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Population Structure and Reproduction of *Padina concrescens* Thivy (Dictyotales: Phaeophyta) in Southwest Baja California Peninsula, Mexico

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The brown algae *Padina concrescens* is widely distributed in the northwestern Pacific México. We described the population of *P. concrescens* based on population parameters such as cover, density and size structure and reproduction at two levels tide at the intertidal area in the southwestern Baja California Peninsula. Monthly visits from January to December 2003 were done. Both cover and density were measured *in situ* by quadrants method. Samples were collected to obtain size structure and percentage of reproductive fronds. Our results show there is spatial variation in the population structure more than temporal. Thus, cover and density peak were at different months in each tide level studied, the lower tide level shows the high values in cover as well as density. The frond development was observed in height/width ratio this relation was consistent only in the low tidal zone. Size class distribution has consistently small size plants in both tide levels. Reproduction was seasonal in the tide channel but in both tide levels all the reproductive plants were tetrasporophyte. Our results suggest that this population is pseudoperenial and it strongly as a consequence of the intense competition in the intertidal zone.

Key Words: Dictyotales, Pacific México, *Padina concrescens*, Population, Reproduction

INTRODUCTION

Population studies about species in the Order Dictyotales have been concentrated in temperate areas (Allender 1977; Benson 1986; King and Farrant 1987; Malbran and Hoffman 1990) and some in tropical zones (Ganesan *et al.* 2000; Montanes *et al.* 2006; Paul-Chávez *et al.* 2006). Among the population parameters studied, seasonal changes in cover and size has been found (King and Farrant 1987; Paul-Chavéz *et al.* 2006). However, mostly of the studies were done at the same depth or tide level, broader spatial comparisons are not common (Liddle 1975), specially in relation height/width of the thalli. Density has been used as a population descriptor in other genera (Montanes *et al.* 2006). In relation to reproduction there are contradictory information exist, because in some populations reproduction is continuous (King and Farrant 1987; Phillips 1988; Ganesan 2000) while in other populations reproduction is seasonal with peaks in autumn (Benson 1986) or winter (Malbran and Hoffman 1990). The only coincidence in all the studies is the dominance of tetrasporophyte thalli (Foster *et al.* 1972; Allender 1977; King and Farrant 1987; Montanes *et al.* 2006) and the regeneration from mitotic spores and fragments (Gaillard 1972; Foster *et al.* 1972; Benson 1986).

Population studies of Dictyotales in Mexican Pacific have been done at the southern Gulf of California in where Paul-Chávez *et al.* (2006) developed a population study of *P. caulescens* Thivy, in where strong seasonal variations in biomass, size structure and reproduction were observed while cover remained constant suggesting as a good population parameter for comparisons. A second study in the same area by Altamirano-Cerecedo and Riosmena-Rodríguez (2007), evaluated the influence of geography in the morphology and reproductions of *Dictyota crenulata* J. Agardh. They found variations in size and proportion of reproductive life cycle stages in relation to the geography suggesting strong population changes. In the case of *P. concrescens*, Ortuño-Aguirre and Riosmena-Rodriguez (2007) described the dynamics of the epiphytes in relation to the host. However, studies in other species might let us understand better the population's trends in the subtropical areas (like the Baja California Peninsula) with the hypothesis that permanent populations are present in those areas based on a

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continuous presence and reproduction of the thalli. We select *P. concrescens* at Pacific Coast of Baja California Peninsula because it is common at more than one intertidal level.

The brown algae *Padina concrescens* is one common element in the northwestern Pacific México (Taylor 1945). It is widely distributed in intertidal and subtidal zone growing in beds or in patches over rocky substrates (Taylor 1945), often is found associated to *Sargassum* beds (Espinoza-Avalos 1990; Nuñez-Lopez and Casas-Valdez 1996). Morphologically presents thalli erect with a single frond which is known as fan shape, attached by a rhizoidal holdfast, the growth initiated by an entire marginal row of apical cells in an involute apical fold (Taylor 1945). Taxonomically is delimited by no carbonate precipitation and has 12-18 cells thickness in basal part of the thalli (Paul-Chávez *et al.* submitted) As other member of the order Dictyotales, we assumed that *P. concrescens* presents a life cycle is diplohaplontic and isomorphic with sporangial sori growing in patches or isolated (Bold and Wynne 1985).

