Iheringia
Série Zoologia

e-ISSN 1678-4766
www.scielo.br/isz

Museu de Ciências Naturais
Fundação Zoobotânica do Rio Grande do Sul

Seasonal variation of the crustacean fauna in the belowground and aboveground strata in a *Halodule wrightii* meadow of northeastern Brazil

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Received 25 April 2017
Accepted 08 November 2017

DOI: 10.1590/1678-4766e2017048

ABSTRACT. The different microhabitats provided by seagrasses and the habit of the species determinate the vertical distribution of crustaceans. This study verified the influence of the seasonality on the spatial distribution of the crustacean community associated with a *Halodule wrightii* meadow. From April 2006 to July 2007, we performed fifteen samplings in Goiabeiras Beach, Ceará State, each with five sectioned replicates in belowground and aboveground. Cumaceans and the amphipod *Hyale media* (Dana, 1853) had a higher frequency, density, and dominance than the other taxa, in both strata. The community exhibited gradual changes along the study, in both the belowground and aboveground strata, but the seagrass structure was not sufficient to explain the vertical distribution of the crustacean fauna along the time.

KEYWORDS. Seagrass, shoal grass, benthic communities.

RESUMO. Variação sazonal da fauna de crustáceos nos estratos subterrâneo e aéreo em uma pradaria de *Halodule wrightii* do nordeste do Brasil. Os diferentes microhabitats proporcionados pelas pradarias marinhas e o habito das espécies determinam a distribuição vertical de espécies de crustáceos. Este estudo verificou a influência da sazonalidade sobre a distribuição espacial da comunidade de crustáceos associada a uma pradaria de *Halodule wrightii*. De abril de 2006 a julho de 2007, foram realizadas 15 amostragens na praia das Goiabeiras, estado do Ceará, em cada uma com cinco amostras seccionadas em partes aérea e subterrânea. Cumáceos e o anfípode *Hyale media* (Dana, 1853) tiveram a maior frequência, densidade e dominância em relação a outros táxons, em ambos os estratos. A comunidade exibiu mudanças graduais ao longo do estudo, em ambos os estratos aéreo e subterrâneo, mas a estrutura da pradaria não foi suficiente para explicar a distribuição vertical da fauna de crustáceos ao longo do tempo.

PALAVRAS-CHAVE. Pradarias marinhas, capim marinho, comunidades bentônicas.

Seagrasses are marine angiosperms that provide a tri-dimensional habitat for benthic organisms, with a canopy along the water column and a root system that penetrates the sediment (Orth *et al.*, 1984; Hemminga & Duarte, 2000; Nakaoka, 2005; Björk *et al.*, 2008). Thus, these habitats are used in several ways, with algae and animals attached to the leaf surface (epiflora and epifauna), dispersed along the bottom (epibenthic organisms), or in the sediment (infauna) (Nakaoka, 2005). The settlement of these organisms attracts visiting groups, especially fish shoals and large herbivores, and promotes increased productivity in the ecosystem (Zieman & Zieman, 1989; Nakaoka, 2005; Björk *et al.*, 2008).

In general, studies on the macrofauna associated with seagrasses address different groups of the benthic fauna (Corbisier, 1994; Jernakoff & Nielsen, 1998; Nakaoka *et al.*, 2001; Bologna & Heck Jr., 2002; Harriage *et al.*, 2006; Rosa & Bemvenuti, 2007; Barros & Rocha-Barreira, 2009/2010). Few studies are still realized on specific faunal assemblages, such as molluscs (Toyohara *et al.*, 1999; Alves & Araújo, 1999; Costa & Ávila, 2001; Creed & Kinnupp, 2011; Barros & Rocha-Barreira, 2013; Barros *et al.*, 2013), polychaetes (Bone & San Martín, 2003; Omena & Creed, 2004), nematods (Da Rocha *et al.*, 2006) and crustaceans (Garcia *et al.*, 1996).

Despite of the few specific surveys in seagrass meadows, crustaceans are one of the main groups of seagrass meadows, also composing most of the benthic macrofauna associated with these substrates (Kikuchi, 1974; D'Incao, 1982; Phillips & Meñez, 1988; Garcia *et al.*, 1996; Hemminga & Duarte, 2000; Nakaoka *et al.*, 2001; Nakaoka, 2005; Harriage *et al.*, 2006). Moreover, amphipods, copepods and shrimps are important components of the diet of fishes, including species that are commercially and recreationally important (HEMMINGA & DUARTE, 2000).

