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Temporal Variation in Size-Class and Tempo-Spatial Variation in Proportion of Reproductive Fronds of *Amphiroa vanbosseae* (Corallinales, Rhodophyta) in the Southwestern Gulf of California, Mexico

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Temporal variation in size class along with temporal and spatial variations in reproductive fronds of *Amphiroa vanbosseae* Lemoine were studied in a shallow population in the southwestern Gulf of California. Thalli were collected monthly from a dense population (3-5 thalli m^{-2} at 2-3 m depth) at El Sargento, BCS, México. Two size-class groups were dominant (50-59 and 60-69 mm) over eight months suggesting very little variation in plant height was present among months. However, when the data were grouped seasonally, the size-class structure showed a trend of bigger plants in spring, suggesting recruitment and mortality were similar over the year with small windows of variation. Temporally, the plants were reproductive all year with a higher proportion of reproductive plants in summer. Spatially, only mature conceptacles were observed in the apical and middle area of the thalli, while in the basal area the plant never became reproductive. However, our observations showed that this population was dominated by bi-tetrasporophyte. *Amphiroa vanbosseae* appears to grow and reproduce all year, but with a maximum in reproduction during summer when other seaweed species disappear due to environmental stress.

Key Words: *Amphiroa vanbosseae*, Corallinales, Gulf of California, Rhodophyta, temporal variation

INTRODUCTION

Geniculate coralline red algae are widely distributed in rocky intertidal and subtidal habitats (Johansen 1981). Some species have shown significant differences in thallus height and density between shallow and deep populations (Johansen and Colthart 1975; Konar 1993) and different recruitment between horizontal and vertical platforms (Goldberg and Foster 2002) in a temperate area. Additional variation in height has been related to geographical (spatial) (Rojas-Pique 1984; Riosmena-Rodriguez and Siqueiros-Beltrones 1995) and seasonal (temporal) changes (Baba *et al.* 1988). Geniculate coralline red algae in one temperate area have seasonal recruitment (Konar and Foster 1992; Goldberg and Foster 2002). This might be related to factors such as light intensity (Algarra and Niel 1987; Goldberg and Foster 2002).

Most of the above studies, however, have been done in temperate areas on species from the subfamily Corallinoidae (Baba *et al.* 1988; Konar and Foster 1992; Konar 1993; Goldberg and Foster 2002). The only previous report from tropical areas is by Lee and Johansen (1984) on *Amphiroa fragilissima* (Linnaeus) Lamouroux and *A. rigida* Lamouroux. This study examined the timing of reproduction, but no other population information was available for this genus. Because of this lack of phenological information on geniculate algae in tropical areas, we investigated temporal variation (months/seasons) of thalli height and explored the spatial (within thalli) and temporal (months/seasons) trends in the reproduction. We hypothesized that *A. vanbosseae* Lemoine would have less seasonal variation in thallus height (representing overlapping of cohorts) and more frequent reproduction as a result of the less variable nature of the tropical areas. Thus, populational changes are related with enviromental features.

Our goals were: 1) Describe the temporal variation in height of the population during the year, 2) determine the spatial variability in reproduction of *A. vanbosseae*, and 3) determine temporal variability in reproduction of

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A. vanbosseae during a year.

MATERIALS AND METHODS

Amphiroa vanbosseae is one of the most common shallow water geniculate coralline red alga in the Gulf of California (Norris and Jonasen 1981; Riosmena-Rodriguez and Siqueiros-Beltrones 1996). The present study was conducted in an extensive population of this species occurs in the southwestern Gulf at El Sargento (Riosmena-Rodriguez and Siqueiros-Beltrones 1996; 24° 05′ N y 109° 59′ 30″ W). *Amphiroa vanbosseae* occurs as understory species beneath of *Sargassum* forests in the region., and was distributed in Sargento in a rocky platform from 1 to 3 m deep. There were 5-6 m^{-2} plants in Sargento but < 1 m-2 present in other populations. During monthly visits 15 thalli were collected using SCUBA, each thalli was bagged individually and transported to the laboratory where they were fixed in a 4% formalin-seawater solution.

In the laboratory, two fronds were randomly selected from each plant to determine the temporal changes in frond height. Height from the holdfast to the top of the plant was measured to the nearest 0.25 mm using a vernier calipers. To determine the spatial variation in conceptacle presence, each frond was divided into three areas: basal (the first intergeniculum above the holdfast), medium (between the basal and the apical) and apical (the last intergeniculum present) areas. Each intergeniculum was decalcified and then dissected under the stereoscope and mounted on a slide for analysis of reproductive status (bi-tetrasporophytic or gametophytic). Temporal (months/seasons) variation in the presence of conceptacles in the intergenicula was calculated using the number of fertile fronds observed per month. Voucher specimens were deposited in the Phycological Herbarium of Universidad Autonoma de Baja California Sur [FBCS].