The aim of this study was to describe, in function to aspects such as cover, density, height/width, size structure and proportion of reproductive fronds, the population of *Padina concrescens* in the southwest coast from the Peninsula of Baja California, México.

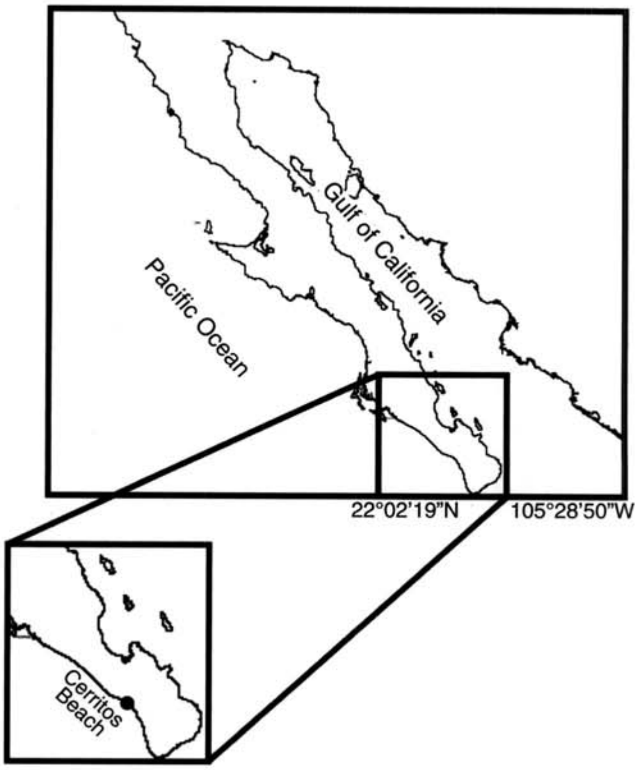

Fig. 1. Location of study area.

MATERIALS AND METHODS

Study site

This study was conducted in Los Cerritos, Baja California Sur, México (23° 19' 79" N, 110° 10' 69" W) this area has high energy waves (Fig. 1). Samples were collected monthly intervals between February and November 2003, all sampling were done during low tide based on the tide tables from CICESE (www.cicese.mx). *Padina concrecens* was growing in 2 tide levels: 1) mid tide in pools and 2) low tide in channel, therefore are considered as two environments as described by Dethier (2002).

Population parameters

Cover and density parameters were estimated *in situ* using 0.25 x 0.25 m quadrants (with 5 x 5 cm squares) for cover, and without squares for density. Ten quadrants were randomly placed along a transect over the area cover by the species. Cover estimation was done counting the interception points with each holdfast of *Padina concrescens* and this was done from March to August and November. While density estimation was done counting the total of frond inside of the quadrant and this was possible from February to August and November. During September and October, we did not sampling any parameter due to the presence of four consecutive hurricanes. For the tide channel sampling for size structure were not possible in February and March because the size of the plants (less than 0.5 cm) and for the tide pool sampling for size structure were not possible in November because the scarcity of the plants. In order to determinate size structure, reproductive proportion and qualitative aspects, five quadrants were collected randomly for each site. The samples transported to the laboratory into plastic bags previously labeled.

In the laboratory the samples were clean up of sediments and other organisms associated and were preserved using 4% formaldehyde in seawater. The identification of the samples was done according to Taylor (1945). After determination of the species, height/width was measured in the plants (Fig. 2) to evaluate if there is relationship in the development of the plants.

