significant difference was found among these values ($F_{(3, 176)} = 6.3770$, $p<0.004$). Tukey's test for comparison of means showed that El Datilito was significantly different compared to all other locations.

As regards the substratum, El Cardoncito and Las Boyitas shared similar characteristics, with the main substratum constituted by sedimentary materials lying upon a rocky basement, forming sloped marine terraces, occasionally dissected by steep slopes and with rock fragments at the bottom including gravel, boulders and some large rocks. Chester Rock had a mostly sedimentary rocky basement with occasional toleitic basalt intrusions covered by patches of sand of an organic (shell fragments) and inorganic origin, forming small ravines alternated with platform-like flat rocky areas. El Datilito included an extensive continental shelf with a sedimentary substratum composed of sand, small pebbles and gravel in the shallower areas, as well as boulders; some sedimentary-rock blocks were observed, although of a smaller diameter than those found in all other locations.

The upwelling-index values for the 25.5º-28.5º N oceanic quadrant oscillated between a maximum of 169 m^3 s^1 in the spring and a minimum of 93 m^3 s^1 in the fall (Fig. 4). Upwellings are constant and have a direct influence on Las Boyitas and El Cardoncito, and indirectly on Chester Rock.

Spatial analysis. The similarity dendrogram derived using the Bray-Curtis technique revealed that El Cardoncito and Las Boyitas formed a group at a similarity level of 91.7%, to which Chester Rock joined afterwards (65%), while El Datilito remained independent (Fig. 5).