Monthly and seasonal differences were evaluated statistically. First, normality (Chi-square and Kolmogorov-Smirnov) and homoscedasticity (Barlett test) were evaluated in all the data (Zar 1996). The assumptions were met, and an ANOVA (one way Model I) was used to determine whether significant differences in the size of the population existed as a function of months or seasons ($n = 30$/moth or 90/season, $\alpha = 0.05$). We also used histograms to examine temporal trends (monthly or seasonal) in the size structure of the population. Tempo-spatial variation in reproduction was evaluated using

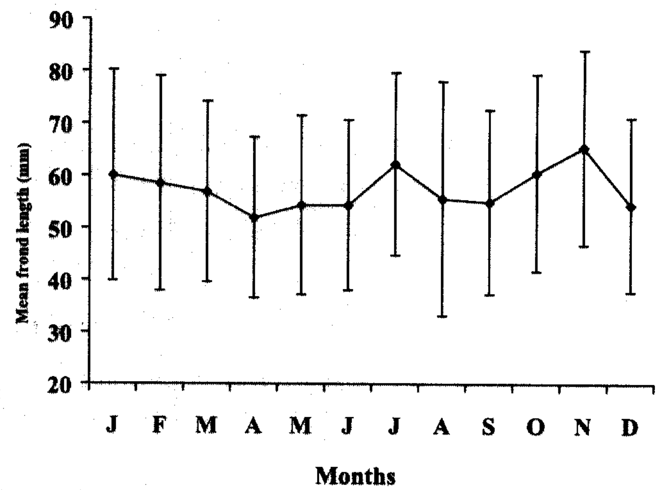

Fig. 1. Frond height (mean ± std err) variation in *Amphiroa vanbosseae*.

the proportion of basal, medium, and apical intergenicula with conceptacles during each month. Finally, to evaluate the potential relationship of temperature or photoperiod with reproduction a Spearman correlation test was conducted ($n = 12$, $\alpha = 0.05$). Water temperature was measured during each visit and photoperiod was estimated based on the sunrise and sunset data in Robles-Gil-Mestre (1998).

RESULTS

Plant height was similar among months (Fig. 1), with the mean varying between 51.9 mm in April and 65.5 mm in November. The standard deviations were similar along the year, with a minimum of 16.3 mm (June) and maximum of 22.4 mm (August). The size-class distribution per month showed that most of the time (8 months) the mode was in the middle of the histogram around the size-classes 50-59 mm and 60-69 mm (Fig. 2). In March, the mode was displaced to the bigger size-class (70-79 mm; Fig. 2). In January, September and November, two distinctive modes were observed in our data (Fig. 2). January presented a mode in 60-69 mm size-class and a similar frequency in 80-89 mm size-class. October showed another pattern with one mode in 50-59 mm and the second in 80-89 mm size-class. There were two modes in October (50-59 mm and 80-89 mm size-class; Fig. 2).

No individuals smaller than 10 mm were observed. The smallest size-class (10-19 mm) was observed in February, August, September, and December (Fig. 2).