In order to determinate size structure a size of sample was obtained through mean accumulative method (Daniel 1999) given as result 60 fronds/month for each site, these fronds, also was obtained random way. At

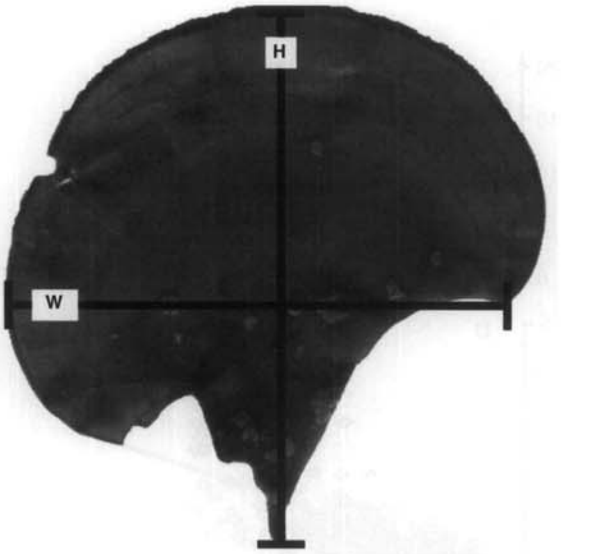

Fig. 2. Example of the way we measured height (H) and width (W) in *Padina concrescens* from our study area.

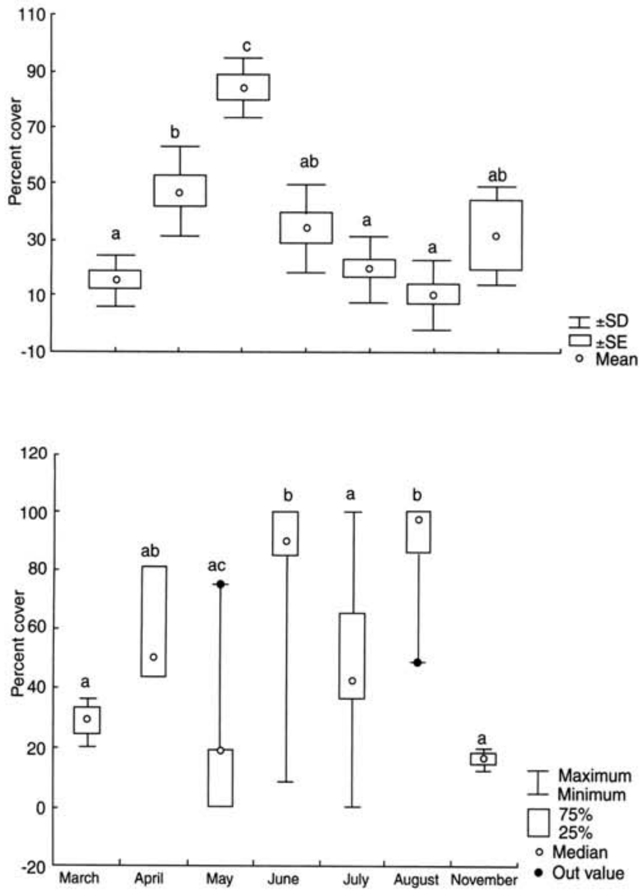

Fig. 3. Temporal variations of percentage cover both sites. A) Tide pool; B) Channel, changes in median and percentiles are showed. Error bars with different letters are statistically different ($p < 0.05$).

