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## Association of *Epialtus brasiliensis* Dana, 1852 (Brachyura, Majoidea) with different species of seaweed

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### ABSTRACT

Seaweed aggregates form secondary substrates on rocky shores, providing habitats for phytal organisms such as the spider crab *Epialtus brasiliensis* Dana, 1852. This species is one of the most abundant macroinvertebrate component from seaweed communities. Although the literature suggests that *E. brasiliensis* lives in many species of seaweed, their density has only been reported in communities of *Sargassum* spp. This study assessed the density of the spider crab *E. brasiliensis* associated with the seaweed *Sargassum cymosum* Agardh, 1820, *Hypnea musciformis* (Wulfen) Lamouroux and *Acanthophora spicifera* (Vahl) Borgesen. We expected to observe a higher density of *E. brasiliensis* in *S. cymosum*, which shows greater morphological complexity, followed by *H. musciformis*, with intermediate complexity, and then by *A. spicifera*, with low complexity. We found that the density of these crabs can be as abundant in *H. musciformis* as has been previously reported for *S. cymosum*, but in both species, the density was higher than in *A. spicifera*. Overall, our findings improve the knowledge of the phytal habitats used by *E. brasiliensis* in rocky shore environments.

### KEYWORDS

Majoidea, distribution, habitat complexity, rocky shore.

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## INTRODUCTION

One of the main goals in ecology is to understand the distribution of organisms in the environment (Veiga *et al.*, 2014; Jermacz *et al.*, 2015). Habitat complexity is one of the regulatory factors in organismal differential distribution (Figueiredo *et al.*, 2013; Gartner *et al.*, 2013). In general, habitat complexity influences community dynamics, with higher complexity providing better protection against biotic and abiotic factors and greater availability of food resources (Cacabelos *et al.*, 2010). In marine environments, habitat complexity may be due to physical structure and/or presence of biotic secondary substrates, such as mussels and seaweed (McCoy and Bell, 1991; Kovalenko *et al.*, 2012; Carvalho and Barros, 2017). These organisms, when developed in an aggregate form, change the composition and availability of resources for other taxa, and have been defined as ecosystem engineers (Jones *et al.*, 1994; 1997). Seaweed may also reduce the impacts of predation, desiccation and wave action for animals living in association with them (Borsje *et al.*, 2011).

Among the ecosystem engineers, seaweeds show structural differences, such as distinct morphology, size, volume and number of branches, creating a range of complex environments (McCoy and Bell, 1991; Veiga *et al.*, 2014). Mobile rocky shore species may seek refuge in seaweed beds, using seaweed as habitat (Williams and Seed, 1992; Clarkin *et al.*, 2012). Crowe (1996), Blanco *et al.* (2011) and Clarkin *et al.* (2012) demonstrated that, due to their structural complexity, seaweeds show higher abundances of associated animals than bare rock surfaces.

The spider crab *Epialtus brasiliensis* Dana, 1852 is a phytal organism that inhabits the intertidal zone up to a depth of 10 m. They are frequently found associated with seaweed on hard substrates (Negreiros-Fransozo and Fransozo, 1991; Mantelatto and Correa, 1996; Melo, 1996; Barros-Alves *et al.*, 2018). This spider crab has a sharp dactyl curved inward on each pereopod, which provides better grip onto the seaweed and prevents dislodgement by the force of water (Castaño and Campo, 2003). On the Atlantic coast, *E. brasiliensis* are distributed from northern Florida, USA to the Rio Grande do Sul, southern Brazil (Rathbun, 1925; Tamburus and Mantelatto, 2012). Reports have shown that these spider crabs are preyed upon by rocky shore

fish, such as *Stephanolepis hispidus* Linnaeus, 1766 (Dubiascki-Silva and Masunari, 2008) and octopus *Octopus insularis* Leite and Haimovici, 2008 (Batista and Leite, 2016; Leite *et al.*, 2016). Furthermore, *E. brasiliensis* may constitute the majority of the benthic epifauna in seaweed communities (Barros-Alves *et al.*, 2018).