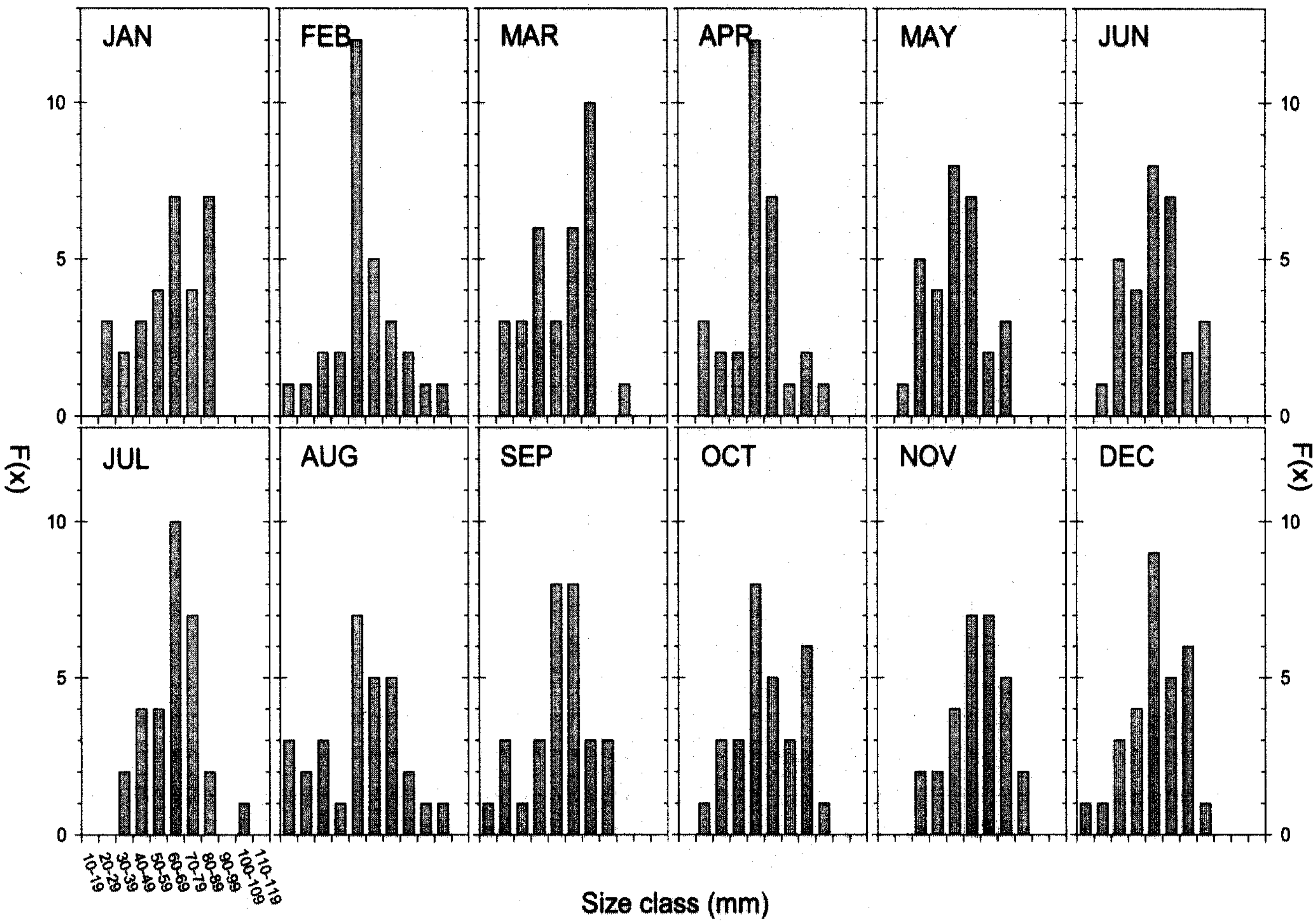

Fig. 2. Monthly size-class histograms in 1994-5 showing that the mode is commonly around the middle size-class.

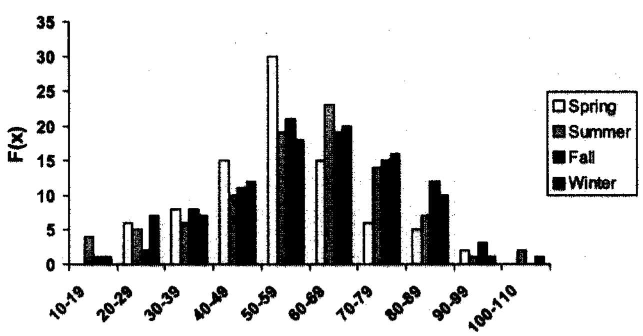

Fig. 3. Size-class histograms grouped by seasons showing that the frequency of individuals are clearly displaced to the lower size-classes in spring.

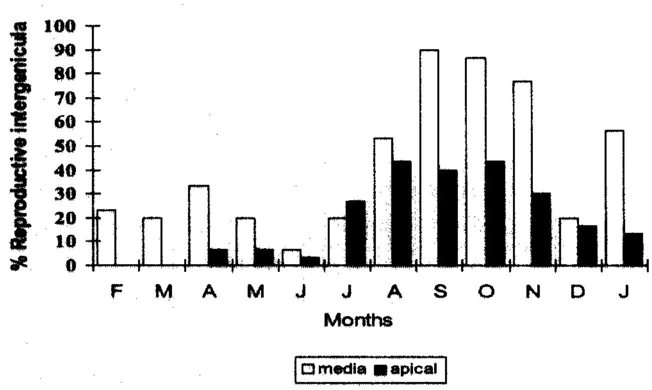

Fig. 4. Tempo-spatial variation in the proportion of intergenicula with conceptacles (m = medial intergenicula, a = apical intergenicula).