Many species of crustaceans settle on the meadows after the larval stage and remain there until reaching the adult phase (HEMMINGA & DUARTE, 2000; NAKAOKA, 2005; BJÖRK *et al*., 2008). They include a diversity of forms of organisms that can live in different habitats provided by these plants, as the sediment rich in organic matter and the surface of the stable sediment provided by the rhizome/root system, and also the leaves canopy, which can offer food and more stable environmental conditions (ABELE, 1974; ZIEMAN & ZIEMAN, 1989; GAMBI *et al*., 1995; HEMMINGA & DUARTE, 2000; WILLIAMS & HECK, 2001).

Thus, the literature suggest that the different microhabitats provided by the seagrass added to the species habits are sufficient to determinate the vertical distribution of the crustacean species. The aim of this study was to observe the influence of the seasonality on the crustacean community associated with the belowground and aboveground strata of a *Halodule wrightii* Ascherson meadow of the semiarid coast of northeastern Brazil.

MATERIAL AND METHODS

Study Area. Goiabeiras beach (03°41'31"S 38°34'49"W) is located to the east of the Ceará river outfall, Fortaleza, state of Ceará (Fig. 1), on the semiarid coast of northeastern Brazil.

Beach rocks cover an area of approximately 500 m parallel to the coast, where macroalgae banks cohabit with a small meadow of the seagrass *Halodule wrightii*, with a maximum width of around 30 m. The meadow is regularly immersed during low spring tides (BARROS & ROCHA-BARREIRA, 2014). The local climate is rainy tropical with a long dry season – Aw' (KÖPPEN, 1948). The rainy season occurs between February and May, with weak winds intensifying in the dry season, between August and November (MORAIS *et al*., 2006).

Fieldwork and material processing. Fifteen monthly samplings were performed from April 2006 to July 2007, each with five random replicates, collected with the help of a core (0.0078 m^2) buried at 10 cm. The number of samples was determined after the elaboration of a performance curve for the macrofauna groups from a previous sampling. The subsequent samplings took into account the size of the small seagrass meadow studied here, as recommended by DUARTE & KIRKMAN (2001), using a sampling design based on BURDICK & KENDRICK (2001) for patched meadows. Each core was sectioned in belowground and aboveground, the former of which included a thin upper layer (smaller than 0.5 cm) of the sediment.

The samples were transported to the Laboratório de Zoobentos do Instituto de Ciências do Mar, Universidade Federal do Ceará (Brazil) and washed in running water with a 0.5 mm sieve to retain the macrofauna. Specimens were preserved in a 70% alcohol solution, and the crustacean fauna was subsequently identified in the Laboratório de Carcinologia da Universidade Federal de Pernambuco to

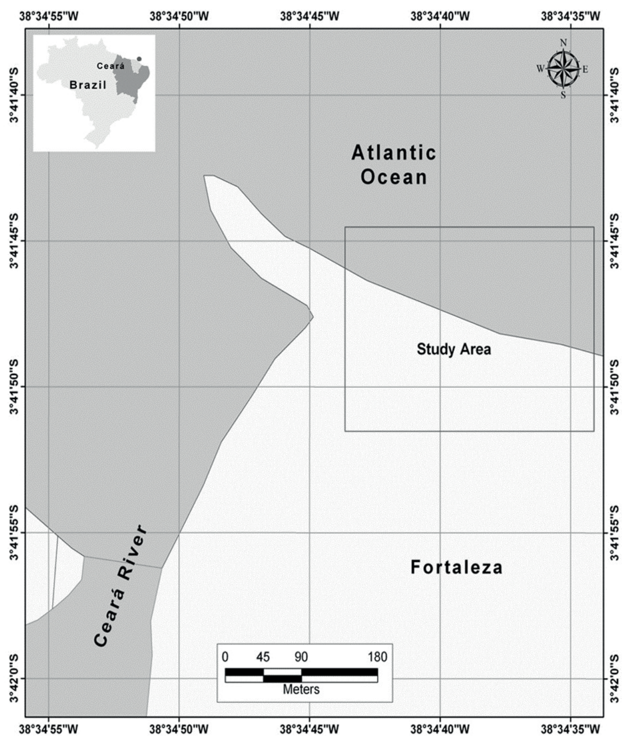

Fig. 1. Location of study area. Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil.

the lowest possible taxonomic level, excepting cumaceans and mysids, due to the lack of taxonomists.