*Epialtus bituberculatus* Edwards 1874 was previously morphologically differentiated from *E. brasiliensis* due to the presence of a spine on the ventral surface of the propodus of their ambulatory pereopods (a key diagnostic character). Even so, species differentiation is characterized as difficult and raises questions. Specifically, the distribution or misidentification of specimens may be due to similarities in morphological characteristics because they share the same habitat (see Tamburus and Mantelatto, 2016). Recently, however, their morphological and phylogenetic analyses unified both species as *E. brasiliensis*, and thus we used this classification here.

Despite the wide geographic distribution along the western Atlantic coast, their ecological potential as prey and their preponderance in seaweed communities, little is known about the life history, diet and habitat diversity of the spider crab *E. brasiliensis*. The species has been mostly reported to be associated with *Sargassum* spp. communities (see Negreiros-Fransozo and Fransozo, 1991; Mantelatto and Correa, 1996; Széchy and De Paula, 2000; Cobo and Barros, 2009; Barros-Alves *et al.*, 2013; Barros-Alves *et al.*, 2018). In habitats constituted by *Sargassum cymosum* Agardh, 1820, *E. brasiliensis* may reach densities of 1.27 to 34.67 individuals per liter (Barros-Alves *et al.*, 2013). *Epialtus brasiliensis* has also been reported to occur in association with other seaweed genera, such as *Acanthophora* sp., *Hypnea* sp. and *Padina* sp. (see Negreiros-Fransozo and Fransozo, 1991; Melo, 1996; Masunari *et al.*, 1998), but nothing is known about their density among other seaweed species. Considering that the density of *E. brasiliensis* is unknown in other habitats, the real importance of this spider crab in phytal communities is likely underestimated.

On the southeast Brazilian coast, *Epialtus brasiliensis* associates with the seaweed *Sargassum cymosum*, *Hypnea musciformis* (Wulfen) Lamouroux and *Acanthophora spicifera* (Vahl) Borgesen (Negreiros-Fransozo and Fransozo, 1991; Barros-Alves *et al.*, 2013). The seaweed

*S. cymosum* has a robust and bushy frond that can reach up to 60 cm in length, a thallus that can differ in cauloid, phylloid and appressory characters and phyllodes that are non-branched lanceolate, with a smooth edge that contain small teeth (Nassar, 2012). *Hypnea musciformis* shows a branched-cylindrical thallus with hook-shaped endings (tendrils) that can reach 20 cm in length (Nassar, 2012). *Acanthophora spicifera* shows a short and branched-cylindrical thallus that can reach 10 cm in length (Nassar, 2012). Based on the morphological characteristics of these three species, such as their size and branching, these seaweeds can be ordered in a gradient of complexity in which *S. cymosum* is more complex than *H. musciformis*, followed by *A. spicifera* (Carvalho and Barros, 2017).

Herein, our goal was to test whether the density of *E. brasiliensis* varies according to the seaweed species with different levels of morphological complexity. Considering that pronounced habitat complexity can provide better protection and greater resource abundance, our expectation was to find a higher density of *E. brasiliensis* in the morphologically-most complex seaweed *S. cymosum*, followed by *H. musciformis* and lastly by *A. spicifera*.