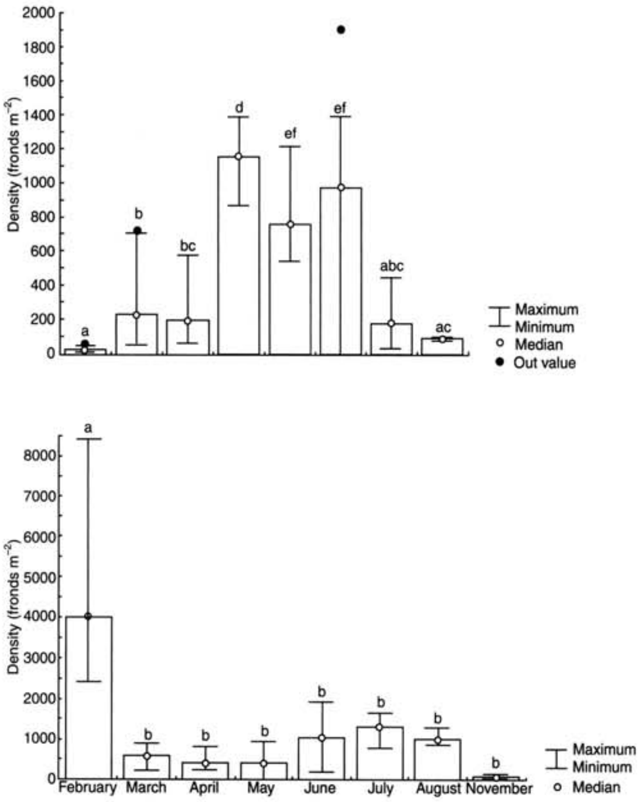

Fig. 4. Density variations (Median and Percentiles) both sites. A) Tide pool; B) Channel. Error bars with different letters are statistically different ($p < 0.05$).

same time the reproductive condition was determined, first the fronds were observed under stereoscopic microscope to evaluate proportion vegetative versus reproductive fronds.

All data were grouping by sites over time in database for analysis. Cover and density parameters statistical analysis was applied first tested for homocedasticity and normality (Zar 1996). In some cases the assumptions were meeting (like in cover) and in others did not (like in density). In the case of height and width we explored the linear relationship between them in each habitat over time and only significant observations are shown.

RESULTS

Our observations showed different population trends at both sites, in particular we notice that *Padina concrescens* population in tide pool was always present (Figs 3A, B). We found progressives changes in cover, were in the tide pool population a peak of cover occurred in May (around 80%, Fig. 3A) which is statistically different from others ($p < 0.05$). The minimum value was observed in August (< 10%) and noticeable increment happen in