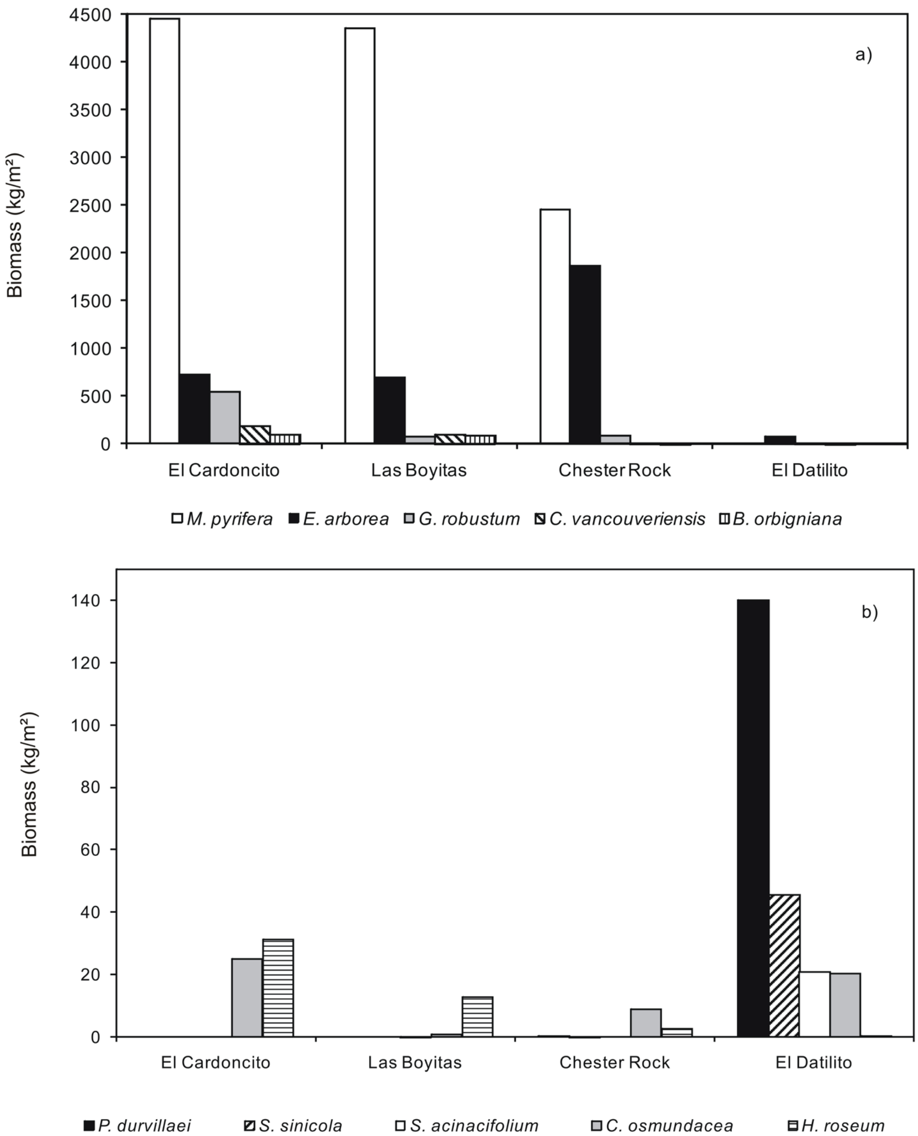

Figure 3. Biomass of the five most abundant species in a) El Cardoncito, Las Boyitas and Chester Rock and b) El Datilito

The PCA defined a close relationship between El Cardoncito and Las Boyitas, while Chester Rock and El Datilito remained independent. Although Chester Rock shared intermediate characteristics with the first two locations, the PCA analysis placed Chester Rock on the positive side of component 1, similar to El Cardoncito and Las Boyitas (Fig. 6). Two components accounted for 99% of the original data variability. According to eigenvectors, substratum was the most important variable in the first component, while depth, was the most important variable in the second component.

DISCUSSION

Parrish *et al.* (1981) mention that the area comprised from Punta Baja to the south of Punta Eugenia includes the zone with the maximum upwelling around the Baja California peninsula. Las Boyitas and El Cardoncito are part of this area. At Chester Rock, located at Sebastian Vizcaino Bay, winds blow perpendicular to the coast due to its shape, leading to a relative debilitation of the wind's component running parallel to the coast, and hence also of Eckman's transport off the coast (Amador *et al.,* 1995); however, the water exchange through Dewey's channel carries nutrient-rich waters from the surrounding area. Water circulation in Sebastian Vizcaino Bay is dominated by an anti-ciclonic eddy of relatively warm water (Amador *et al.,* 1995, Palacios *et al.,* 1996). The eddy's portion that runs to the west by the coast flows towards Dewey's channel (except when restricted by tides), carrying warm water from the exchange of Ojo de Liebre, and Guerrero Negro lagoons. This leads to the

