Effects of season and color variants of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) on the abundance of associated amphipods

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Abstract

Peracarid crustaceans are usually the most abundant animals among the numerous species living in association to seaweeds. In this work we analyze the amphipod families associated to *Kappaphycus alvarezii* in experimental field cultivation at Ubatuba, northern coast of São Paulo State, Brazil, and describe changes in their abundance hierarchy as effect of factors such as season and color of the algal substrate. Four thalli of three different color morphotypes were selected, planted in floating rafts and harvested after 29 days in summer and 35 days in winter. Amphipods were sorted from the collected organisms and identified to family level under binocular microscope. Two-way Multivariate Analysis of Variance was employed on rank-transformed data to verify the effect of season and color of the algal substrate as main factors in accounting for distribution of amphipods. Season affected all amphipod families. Regarding the factor color, abundances were significantly different only for caprellids, with higher values on green thalli.

Key words: amphipod families, phytal, *Kappaphycus alvarezii*, season, color variants.

Introduction

Epifauna inhabiting seaweeds (the 'phytal' communities) consists of a large number of species, with contrasting habits and life-histories (Brawley, 1992). The non-sessile species of the phytal macrofauna (organisms retained by a 500 μm sieve) occur on a wide range of algal species where peracarid crustaceans are among the most abundant (Edgar, 1983a; Viejo, 1999; Tanaka and Leite, 2003). In this relation between algae and animals, algae provide substrate, shelter from water currents and from predation, and also, protection against desiccation during periods of low tide (Edgar and Moore, 1986).

Wild and farmed crops of the seaweed *Kappaphycus alvarezii* (Doty) Doty ex P. Silva (Rhodophyta, Solieriaceae) occur throughout the Indo-Pacific region between 20° North and South latitudes. *Kappaphycus alvarezii* cultivated in the Philippines and Indonesia is the main source of *k*-carrageenan in the world trade (Doty, 1986).

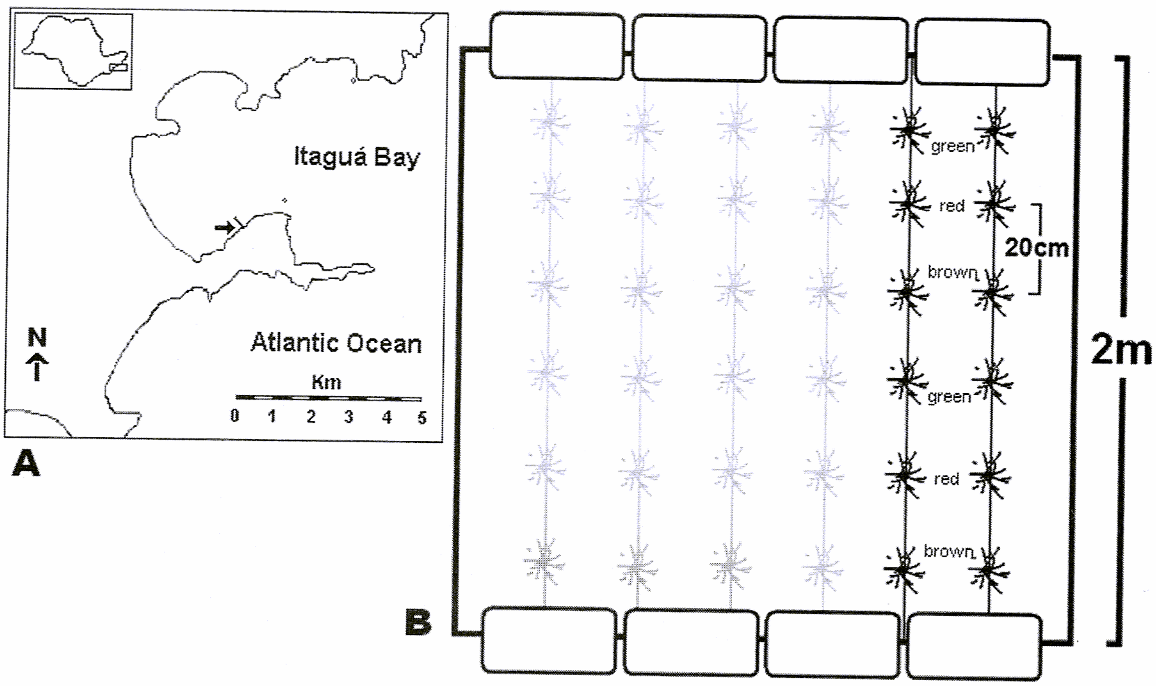
Carrageenans are commercially important polysaccharide colloids with several applications in the human food industry such as ingredients for cakes and flan powders and condiments for salads, gel for the production of toothpastes, animal ration and other uses (Paula *et al.* 1998).