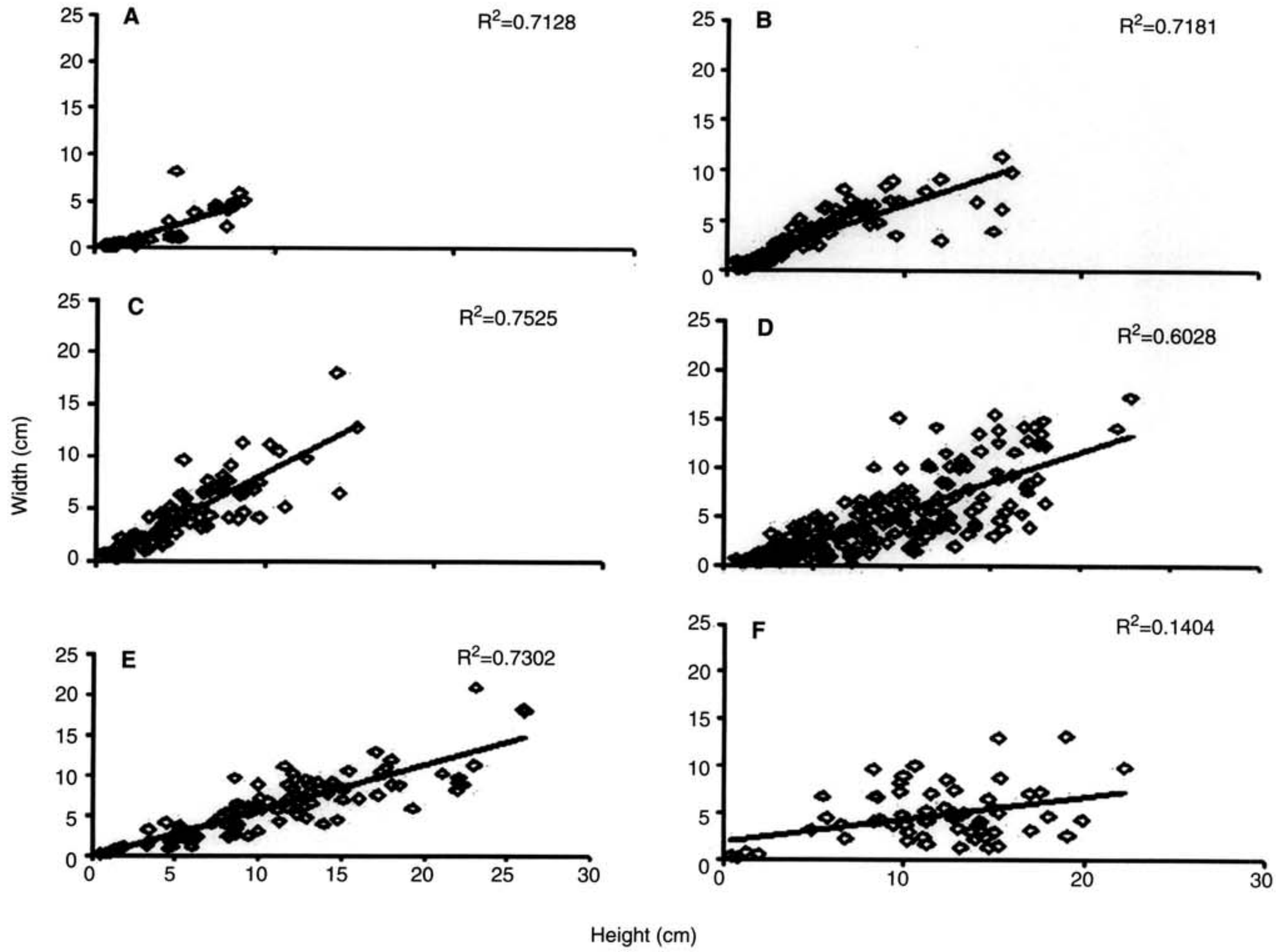

Fig. 5. Height-Width relationship from the tide channel samples showing the persistent relationship of the plants.

November but it was no significant (Fig. 3A). In contrast, the tide channel showed no tendency without a typical month (Fig 3B). Values of cover were higher than in tide pool, with two observed peaks (around 90%), the first one in June and second one in August (Fig. 3A).

In relation to density we found that both sites has progressive abundance (Figs 4A and 4B), but the difference was once again in the amount of fronds at each site, while in tide pool February represents the minimum value with less of 100 fronds m^{-2} in tides channel February has the maximum value different to rest of the months (4000 fronds m^{-2}). Density at tide pools have shown a peak in May (Fig. 4A) but with statistical differences in all the months ($p < 0.05$). In the case of the tide channel we found a consistent decrement from a maximum density in February (Fig. 4B) to November where the lower values were observed, significant difference where observed between February and the other months ($p < 0.05$).

In the case of the development of the thalli, height/width was evaluated over time with significant relationships for most months in the tide channel samples (Fig. 5). Most of the time we found a close relationship in April ($r^2 = 0.7128$), May ($r^2 = 0.7181$), June ($r^2 = 0.7525$) and August ($r^2 = 0.7302$) and a non significant relationship in November (0.1464). In the case of the tide pool, only in March ($r^2 = 0.7366$) and April ($r^2 = 0.7767$) were found a close relationship while in the other sampled months very low values were observed.

In relation to size structure we found a consistent present of small size class plants in most sampled months (Figs 6 and 7). Fourteen size intervals were found, in tide pool size of fronds fall in first eight groups (Fig. 6), while in tide channel the structure is extended to the fourteen (Fig. 7). In the tide pool, size structure in the first 3 months (February to April) were similar with a dominance of the smallest size-class (0-1.99 cm); while in May the medium size class (4-5.99 cm) are the most abundant (Fig. 6D). The structure change again in June with a very similar abundance of the 6 size classes observed while in