Statistical analysis. We determined frequency of occurrence (F<10% - rare; 10%< F< 40% - few common; 40%< F< 70% - common; F>70% - more common), density (specimens per grams of dry weight of *H. wrightii*), and species dominance for the belowground and aboveground strata, in the dry and rainy seasons. We also obtained the Shannon diversity and Pielou evenness indices, which were submitted to a two-way ANOVA in order to observe the isolated and combined effects of the vertical distribution in the meadow (below/aboveground stratum), and seasonality (dry/rainy period).

Bray-Curtis analyses were performed to determine similarities among the samples of crustacean fauna in each stratum of the seagrass meadow, using the abundance of the species, previously transformed in log (x+1). After obtaining the graph of similarity (Cluster), the groups of samples with more than 40% of similarity were compared using the similarity percentage (SIMPER) analysis to determine the taxa that favoured similarity among the samples. An analysis of similarity (ANOSIM) was performed to determine the significance of seasonal variations in the groups of samples in each stratum.

These analyses (diversity, evenness, Bray-Curtis, SIMPER and ANOSIM) were performed with the aid of the Primer® (Plymouth Routines in Multivariate Ecological Research) programme, 6.1.6 version. The two-way ANOVA was obtained with the STATISTICA® programme (7.0 version).

RESULTS

A total of 1,477 specimens of 28 taxa were captured, belonging to the orders Amphipoda, Isopoda, Tanaidacea, Decapoda, Cumacea, and Mysidacea. Cumaceans were the most abundant group, accounting for 50% of the crustacean fauna, followed by amphipods (42%). Isopods, brachyurans, and tanaidaceans each accounted for 1% of the community.

All taxa occurred in both strata, except mysids and brachyurans that occurred only in the aboveground stratum. Cumaceans and amphipods were more abundant in the belowground stratum, whereas isopods and tanaidaceans were more abundant in the aboveground stratum (Fig. 2). Amphipods of the family Megaluropidae and *Photis* sp. were only associated with the belowground. Brachyuran juveniles and adults were associated exclusively with the aboveground stratum, but the megalops were captured in the belowground stratum during the dry season (Tab. I).

The amphipods *Hyale media* Dana, 1853 and *Ampithoe ramondi* Audouin, 1828 were the most frequent taxa in the belowground stratum, whereas *Microphoxus uroserratus* Bustamante, 2002 was the most frequent taxa in the aboveground stratum.

Hyale media was dominant during the dry season in both the belowground (41.7%) and aboveground (37%) strata, whereas cumaceans dominated during the rainy season in these respective strata (70.9% and 86.3%). In the belowground stratum, cumaceans were the densest taxon during both the dry (0.96 ind/g) and rainy (6.27 ind/g) seasons. In the aboveground stratum, cumaceans (16.9 ind/g) and *H. media* (10.3 ind/g) were the densest taxa in the dry season and cumaceans were the densest in the rainy season (59.9 ind/g). Among the community descriptors, despite of the variation found the seasonality significantly influenced only on the evenness (Fig. 3).

Although some species occurred in both strata, the similarity analysis indicated gradual changes in the crustacean fauna throughout the study occurring almost simultaneously

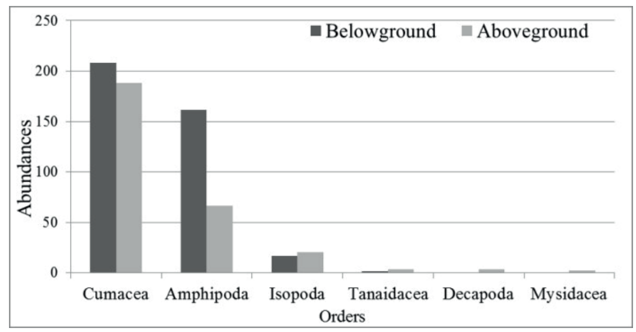

Fig. 2. Abundance of crustacean fauna captured in belowground and aboveground strata of *Halodule wrightii* meadow on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil.