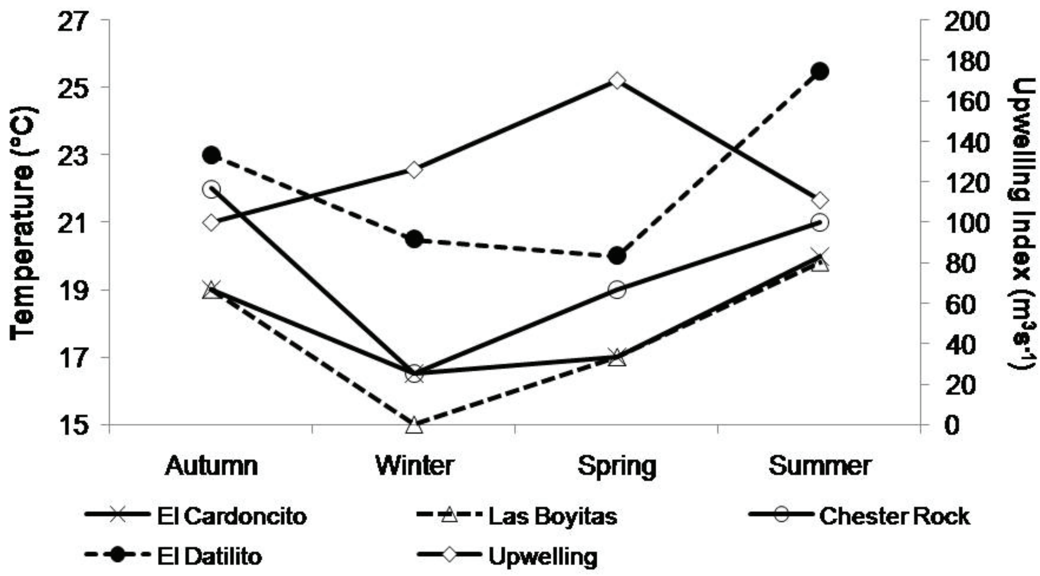

Figure 4. Temporal variation in surface sea temperature and upwelling index in locations of central of temperate-tropical transition zone of Baja California Peninsula.

conclusion that Chester Rock is subjected to the influence of the bay's warm water. As observed in the temperature graph, this location presents intermediate temperature values compared to El Cardoncito, Las Boyitas, and El Datilito.

The biomass variation in a macrophyte community is related to a number of biotic factors, including the species composition, ecological factors like phenological changes, recruitment to the local populations, predation by grazing species, etc. (Untawale *et al.,* 1989) and abiotic factors like temperature, light, nutrients, substratum type, wave force and salinity (McQuaid, 1985, Graham & Wilcox, 2000).

Biomass values were very high in El Cardoncito and Las Boyitas, high in Chester Rock and considerably lower in El Datilito. This can be explained in terms of the great difference in species composition, along with the environmental characteristics in each of them, which determine the specie's phenology, seasonality and abundance. Biomass data for the three first locations fit well within the range reported (0.5 kg m^{-2} – 8 kg m^{-2}) for temperate kelp forests dominated by *Macrocystis pyrifera* (Foster & Schiel, 1985), and are similar to macrophyte biomass data at San Nicolas and Rosa Island in the Southern California Bight (Littler, 1980). Likewise, Hernández *et al.* (1989b, 1991) report harvestable biomass values for *Macrocystis*

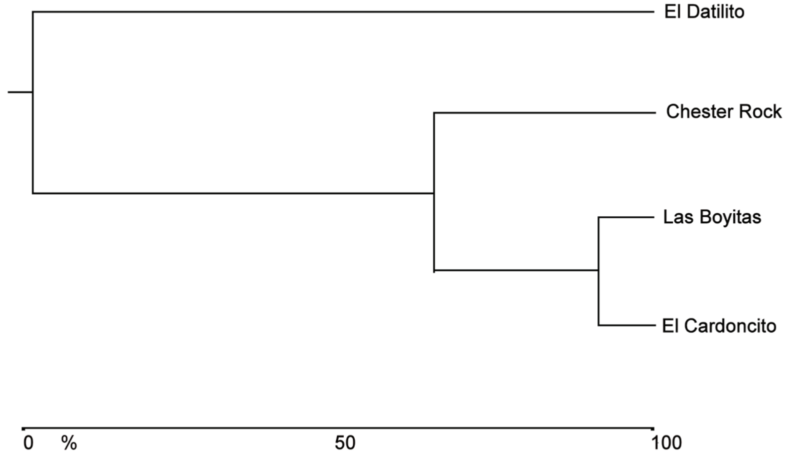

Figure 5. Similarity dendrogram between locations (according total biomass) for the annual cycle in the central part of pacific coast of Baja California Peninsula.