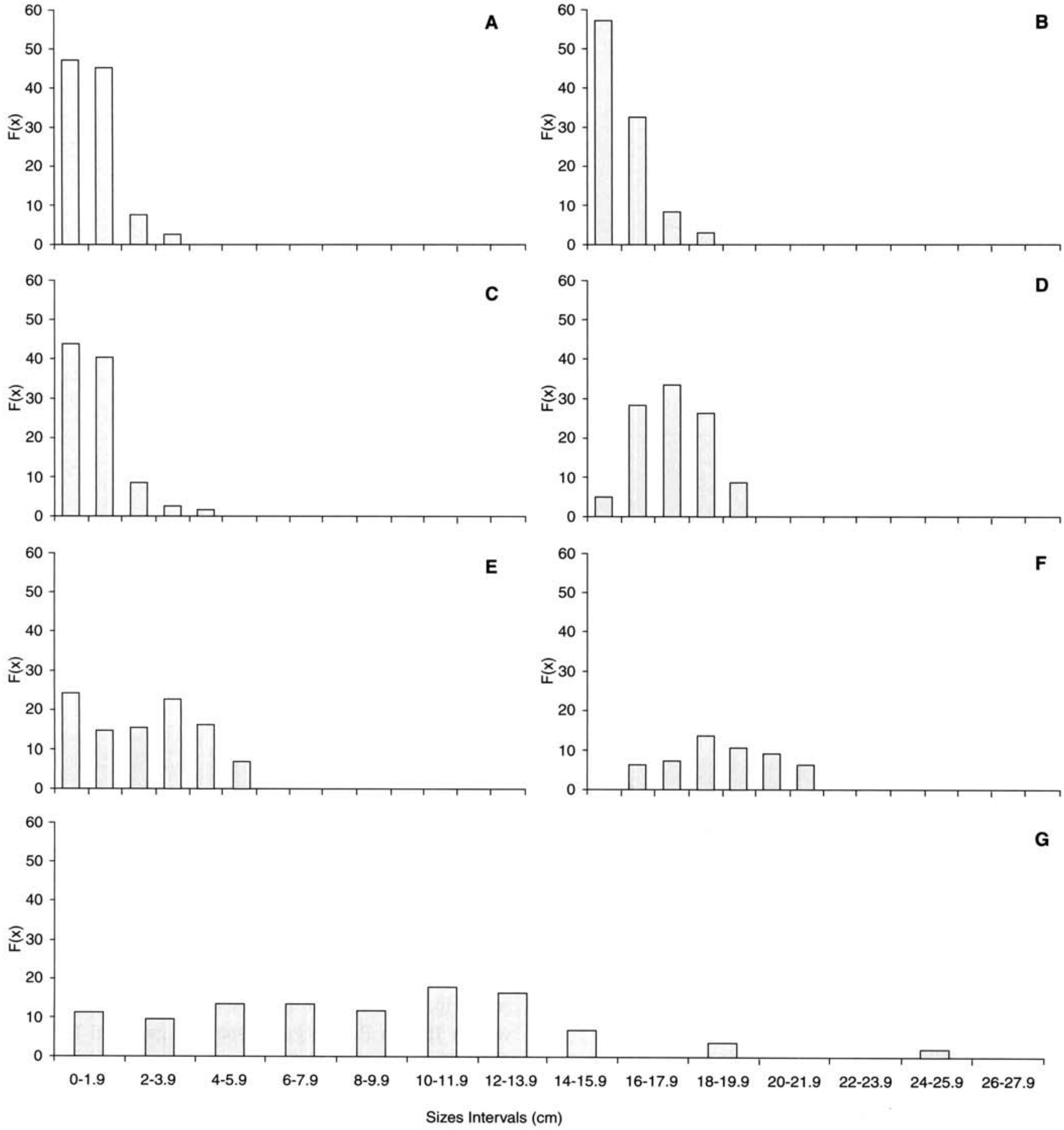

Fig. 6. Size structure in tide pool population. A. February, B. March, C. April, D. May, E. June, F. July, G. August.

July the structure was similar to May (Fig. 6F) and in August the presence of more size classes without a dominant was observed. While in the tide channel, the first three sampled months (April to June) the size class structure were similar with a dominance of the first two size class (0-1.99 and 2-3.99 cm; Figs 7A, 7B and 7C) while the other 3 months (July, August, November) all observed size classes were similar in abundance (Figs 7D, 7E and 7F).

The peak of reproductive fronds occurs in August in both habitats (Figs 8A and 8B) and only tetrasporangial plants were observed. However, the proportion of reproductive fronds in the tide pools was always under 10% (Fig. 8A). While in the channels at least in 2 months June (30%) and August (50%) were highly reproductive (Fig. 8B).