Tab. I. Frequency of occurrence and spatiotemporal distribution of crustacean fauna in *Halodule wrightii* meadow on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil.

Order	Species	Frequency of occurrence		Spatiotemporal distribution			
		Belowground	Aboveground	Belowground		Aboveground	
				Dry	Rainy	Dry	Rainy
Mysidacea			Rare			X	X
Cumacea		Common	More Common	X	X	X	X
Decapoda	*Acantholobulus bermudensis* Benedict & Rathbun, 1891		Few Common			X	X
	Acanthonyx dissimulatus Coelho, 1993		Rare			X	
	Brachyuran megalopae	Few Common			X		
	Calappa angusta A. Milne-Edwards, 1880		Rare			X	
	Callinectes ornatus Ordway, 1863		Few Common			X	
	Epialtidae sp.		Rare			X	
	Pagurus sp.		Rare			X	
	Panopeidae spp.		Common			X	X
Tanaidacea	*Chondrochelia dubia* (Krøyer, 1842)	Few Common	Few Common	X	X	X	X
	Paratanais sp.		Rare			X	
	Sinelobus stanfordi (Richardson, 1901)	Few Common	Few Common	X		X	X
Isopoda	*Astacilla* sp.	Few Common	Common	X	X	X	X
	Erichsonella sp. 1	Few Common	Rare	X	X	X	
	Erichsonella sp. 2	Few Common	Rare		X		X
	Jaeropsis sp.	Common	Common	X	X	X	X
	Paracerceis sp.	Common	Common	X	X	X	X
Amphipoda	*Ampithoe ramondi* Audouin, 1828	More Common	Few Common	X	X	X	X
	Caprella penantis Leach, 1814	Few Common	Rare	X	X	X	
	Cerapus sp.	Common	Few Common	X	X	X	X
	Elasmopus rapax Costa, 1853	Common	Few Common	X	X	X	X
	Erichtonius brasiliensis Dana, 1853	Common	Few Common	X	X	X	
	Hyale media Dana, 1853	More Common	Common	X	X	X	X
	Lysianassidae sp. 1	Few Common	Few Common		X	X	X
	Lysianassidae sp. 2	Few Common	Few Common	X	X	X	
	Megaluropidae sp.	Rare		X	X		
	Microphoxus uroserratus Bustamante, 2002	Common	More Common	X	X	X	X
	Nototropis sp.	Common	Common	X	X	X	X
	Photis sp.	Few Common		X	X		

in both strata, but primarily in the aboveground stratum, which also had a more clearly defined seasonal variation.

The similarity (46%) of the community from the belowground stratum was mainly due to the abundance of *H. media* (27.7%), cumaceans (20.91%), and *A. ramondi* (11.2%). Above 35% of similarity, these samples indicated two main groups (groups I and II) following seasonal sequences (Fig. 4). The dissimilarity between these groups and the other samples was of 76.9%, also determined by cumaceans (21.6%) and *H. media* (21.3%).

Group I consisted of samples of the crustacean fauna captured between November 2006 and March 2007, with a similarity of 51%, mainly due to the abundance of *H. media* (51%). Group II comprised samples captured from April 2007 to July 2007, with a similarity of 60%, mainly due to the abundance of cumaceans (36%). The dissimilarity between groups I and II was of 50.4%, determined by the abundances of *H. media* (24.2%), cumaceans (14.8%), and *Paracerceis* sp. (10.5%).

In the aboveground stratum, we also observed two main groups of samples (groups I and II) (Fig. 5), with a total similarity of 36.5%, mainly due to the abundances of cumaceans (52.7%). The similarity was of 48.4% in Group I, which comprised samples related to the rainy season (April to July 2006 and 2007) and October 2006. The abundance of cumaceans (75.3%) was the main variable explaining the similarity of these samples. Group II comprised the samples from the dry season and the beginning of the rainy season (August 2006 to February 2007), with a total similarity of 40.4%, mainly due to the abundance of *H. media* (46%). The dissimilarity between these two groups of samples (70.2%) was related to the abundance of cumaceans (29%) and *H. media* (20.7%).

The ANOSIM indicated a similar composition of the samples from the below and aboveground strata of the studied *H. wrightii* meadow, considering both the seasons and the two main sequences of samples (groups I and II of the two strata), with a similarity greater than 40% in both strata (Tab. II).