## MATERIAL AND METHODS

Since the abundance of crabs could be influenced by the frond size regardless of the seaweed species (Leite *et al.*, 2007; Barros-Alves *et al.*, 2018), we added seaweed volume as a co-factor in our analysis. The density of crabs ( $d$ ) was calculated as the total number of *E. brasiliensis* individuals divided by the total seaweed volume (in L); it was expressed as individuals/L. Thus, we were able to test whether the density of *E. brasiliensis* varies among species of seaweed, regardless of the morphological complexity of the seaweed. Crabs and seaweed were collected in the mesolittoral fringe of a sheltered rocky shore from Enseada (23°26'29"S 45°04'34"W) and Lamberto (23°29'55"S 45°07'3"W) beaches, Ubatuba, São Paulo, southeastern Brazil. Samples were collected during low tide in April 2013. Previous studies demonstrated that crab density and seaweed volume may vary throughout the year (Masunari *et al.*, 1998; Barros-Alves *et al.*, 2013; 2018). Thus, we standardized the collection of

crabs and target seaweed species in the same month to avoid the interference of seasonal factors in our model.

We followed Dethier *et al.* (1993) in using fifty-six 10 x 10 cm squares to delimit sampling of the target seaweed species. Whole seaweed thalli were collected from the substrate with a spatula and packed inside plastic bags. Samples were frozen prior to laboratory analysis. In the laboratory, samples were thawed and individually examined under a stereomicroscope by screening all associated organisms. All samples were subsequently preserved in 10% formalin. Crabs were counted and identified to the species level according to Tamburus and Mantelatto (2016). After screening, seaweeds were identified according to Joly (1967) and their volume was measured by water displacement in a graduated cylinder, according to Montouchet (1979).

We used a zero-inflated generalized linear model (GLM) to evaluate whether the density of *E. brasiliensis* between seaweed species was influenced by seaweed volume. The dependent variable was the count data of *E. brasiliensis* density. Seaweed volume and species (three levels: *S. cymosum*, *H. musciformis*, and *A. spicifera*) were fitted as predictor factors. Data were fitted to a binomial distribution with a logit link function, and the overdispersion parameter was checked in the model. When relevant, post-hoc evaluations for all comparisons at the different levels between factors were performed. We provided results from the estimated best model (with the lowest AIC; Burnham and Anderson, 1998). The GLM analysis was performed in R (R Core Team 2018), using the package MASS (Venables and Ripley, 2002) and *lsmeans* (Lenth, 2016) for post-hoc comparisons.

## RESULTS

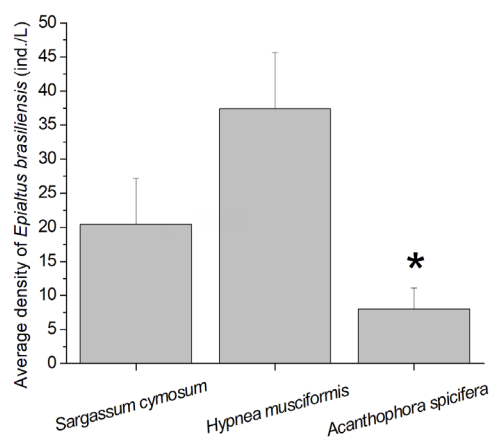
The density of the spider crab *Epialtus brasiliensis* as a function of volume differed between seaweed species (GLM test; Tab. 1). The highest density of *E. brasiliensis* (mean  $\pm$  standard error) was  $37.39 \pm 8.27$  individuals/L observed on *Hypnea musciformis*, which did not differ from  $20.47 \pm 6.71$  individuals/L on *Sargassum cymosum* (Tukey test:  $p = 0.98$ ; Fig. 1). However, the density of both species differed from that on *Acanthophora spicifera*, on which *E. brasiliensis* showed  $8.02 \pm 3.07$  individuals per liter (Tukey test:  $p < 0.005$ ; Fig. 1). In both *H. musciformis* and *S. cymosum*, the density

of *E. brasiliensis* varied from 0 to 250 individuals/L, whereas the variation observed on *A. spicifera* was from 0 to 100 individuals/L. The volume of seaweed samples ranged from 3 to 50 mL (mean: 23.78 mL)