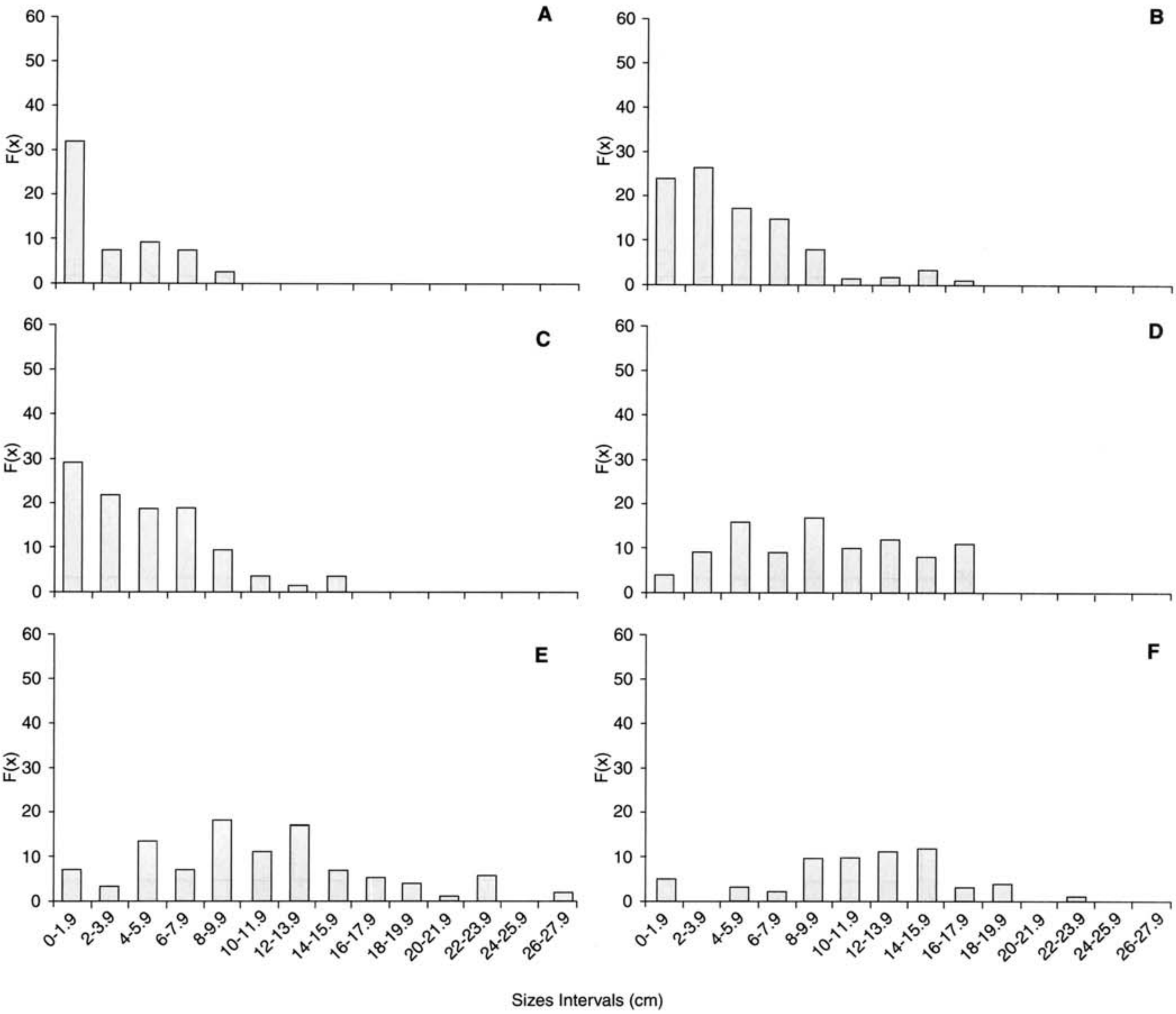

Fig. 7. Size structure in tide channel population. A. April, B. May, C. June, D. July, E. August, F. November.