DISCUSSION

The majority of the taxa identified in the studied *Halodule wrightii* meadow occurred both in belowground and aboveground strata, which did not allow us to clearly discriminate the groups of species that belonged to the infauna or epifauna, as also observed for the molluscs associated (Barros & Rocha-Barreira, 2013). Moreover, expected significant differences were also not found among different habitats or species of seagrass (Yokel, 1975; Lewis, 1984; Heck Jr *et al.*, 1989; Edgar, 1990; Corbisier, 1994; Garcia *et al.*, 1996; Jernakoff & Nielsen, 1998; Nakaoka *et al.*, 2001; Rosa & Bemvenuti, 2007).

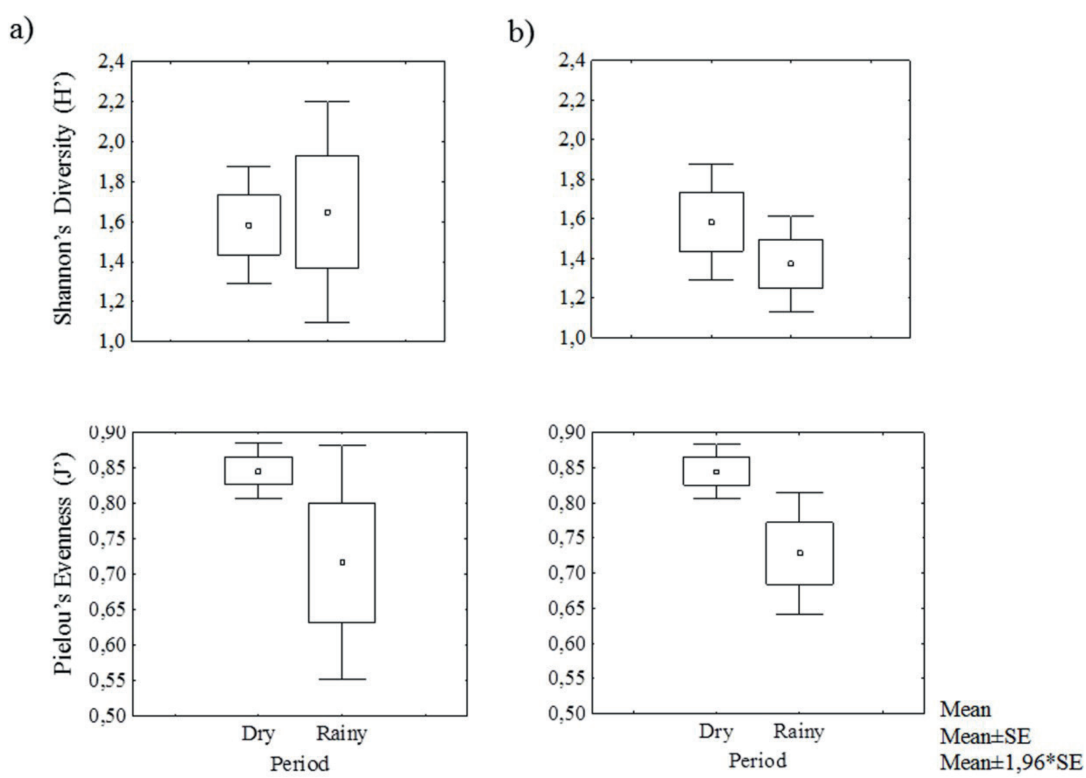

Fig. 3. Mean Shannon diversity and Pielou evenness indices of crustacean fauna associated with belowground and aboveground strata of *Halodule wrightii* meadow in dry and rainy seasons on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil (a, indices for community associated with belowground stratum; b, indices for community associated with aboveground stratum).