Kappaphycus alvarezii vary greatly in form, as a result of the environment in which they grow (Doty, 1986). Different color morphotypes include green, red and brown variants (Dawes, 1992). Over the last 30 years, strains of *K. alvarezii* from the Philippines have been introduced into several non-native tropical countries (e.g. Ohno *et al.*, 1994, for Japan, and Paula *et al.*, 1998, for Brazil) for mariculture purposes (Doty 1986; Paula *et al.* 1998). In Brazil, Paula *et al.* (1998) set out a careful program to evaluate risks of introduction and commercial feasibility of

K. alvarezii at Itaguá Bay, Ubatuba. For this seaweed, there are no studies referring to the associated amphipods. The present study analyzes the influence of season and color of the algal substrate on the abundance of amphipod families associated to *K. alvarezii* in field cultivation at Ubatuba.

Material and Methods

The study was performed at Instituto de Pesca (Núcleo de Pesquisa do Litoral Norte da Secretaria de Agricultura e Abastecimento do Estado de São Paulo), located at Itaguá Bay (23°26.9' S, 45°0.3' W), Ubatuba town, northern coast of São Paulo State, Brazil (Fig. 1A).



Four healthy thalli of each green, red and brown color variants of *K. alvarezii* were selected from the amount resulting from the experimental cultivation (see Paula *et al.* 1998). With existing fauna previously removed, thalli (initial wet weight = 60g) were systematically tied at 20 cm intervals on two polypropylene ropes, 3,0 m long and held 0,40 m apart, properly furnished with ballast, placed horizontally at a constant depth of 25-35 cm from de sea surface, in a floating raft located 30 m apart from the rocky shore line (Fig.1B). A 3-meter water column separates the raft from a muddy-sandy bottom.

Seaweeds were harvested after 29 days in summer and 35 days in winter. Non-sessile phytal macrofauna was collected by washing each thallus on a 0,5 mm size-graded sieve under running water. The extraction procedure was repeated until no further visible animals remained entangled on the thallus or retained by the sieve. Animals were fixed in 4 % formalin and preserved in 70% alcohol. After collecting phytal macrofauna, we cut and remove new biomass leaving behind the original seaweed thalli (wet weight = 60g) to regrow in the floating rafts for winter samples.

Afterwards, amphipods were sorted into family groups and counted under a binocular microscope. Abundances were standardized to numbers per 100 g algal wet weight. Unfortunately, during winter samples, three brown thalli were lost from the ropes, probably due to strong water currents.

Hierarchical agglomerative cluster analysis was used to have an overview of amphipods distribution. Next, two-way multivariate analysis of variance (MANOVA, Legendre and Legendre, 1998) was employed on rank-transformed abundance of amphipod families to verify the effects of season and color of the algal substrate on the hierarchical abundance of amphipod families. Tukey multiple comparison tests were performed to detect which color morphotype attracted more amphipods. Statistical analyses were performed with MVSP (Warren Kovach, www.kovcomp.com) and SPSS (SPSS Inc., 1989-1999) softwares.

Results

A total of 5498 individuals in summer and 3966 individuals in winter, belonging to Podoceridae, Melitidae, Stenothoidae, Hyalidae, Corophiidae, Ischyroceridae, Ampithoidae and Caprellidae were sampled (Fig.2). Hyalid amphipods were found only in summer with few individuals (n = 12). For this reason, this family was not considered in the analysis. In summer, the highest and lowest densities of amphipods were found on green thalli. In winter, the highest abundances were also concentrated on green morphotype (Fig. 3).