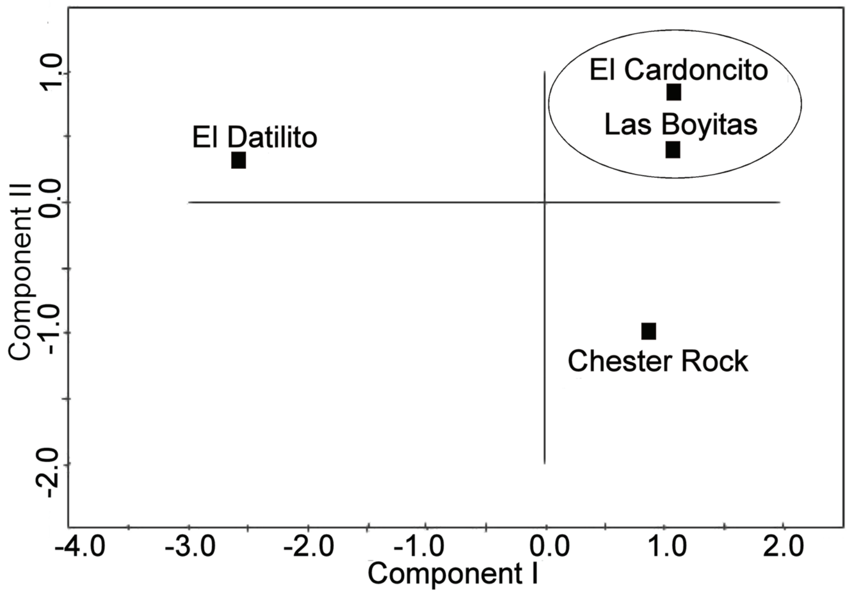

Figure 6. Principal components analysis with Bray-Curtis index for similarity analysis between locations.

of 6.3 ± 0.9 kg m^{-2} in El Cardoncito and 5.9 ± 1.2 kg m^{-2} for Chester Rock during the spring of 1986, and 4.2 ± 1.0 kg m^{-2} and 4.5 ± 1.2 kg m^2 in the summer of the same year for the same locations.

The Ojo de Liebre and San Ignacio lagoons are located in the northern Pacific coast of Baja California Sur. Average biomass values reported for these lagoons are substantially lower (62.5 and 20.6 g m^{-2}, respectively) (Aguila *et al.,* 2003, Núñez & Casas, 1998) than biomass values observed in the present work, likely because these lagoons are closed water bodies with scarce hard substrates. Respect to this point Trono and Saraya (1987) mentioned that the species number and abundance are mostly influenced by the substratum's type, physical structure, hardness and degree of compaction. For this reason substratum is regarded as one of the key factors determining that the highest algal abundance occur in areas with the largest surface area covered by hard substratum (El Cardoncito, Las Boyitas, and Chester Rock), and the lowest abundance where the substratum is predominantly sandy (El Datilito).

El Cardoncito and Las Boyitas show similar depths with a rocky substratum where large rocks predominate; these are exposed zones strongly influenced by low temperatures from the California Current (temperature oscillated from 15ºC to 20ºC), with upwelling events carrying nutrient-rich water to the surface. These factors lead to the development of perennial species with a temperate affinity, large sized and hence having a high biomass, including *Macrocystis pyrifera* that forms dense forests encompassing wide areas. This species contributed 64% and 77% of the total biomass in the above mentioned locations, followed by *Eisenia arborea* with 12.5% and 15%, and *Gelidium robustum* with 13% and 1.6%, respectively. Together, these three species accounted for over 85% of total biomass in these locations. The decrease in biomass observed in Las Boyitas compared to El Cardoncito might be due to the fact that wave force is stronger in the first. Molloy and Bolton (1995) report a decreased in seaweed biomass associated with a highly intense water movement. Furthermore, Tegner and Dayton (1987) mention that the tallest perennial canopy is more susceptible to wave stress.

Chester Rock displays conditions that are intermediate between the first two and the latter location, being less exposed than the first and with large rocks, boulders, pebbles, and sand patches substratum. It is influenced by both cold water (temperature varied between 16.7ºC and 21ºC) from upwelling off Punta Eugenia, and warm water from the exchange of coastal water with Ojo de Liebre and Guerrero Negro lagoons, although the latter is regarded as a lesser influence. Although the temperate species dominate, the number of tropical species increases, besides showing the highest species richness (Hernández-Guerrero *et al.,* 2001). To this respect Dawson (1952) points out that, because of tidal currents, the flora of Punta Eugenia is alternately washed by cooler upwelled water and by warmer bay water, with a greater influence of the former. *Macrocystis pyrifera's* biomass drops in this location while that of *Eisenia arborea* increases, both species accounting for 94% of total biomass.