The largest size-classes (90-99 mm and 100-109 mm) were present in February, April, May, July, August, October, and November (Fig. 2). Seasonally, during spring and fall the mode was in 50-59 mm size-class, while for summer and winter the mode was 60-69 mm size-class (Fig. 3). In general, the frequencies of individuals in spring were clearly displaced to the lower size-classes. Difference in plant height among months or seasons were not statistically significant.

The spatial variation existed in the intergenicula with conceptacles. From 8 to 90% of the medial intergenicula

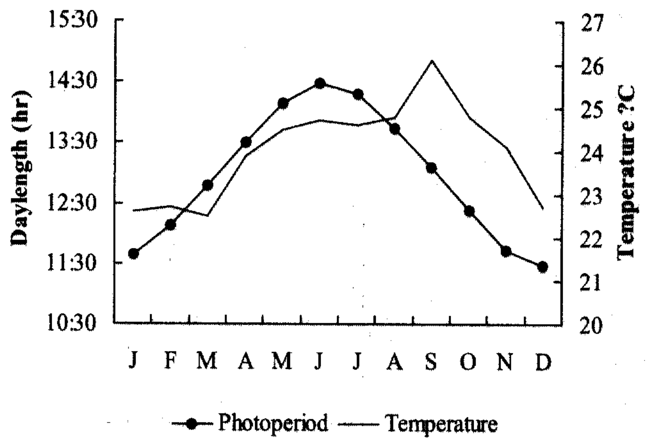

Fig. 5. Temporal variation of water temperature and photoperiod during the study.

possessed, 5 to 45% of the apical intergenicula and no conceptacles were ever observed in the basal intergenicula (Fig. 4). The temporal variation of conceptacles in the apical zone was highest between August and November and lowest from February to July. The trend was similar in the medial intergenicula (Fig. 4). Seasonally, fronds from all sizes were reproductive and only bi-tetrasporangial conceptacles were observed in this population. The Spearman correlation test indicated a significant positive relationship between water temperature (Fig. 5) and the proportion of reproductive intergenicula [r = 0.756; P = 0.004]. The relationship with photoperiod was not significant [r = –0.252; P = 0.430].

DISCUSSION

The lack of variation in height during the year was clearly related to the seasonal size that varied little in time (Figs 1, 3). This pattern, previously described for *Bossiella* sp. Silva and interpreted as continuous recruitment, growth, and mortality (Konar 1993), is supported because the basic structure of the histograms was modified by the presence of individuals of smaller (10-19 mm) and bigger size-classes (70-79 mm) as in February and December (Fig. 2).

The smallest size-class (10-19 mm) appeared more than once in a year suggesting that recruitment is constant. This pattern suggests that in this population cohorts may overlap during the year because there was no difference in size. The above observation is supported by the seasonal trends (Figs 2, 3). The largest size-class (> 70 mm) also had a lower frequency than the mode (Fig. 2) at all times. Konar (1993) found that juvenile (< 5 cm) *Bossiella* sp. were less abundant than adults (> 5 cm). The data for *A. vanbosseae* suggests three age classes: Age 1 (10-39 mm), Age 2 (40-69 mm) and Age 3 (70-119 mm), with the most abundant being in Age 2. The relatively higher abundance of Age 2 perhaps is related to the differential growth rates (in combination with low recruitment and high mortality) between Age 1 and 3. In both cases, the low number of juveniles suggested that recruitment was low and that growth rate and mortality was related to age as in *Calliarthron tuberculosum* (Johansen and Austin 1970). This tropical species showed a similar trend in their population structure as in the temperate species.

Seaweeds show seasonal growth patterns influenced by light, nutrient availability, and water temperature (Norton *et al.* 1981). These environmental factors also influence the distribution of size-classes during the year. In the case of *A. vanbosseae*, 40-59 mm fronds were more abundant in spring. This may represent a stronger recruitment period but this needs to be tested. Our data suggest that higher growth occurs during spring (Fig. 4). This is the season with the maximum photoperiod (Fig. 5) and highest nutrient availability (Alvarez-Borrego 1983).

The conceptacles occurred in the middle and apical sections of fronds with a maximum in summer (Fig. 4). Their absence in the basal interegenicula may be related to their mechanical function of the thalli (Johansen 1969). A major proportion of the conceptacles in the middle, along with the thallus morphology (Fig. 4), might be interpreted as way to protect these structures. Also the growth which occurred in the apical region (Johansen 1981) suggested some inhibition in the conceptacle production. *Amphiroa vanbosseae* appeared to grow and reproduce all year, but with a maximum reproduction during summer when other seaweeds species disappeared due to environmental stress (Riosmena-Rodriguez unpublished data).

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