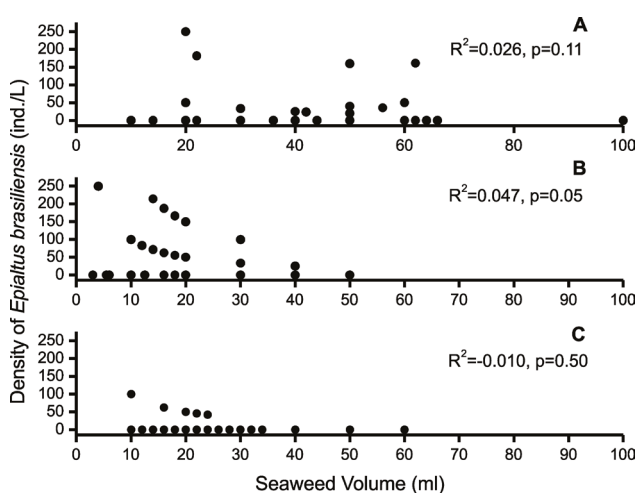
for *H. musciformis*, 10 to 100 mL (mean: 39.75 mL) for *S. cymosum* and 10 to 50 mL (mean: 20.73 mL) for *A. spicifera*. No relationship was observed between the volume of algae and the density of the crabs (Fig. 2).

**Table 1.** *Epialtus brasiliensis* density between the seaweed *Sargassum cymosum*, *Hypnea musciformis* and *Acanthophora spicifera*, according to GLM analysis. Density of *E. brasiliensis* was compared between treatments, according to the influence of seaweed species (categorical variable) and seaweed volume (continuous variable). Asterisks indicate a significant difference ( $p < 0.001$ ) according to the GLM analysis.

Factor	Df.	X <sup>2</sup>	p
Density of <i>Epialtus brasiliensis</i>			
Seaweed species	2	141.78	<0.0001*
Volume	1	290.42	<0.0001*
Seaweed species * Volume	2	70.28	<0.0001*



**Figure 1.** Mean density ( $\pm$  standard error) of the spider crab *Epialtus brasiliensis* among the seaweed *Sargassum cymosum*, *Hypnea musciformis* and *Acanthophora spicifera*. Asterisks indicate a significant difference ( $p < 0.005$ ) according to the GLM analysis, in which the average density of the spider crabs was compared between the seaweed species, which were considered to influence the seaweed volume.



**Figure 2.** Linear regressions between density of the spider crab *Epialtus brasiliensis* and the seaweed volumes. A, *Sargassum cymosum*; B, *Hypnea musciformis* and C, *Acanthophora spicifera*.

## DISCUSSION

The spider crab *Epialtus brasiliensis* showed a higher occupation diversity in phytal habitats than has been previously reported (e.g., Negreiros-Fransozo and Fransozo, 1991; Mantelatto and Correa, 1996; Széchy and De Paula, 2000; Cobo and Barros, 2009; Barros-Alves et al., 2013; 2018). Herein, we showed that this species can live in the seaweed *Sargassum cymosum*, *Hypnea musciformis*, and *Acanthophora spicifera*. We showed that their density in *H. musciformis* habitats can be as high as that which, until now, has only been described for *S. cymosum* habitats. Although a higher density of these crabs was more frequently observed in *H. musciformis* and *S. cymosum* than in *A. spicifera*, we demonstrated that such variation is not directly associated with the structural complexity of the seaweed.

In the present work, we found the highest density of *E. brasiliensis* that has ever been reported, reaching a maximum of 250 individuals per liter (ind./L). In habitats composed of the seaweed *H. musciformis* and *S. cymosum*, the spider crab *E. brasiliensis* showed a mean density of 37.39 and 20.47 ind./L, respectively. These values are higher than those reported for *E. brasiliensis* by Barros-Alves et al. (2013) in *S. cymosum* on the beaches of Domingas Dias and Praia Grande at Ubatuba Bay – São Paulo State (minimum and maximum: 3.11 to 34.67 and 1.27 to 25.45 ind./L, respectively) and Barros-Alves et al. (2018) (mean: 12.10 and 5.97 ind./L, respectively). In Guaratuba Bay – Paraná State, Masunari et al. (1998) noted *E. brasiliensis* density ranging from 0.74 to 12.24 ind./L in a mixed assemblage of seaweed.