MANOVA showed no significant interaction between season and color of the algal substrate ($p=0.10$). At the univariate level, interaction was marginally significant for ischyrocerids ($p=0.043$). The main factor season was highly significant ($p=0.000$). When families were treated in separate, season affected all amphipod families ($p \leq 0.039$). Within each season, amphipods differed in their abundances among thalli. In summer, podocerids and melitids were the most abundant. In winter, corophiids and ischyrocerids appeared with the highest densities (Fig.2).

Concerning color morphotypes, abundances were significantly different only for caprellids ($p=0.024$), with higher values on green thalli.

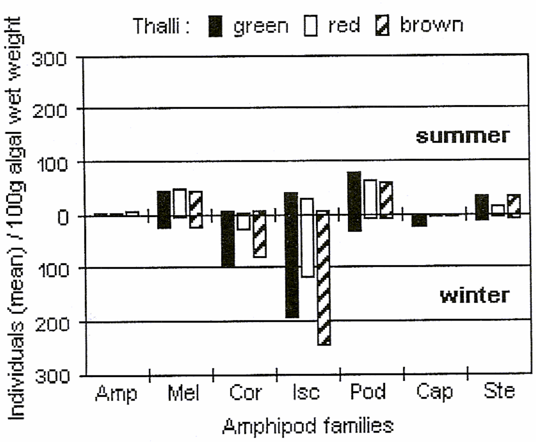


Figure 2: Mean abundance of amphipod families on each thallus

Relative abundances of amphipods (bubbles at nodal cluster, Fig. 3) showed differences between summer and winter samples (Q mode) and between summer and winter amphipod families (R mode). Within each season, differences on abundances between thalli were also detected. In winter, red thalli had the least abundances while in summer thalli with fewer individuals were well spread among the three different color variants.

Podoceridae, Melitidae and Stenothoidae, the most similar families, showed a steady abundance pattern (Fig. 3) along the two studied seasons. On the other hand, Caprellidae and Ampithoidae, which exhibited a seasonal distribution, were the most dissimilar groups comparing to the others.