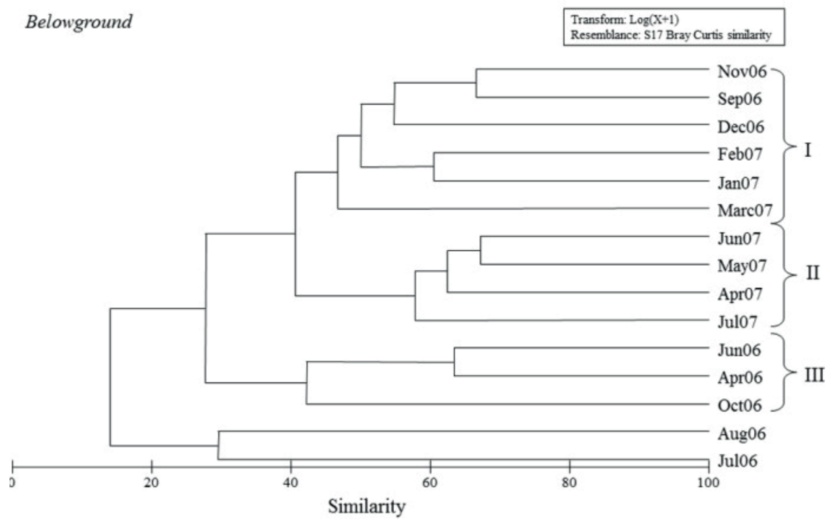

Fig. 4. Similarity among samples from belowground stratum of *Halodule wrightii* meadow on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil; Legend: I) samples collected in predominantly dry months; II) samples collected in predominantly rainy months; III) samples collected in both climatic periods.

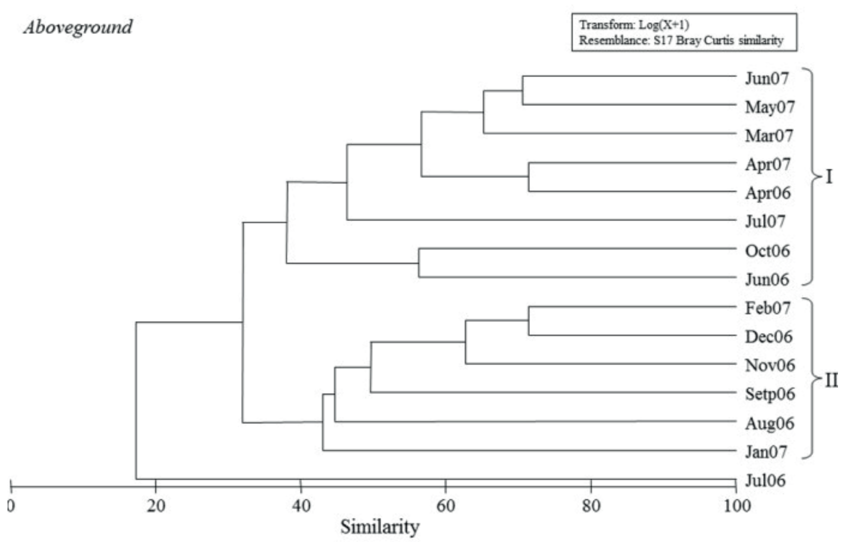

Fig. 5. Similarity among samples from aboveground stratum of *Halodule wrightii* meadow on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil; Legend: I) samples collected in predominantly dry months; II) samples collected in predominantly rainy months.

The lack of significant differences between infauna and epifauna may be also related to the complexity of these ecosystems (Heck Jr *et al.*, 1989; Jernakoff & Nielsen, 1998) and the interference of other external environmental variables (Edgar, 1990; Jernakoff & Nielsen, 1998; Nakaoka *et al.*, 2001), making the role of seagrasses secondary on the community structure (Harriage *et al.*, 2006). Furthermore, in general the benthic macrofauna exhibit variations in vertical distribution related to seasonal changes in the water and sediment (Jorcin, 1999).

The high frequency of cumaceans and *Microphoxus urosserratus* in the aboveground stratum is probably associated with their feeding habits, as also pointed out by other researchers for crustaceans and molluscs (Jernakoff & Nielsen, 1998; Nakaoka *et al.*, 2001). Both taxa leave buried or semi-buried and often feed on the sediment surface

Tab. II. Results of one-way ANOSIM for samples collected in dry and rainy seasons and groups with similar abundance values in *Halodule wrightii* meadow on Goiabeiras Beach, city of Fortaleza, state of Ceará, northeastern Brazil.

Stratum	Factors	R value	p value
Belowground	Dry x Rainy seasons	0.001	0.410
	I x II groups	-0.008	0.467
Aboveground	Dry x Rainy seasons	0.058	0.272
	I x II groups	0.109	0.137

(MacDonald *et al.*, 2010). The feeding habit could also explain the increased densities of cumaceans in both strata during the rainy season, when occurs an increase of organic matter in the sediment (Barros & Rocha-Barreira, 2013), and probably in the water column. Unfortunatelly, we could not identify them to specific level. It would define key-species of the group in this ecosystem, which could help in future monitoring activities of this meadow.