El Datilito is a protected zone, being shallower, with a predominantly sandy substratum, and highly influenced by the conditions affecting Sebastián Vizcaíno bay, which has a wide continental platform and poor water circulation (Dawson, 1952). Sun radiation is intense in this area, and no evidence of upwelling exists, whereas an anticiclonic eddy along with an exchange of coastal water with Ojo de Liebre and Guerrero Negro lagoons results in a higher surface temperature across the whole bay compared to the rest of the peninsula (Amador *et al.,* 1995). In this location temperatures were the highest recorded in the present study, temperature being 4ºC higher throughout the year. This combination of factors is believed to result in both the absence of *Macrocystis pyrifera* beds (the species with the highest biomass values in the present study) and in the establishment of a higher number of species with a tropical affinity, showing the lowest biomass values. *Macrocystis* grows better in colder regimes and needs a nitrate concentration up 1 µm (Tegner & Dayton, 1987, Zimmerman & Kremer, 1986, Hernández-Carmona *et al.,* 2001). *P. durvillaei* accounts for 47% of seaweed biomass in this location, being a species that grows in a number of substratum types including sand, rock, pebbles and shell fragments besides having a pantropical affinity (Paul, 2000), so that it grows very well at the temperatures that occur in this location.

The similarity, and PCA analysis revealed a close relationship between El Cardoncito and Las Boyitas while El Datilito remained as independent location. Hernández-Guerrero *et al.* (2001) found the same grouping of locations using algal presence-absence data recorded in these locations. The close relationship observed between the first two locations might be explained by the similarity in terms of high biomass values along with the physiographic and environmental characteristics (depth, large rocky substratum, low temperatures, presence of upwelling, exposed zones). El Datilito has physiographic and environmental features that differ markedly from those in all other locations (shallower and protected zone, sandy substratum, higher temperatures, no evidence of upwelling) along with very low biomass values, hence remaining as an independent location, while intermediate conditions occur in Chester Rock, so that it joins the first group at a lower similarity level (65%) while the PCA places it to the positive side of component I, similar to El Cardoncito and Las Boyitas.

The relationships between locations were found to be determined by macrophyte biomass and specific environmental variables using both principal components analysis (Aguila *et al.,* 2003) and using the Bray-Curtis technique with combined macrophyte and macroinvertebrate mean cover data (Littler, 1980). This later author found that the sites most strongly influenced by the cold California Current system in Southern California Bight formed a close group broadly separated from sites exposed to predominantly warmer water systems. Cruz *et al.* (1998) used a clusters analysis to define phyco-floristic associations in La Paz Bay, finding that variations in biomass, substratum and geographic closeness between locations determined the associations between them.

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REFERENCES

Abbot, I. A. & G. J. Hollenberg. 1976. *Marine algae of California*. Stanford University Press, Stanford California 827 pp.

Aguila, R. N., M. Casas, S. Ortega, R. A. Núñez & M. B. Cruz. 2003. Spatial and seasonal variation of macroalgal biomass in Laguna Ojo de Liebre, Baja California Sur, México. *Hydrobiologia* 501: 207-214.

Amador, B. A., M. L. Argote, P. M. Mancilla & R. M. Figueroa. 1995. Variaciones de periodo corto de la circulación anticiclónica en Bahía Sebastián Vizcaíno, B. C. *Ciencias Marinas* 21: 201-233.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-1971. U.S. Dep. Commer., NOAA *Technical Report* NMFS SSRF-671, 103 p.

Bakun, A. & C. S. Nelson. 1977. Climatology of upwelling related processes off Baja California. *CALCOFI* Report 19: 107-127.