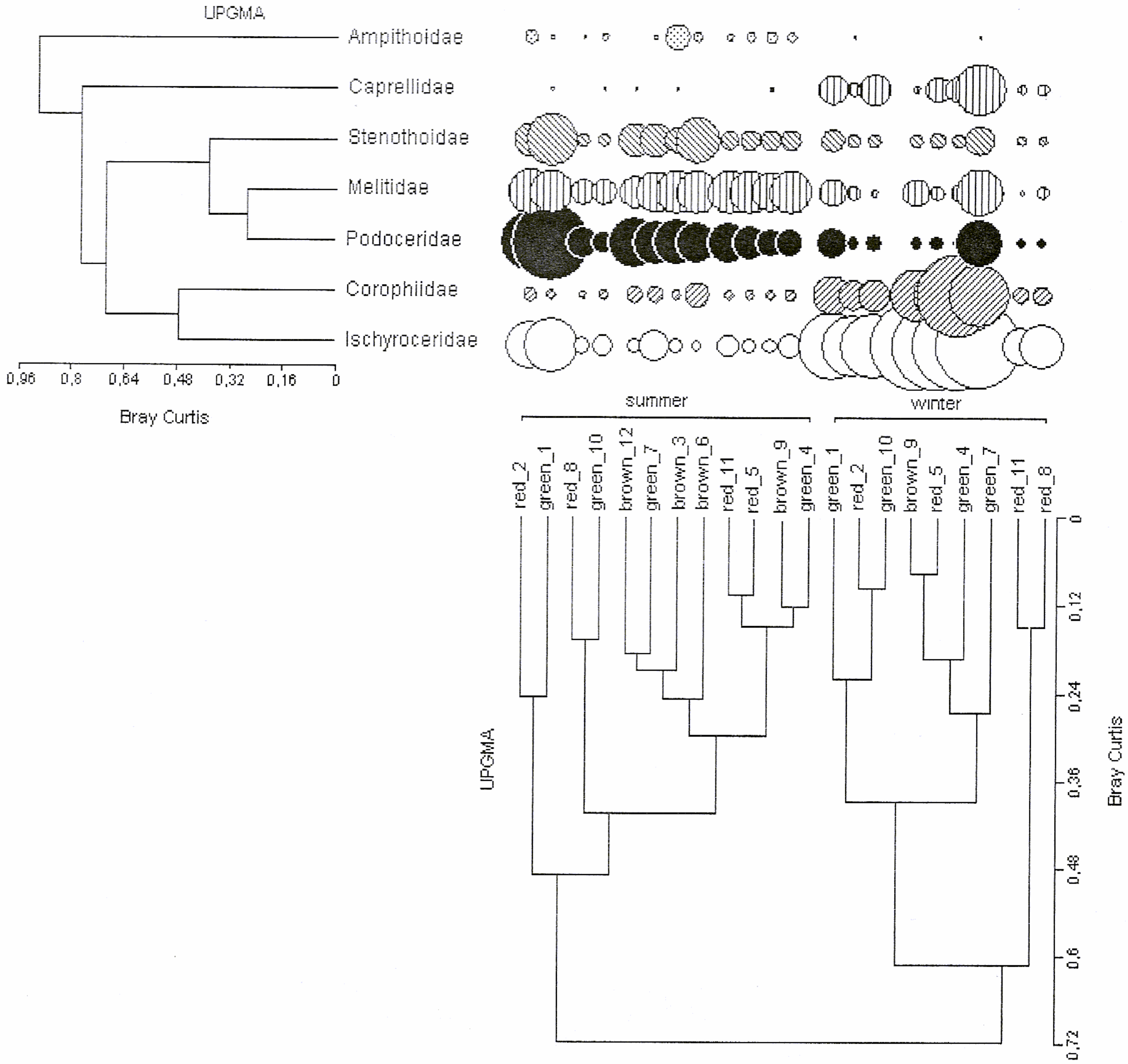


Figure 3: Nodal cluster depicting relations between samples and the relative abundances of amphipods. Numbered labels (Q mode) indicate position of each thallus along the ropes

Discussion

On a study about epifauna colonization (Edgar, 1991), the most rapid increases in animal abundance and species richness occurred between 8 and 24 days of colonization, with a partial leveling off after this period. Accordingly, the 6-day difference of submersion time among summer and winter samples in the phytal macrofauna of *K. alvarezii* seem acceptable.

Seasonality is commonly observed in many phytal communities (e.g. Tararam and Wakabara, 1981; Edgar, 1983b; Edgar and Moore, 1986), where epifaunal abundance fluctuates with predation pressure and food availability. In this preliminary study, the factor season was also significant. Edgar and Moore (1986), Edgar (1990) and Edgar and Aoki (1993) suggested that the seasonal presence of predators might regulate the abundance of amphipods.

Ischyroderidae and Corophiidae, the dominant amphipod families in this study, have been reported in large numbers in association with kelps (see Moore, 1973) and in the phytal macrofauna of *Sargassum stenophyllum* studied by Tanaka and Leite (2003).

We could suspect that *K. alvarezii* produces chemical compounds and presume they differ among color morphotypes, affecting abundance of caprellids. However, according to Teixeira (pers. com.), red macroalgae from the family Solieriaceae might not yield secondary metabolites (polyphenols) as chemical defense against epiphytes (see also Hay and Fenical, 1988). Also, we did not find any information about carrageenan content attracting or repelling macrofauna. Moreover, carrageenan nutritional content does not vary among color morphotypes (Hayashi, 2001).

The feeding habits of caprellids include scraping (remove of encrusting material, e.g. periphyton), browsing filamentous algae, scavenging non-living material like piece of detritus, filter-feeding and even predation (Caine, 1974 and 1977). Thus, the accumulation of this set of organic matter on *K. alvarezii* could be related with the increase in abundance observed for caprellids in winter samples.

Little information was found about the caprellids affinity for green thalli. Caine (1974) reported caprellids cryptic behavior in his work of comparative functional morphology of feeding in three species of caprellids. Thus, we could suggest that green thalli suit better for caprellids associated to *K. alvarezii* at Ubatuba.

Certainly, new experimental studies on the relation between color morphotypes and its effects on epifauna abundance may unravel the affinity of associated caprellid amphipods.

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