After cumaceans, the amphipod *H. media* was an important taxon in terms of density and dominance, as in other seagrass meadows (Jernakoff & Nielsen, 1998). This amphipod lives basically on the surface of the sediment and phytal ecosystems of the intertidal region. Regarding its feeding habits, *H. media* is essentially a scraper and grazer of microorganisms of macroalgae and microalgae (Tararam *et al.*, 1985; 1986; MacDonald *et al.*, 2010). Amphipods may have risen from surrounding macroalgae banks and deposited in the meadow by waves in the dry season or may have been attracted by the availability of epiphytes (*Hypnea musciformis* Lamourox), as the biomass of which increases in this period (Barros & Rocha-Barreira, 2013, 2014). Species richness may increase when other types of habitats are present (Bologna & Heck Jr, 1999; Gillanders, 2006), although this pattern depends on the type of seagrass substrate (Jernakoff & Nielsen, 1998).

In addition to the probable epiphytic contribution, wave action also favoured the input of specimens surrounding the ecosystem, leading to an increase in the average diversity index during the dry season. This was the case of brachyuran juveniles and adults as well as some species of tanaidaceans, isopods, and amphipods, which only occurred in the aboveground stratum during the dry season, as previously reported for some mollusc species (Barros & Rocha-Barreira, 2013). The patchiness of the meadow (Barros & Rocha-Barreira, 2014) probably contributed to the occurrence of these organisms due to the edge effect, where there is a greater concentration of nutrients and organic matter (Eggleston *et al.*, 1999; Bologna & Heck Jr, 2002; Macreadie *et al.*, 2010). This factor may have contributed to the significant increase in evenness indices in the dry season.

The influence of seasonality on crustacean abundance demonstrated in the similarity analysis, with some inter-annual differences between corresponding samples from the different studied years, especially considering the rainy seasons, was also observed by Harriage *et al.* (2006) for the macrofauna associated with *Posidonia oceanica* (Lipkin) in Prelo Bay, Italy. However, these authors considered that physical factors play a secondary role in the structure of the benthic macrofauna, contrary to what was observed in the present study and in a study of Nakaoka *et al.* (2001), who investigated benthic macrofauna associated with *Zostera marina* Linnaeus and *Zostera caulescens* Miki in Otsuchi Bay, Japan. However, this factor is directly associated with the characteristics of the studied site.

The similarity dendrogram revealed slow changes in the community along the study in response to environmental changes. The community from belowground was more stable, as suggested by other authors (Gambi *et al.*, 1995; Jernakoff & Nielsen, 1998), probably because the leaves changed their arrangement primarily in relation to the belowground stratum (Barros & Rocha-Barreira, 2014). In addition to the seagrass structure, the temporal dynamics of the leaves may exert a significant influence on the epifauna (Jernakoff & Nielsen, 1998). Furthermore, the aboveground fauna seems to be more strongly affected by environmental actions (Barros & Rocha-Barreira, 2013). Edgar (1990) also found a significant seasonal difference in the captured fauna associated with seagrass leaves. The lowest seasonal fluctuations are found for the rhizomes and roots (Barros & Rocha-Barreira, 2014) and for the fauna associated with the belowground stratum (Gambi *et al.*, 1995), since this stratum is a less stressful and more stable environment than the aboveground stratum.

Thus, the crustacean community exhibited gradual changes along the study, in both the belowground and aboveground strata, but the seagrass structure was not sufficient to explain the vertical distribution of the crustacean fauna along the time. The taxa were also influenced by external processes associated with the effects promoted by the seasonality on the ecosystem as a whole (i.e. the patched meadow and the edge effect, as well as the action of waves and the input of organic matter in the meadow), which have an important role in the productivity of this meadow.

Acknowledgments. The authors would like to thank Dr. Petrônio Alves Coelho (*in memoriam*) for his assistance at the Laboratório de Carcinologia da Universidade Federal de Pernambuco (Brazil). The first author is also grateful to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for awarding a Master's scholarship at the time of the study.

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