Carballo, J. L., C. Olavaria & T. Garza Osuna. 2002. Analysis of four macroalgal assemblages along the Pacific Mexican Coast during and after the 1997-1998 El Niño. *Ecosystem* 5: 749-760.

Casas, M., G. Hernández, J. R. Torres Villegas & I. Sánchez Rodríguez. 1985. Evaluación de mantos de *Macrocystis pyrifera* "sargazo gigante" en la península de Baja California (verano de 1982). *Investigaciones Marinas CICIMAR* 2: 1-117.

Cruz, M. B., M. Casas & S. Ortega. 1998. Temporal and spatial variation of frondose benthic seaweeds in La Paz Bay, B.C.S., Mexico. *Botanica Marina* 41: 191-198.

Dawson, E. Y. 1944. *The marine algae of the Gulf of California*. Allan Hancock Pacific Expeditions, 3:189-454.

Dawson, E. Y. 1951. A further study of upwelling and associated vegetation along pacific Baja California, Mexico. *Journal of Marine Research* 10: 39-41.

Dawson, E. Y. 1952. Circulation within Bahia Vizcaino, Baja California and its effects on marine vegetation. *American Journal of Botany* 39(7): 425-432.

Dawson, E. Y. 1953. *Marine red algae of Pacific Mexico. I. Bangiales to Corallinaceae subfamily Corallinoideae.* Allan Hancock Pacific Expeditions 17(1): 1-239.

Dawson, E. Y. 1954. *Marine red algae of Pacif Mexico. II. Cryptonemiales (cont.)* Allan Hancock Pacific Expeditions, 17 (2):241-397.

Dawson, E. Y. 1960. A review of the ecology, distribution and affinities of benthic flora. *In*: Taylor & Francis (Eds). *Systematic Zoology.*

Symposium: The biogeography of Baja California and adjacent seas. Part II, Marine Biotas. 9: 93-100.

Dawson, E. Y. 1961. A guide to the literature and distribution of Pacific benthic algae from Alaska to Galapagos Islands. *Pacific Science* 15: 371-461.

Dawson, E. Y. 1962. *Marine red algae of Pacific Mexico. VII. Ceramiales: Ceramiaceae, Delesseriaceae*. Allan Hancock Pacific Expeditions 26(2): 1-207.

Dawson, E. Y. 1963a. Marine red algae of Pacific Mexico. VI. Rhodymeniales. *Nova Edwigia*, 5:437-476.

Dawson, E. Y. 1963b. Marine red algae of Pacific Mexico. VIII. Ceramiales: Dasyaceae, Rhodomelaceae. *Nova Edwigia* 6: 400-481.

Dawson. E. Y. 1966a. *Marine algae in vicinity of Puerto Peñasco, Sonora, México.* Gulf of California field guide series No. 1. The University of Arizona. 57pp.

Dawson, E. Y. 1966b. New records of marine algae from the Gulf of California. *J. Ariz. Acad. Sci.* 4(2): 55-66.

Foster, M. S. & D. R. Schiel. 1985. The ecology of giant kelp forest in California: a community profile. US Fish and Wildlife Service. *Biological Reports* 85(7): 1-152.

Graham, L. E. & L. W. Wilcox. 2000. *Upper Saddle River*: Prentice Hall, U. S. A., 542 p.

Hernández, C. G., Y. E. Rodríguez, J. R. Torres, I. Sánchez, M. A. Vilchis & O. García. 1989a. Evaluación de mantos de *Macrocystis pyrifera* (Phaeophyta: Laminariales) en Baja California, México. I. Invierno 1985 - 1986. *Ciencias Marinas* 15: 1-27.

Hernández, C. G., Y. E. Rodríguez, J. R. Torres, I. Sánchez, M. A. Vilchis & O. García. 1989b. Evaluación de mantos de *Macrocystis pyrifera* (Phaeophyta: Laminariales) en Baja California, México. II. Primavera de 1986. *Ciencias Marinas* 15: 117-140.