The high densities of spider crabs in the present work can be explained by a taxonomic bias. Until recently, *E. brasiliensis* and *E. bituberculatus* were considered distinct species, but here, we considered them as a single species (*sensu* Tamburus and Mantelatto, 2016). In the present study, when we separately considered the density of the *sensu* morphotype called *E. brasiliensis*, we found mean densities of 19.97, 12.67 and 6.32 ind/L in habitats composed of *H. musciformis*, *S. cymosum*, and *A. spicifera*, respectively. Thus, even when considering the two morphotypes separately, the mean density of *E. brasiliensis* in this work was the highest ever described in habitats composed of *H. musciformis* and *S. cymosum*. Alternatively, the high density of *E. brasiliensis* observed in our study could be explained by hydrodynamics because our samples come from sheltered rocky shores. Indeed, Barros-Alves *et al.* (2018) reported that the density of this species is higher in more protected areas. Future studies may investigate this hypothesis by comparing sheltered and exposed rocky shore phytal habitats.

*Sargassum cymosum* are more complex than *H. musciformis*, followed by *A. spicifera* (Leite *et al.*, 2007; Costa *et al.*, 2012; Nassar, 2012), so it is expected that more complex environments, such as *S. cymosum*, would exhibit a higher abundance of spider crabs (Gartner *et al.*, 2013). Usually, larger seaweed volumes are associated with greater complexity and consequently, a higher number of organisms (Hacker and Steneck, 1990; Curvelo and Corbisier, 2000; Gartner *et al.*, 2013). This pattern was not, however, supported in the present study, since the density of *E. brasiliensis* was the same in *S. cymosum* and *H. musciformis*, the former of which had an intermediary volume among the analyzed seaweed species. Although less complex than *S. cymosum*, the seaweed *H. musciformis* has high nutritional value (Duffy and Hay, 1991; Stachowicz and Hay, 1999; Siddique *et al.*, 2013), a feature that could explain the high density of *E. brasiliensis* in these seaweed species. Biological and ecological studies about these spider crabs are necessary to better understand why *E. brasiliensis* occurs at a higher density in *H. musciformis* and *S. cymosum* compared to *A. spicifera*. In this sense, future investigations of *E. brasiliensis* diet, their choice of different phytal habitats or their susceptibility to predators among different seaweed beds could help clarify this issue.

We observed no relationship between the volume of algae and the density of the crabs. Barros-Alves *et al.* (2018) also found that *E. brasiliensis* density was not directly associated with seaweed volume. During seasonal periods, when seaweed shows a dense and complex architecture, some generalist and opportunistic species of Panopeidae and Pilumnidae crabs may use these phytal habitats as foraging areas, thus modifying the structure of *E. brasiliensis* assemblages (Barros-Alves *et al.*, 2018). Our data also corroborated the hypothesis in which the density of *E. brasiliensis* may be favored when seaweed beds show low structural complexity; in our study, high densities of *E. brasiliensis* were observed in samples composed of small-sized seaweed, whose volumes varied from 3 to 100 mL. Therefore, as in Barros-Alves *et al.* (2018), we found that the density of *E. brasiliensis* was not directly associated with seaweed volume. The low structural complexity (small size) of seaweed can support a high density of these crabs.

In conclusion, we improved the knowledge of the phytal habitats used by the spider crab *E. brasiliensis*. The density of these crabs can also be abundant in other seaweed species (*H. musciformis*), as previous works had only reported for *S. cymosum*, but the density is not associated with the structural complexity of seaweed species. Our findings will help future studies to consider a greater diversity of phytal habitats of *E. brasiliensis* and, therefore, clarify the role of these crabs in seaweed communities.

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