DISCUSSION

In many population studies of Dictyotales it is common the use of biomass as a population descriptor (King and Farrant 1987; Ganesan 2000; Ateweberhan *et al.* 2005; Paul-Chavez *et al.* 2006). However, the use of density in the present study was a good descriptor and nondestructive strategy. Contrary to the previous studies (King and Farrant 1987; Malabran and Hoffman 1990; Paul-Chavez *et al.* 2006) the population of *P. concrescens* does not have a strong seasonal change in cover and density of the plants (Figs 3 and 4). Paul-Chavez *et al.* (2006) reported that *P. caulescens* population is seasonal, occurring in winter and disappearing in summer. While *P. concrescens* seems to be present all the time but density are lower in winter like in *Padina gymnospora* (Agan and Lehman 2001). The above studies and our results strongly suggest that populations in Dictyotales are not density-dependence as has been shown in Fucales (Ang and De Wreede 1992) but field experiments will confirm this idea.

Liddle (1975) have been found size class differences between tide levels, we agree with the above observations based on the size class structure between the two microhabitat studied (Figs 6 and 7) suggesting a differential survivorship. This differential behavior, it might be related to the environmental stress of the plants (Liddle 1975) showed in the more consistent pattern between height/width in the tide channel (Fig. 5). Over the tide

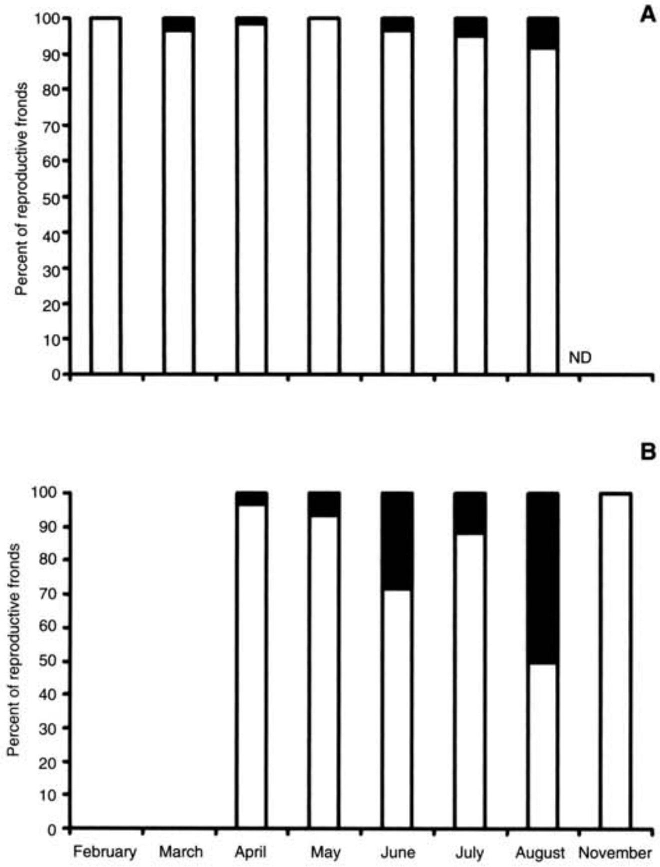

Fig. 8. Temporal variations of reproductive fronds in both sites. A) Tide pool; B) Channel. ■ = Reproductive □ = Vegetative.

pools the force of the current produce more breaking of the plants than in the lower level. The environmental stress it might be related with the low reproductive effort observed in the plants (Fig. 8) and their continuous presence in the same habitat over the years (Riosmena-Rodriguez unpublished information) are more related to overwintering as suggested by Richardson (1979).

Based on our results, we agree with the dominance of tetrasporophyte thalli suggested in previous studies (Foster *et al.* 1972; Allender 1977; King and Farrant 1987) and seems to be related with temperature and survivorship (Liddle 1975; Allender 1977). Also, it seems that each species in Dictyotales have their own reproductive season: some species will reproduce in summer (Montanes *et al.* 2006; our study Fig. 8); other species in autumn (Benson 1986) or winter (Malbran and Hoffman 1990; Paul-Chavez *et al.* 2006) contrary to the idea presented in King and Farrant (1987: 347, Table 1) were most of their studied species reproduce all year around with two exceptions.

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