Hernández, C. G., Y. E. Rodríguez, M. Casas, M. A. Vilchis & I. Sánchez. 1991. Evaluación de mantos de *Macrocystis pyrifera* (Phaeophyta: Laminariales) en Baja California, México. III. Verano de 1986 y variación estacional. *Ciencias Marinas* 17: 121-145.

Hernández-Carmona, G., D. Robledo & E. Serviere-Zaragoza. 2001. Effect of nutrient availability on *Macrocystis pyrifera* recruitment and survival near its southern limit off Baja California. *Botanica Marina.* 44:221-229.

Hernández-Guerrero, C., R. N. Aguila, M. Casas, M. B. Cruz & R. A. Núñez. 2001. Distribución de la ficoflora en la zona central de la península de Baja California, México. *Anales de la Escuela Nacional de Ciencias Biológicas* 47: 85-98.

Littler, M. M. 1980. Southern California rocky intertidal ecosystem *In:* Price, J.H., D.E.G. Irvine & W. F. Farnham (Eds.). *Methods community structure and variability.* Academic Press, London. pp. 556-608.

Ludwing, J. A. & J. F. Reynolds. 1988. *Statistical Ecology*. John Wiley and Sons, New York, N. Y. 337 p.

McQuaid, C. D. 1985. Seasonal variation in biomass and zonation of nine intertidal algae in relation to changes in radiation, sea temperature and tidal regime. *Botanica Marina* 28: 539-544.

Molloy, F. J. & Bolton J. 1995. Distribution, biomass and production of *Gracilaria* in Lüderitz Bay, Namibia. *Journal of Applied Phycology.* 7(4): 381-392.

Núñez, R. A. & M. Casas. 1998. Seasonal variation of seaweeds biomass in San Ignacio lagoon, Baja California Sur, México. *Botanica Marina* 41: 421-426.

Palacios, E., M. L. Argote, B. A. Amador & M. Mancilla. 1996. Simulación de la circulación barotrópica inducida por viento en Bahía Sebastián Vizcaíno, B. C. *Atmosfera* 9: 171-188.

Parrish, P. H., C. S. Nelson & A. Bakun. 1981. Transport mechanism and reproductive success of fishes in the California Current. *Biological Oceanography* 1: 175-203.

Paukert, C. P. & T. A. Witting. 2002. Applications of multivariate statistical methods in fisheries. *Fisheries Research* 27: 16-22.

Paul, L. 2000. *Evaluación taxonómica de las especies del género Padina Adanson 1763 (Dyctiotales: Phaeophyta) para el Golfo de California.* Tesis de Maestría. CICIMAR-IPN, La Paz, B. C. S., México, 93 p.

Stat Soft, Inc. (2003). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Steel, R. G. & H. J. Torrie. 1988. *Bioestadística: Principios y procedimientos*. Eds. McGraw-Hill., México. 622 p.

Taylor W. R. 1945. *Pacific marine algae of the Allan Hancock expeditions to the Galapagos Islands.* The Universidad of Southern California Publications. Vol. XII. 780 pp.

Tegner, M. & P. Dayton. 1987. El Niño effects on Southern California kelp forest communities. *Advances in Ecology Research* 17: 243-279.

Trono, G. C. & A. Saraya. 1987. The structure and distribution of macrobenthic algal communities on the reef of Santiago Island, Bolinao, Pangasinan.l Philippines. *Journal of Science* 17: 63-81.

Untawale, A. G., C. R. Reddy & G. V. Deshmukhe. 1989. Ecology of intertidal benthic algae of northern Karnataka coast. *Indian Journal of Marine Science* 18: 73-81.

Zimmerman, R. C. & J. N. Kremer. 1986. *In situ* growth and chemical composition of the giant kelp, *Macrocystis pyrifera*: response to temporal change in ambient nutrient availability. *Marine Ecology Progress Series* 27: 277-285.

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