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Temporal variation and environmental relationships of an estuarine meadow of *Halodule emarginata* from the semiarid coast of Brazil

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Abstract: This study aimed to observe temporal variations of density, biometrics and biomass of *Halodule emarginata*, and relationships of these characters with meteorological, physicochemical, and geomorphological variables. The survey was executed in an estuarine meadow located within the Brazilian semiarid coast by performing eight monthly samplings, four in each regional climatic season (i.e. rainy and dry). Ten samples were monthly taken with a PVC core (0.0078 m^2), using an experimental design suitable for patched meadows. Plant changes along the months were summarized in two principal components of a Principal Component Analysis, which explained 78.3% of the observed variation. The first principal component represented the overall meadow development, and the second component a contrasting aspect between above and below ground development. In general, the population appeared more developed in the rainy season, when the meadow was densest, and the plants presented longer leaves and roots. These changes were linked to climatic variations, particularly to the number of rainy days per month. Considering that seasonal changes in *H. emarginata* were related to local features, additional studies on meadows growing under different environmental conditions are needed to assess its conservation status.

Keywords: Pacoti river, seagrass meadows, marine angiosperms, *Halodule* genus, Brazilian seagrasses

Resumo. Variação temporal e relações ambientais de uma pradaria estuarine de *Halodule emarginata* da costa semiárida do Brasil. O objetivo deste estudo foi observar variações temporais de densidade, biometria e biomassa de *Halodule emarginata* e relações destes caracteres com variáveis meteorológicas, físico-químicas e geomorfológicas. A pesquisa foi realizada em uma pradaria estuarina localizada na costa semiárida do Brasil, em 8 amostragens mensais, sendo 4 amostragens em cada estação climática da região (i.e. chuvosa e seca), a fim de observar preliminarmente a influência da sazonalidade sobre a morfologia e biomassa desta espécie. Dez amostras foram coletadas com um cilindro coletor de PVC (0,00785 m^2), baseando-se num desenho experimental ideal para pradarias distribuídas em manchas. Modificações das plantas ao longo dos meses foram resumidas em dois eixos principais de uma Análise em Componentes Principais, que explicaram 78,3% da variação observada. O primeiro componente principal representou o desenvolvimento geral da pradaria, e o segundo componente, o contraste entre o desenvolvimento das partes aérea e subterrânea. Em geral, a população pareceu mais desenvolvida na estação chuvosa, quando a pradaria foi mais densa e as plantas tiveram folhas e raízes mais longas. Estas mudanças foram relacionadas às variações climáticas, particularmente ao número de dias chuvosos em cada mês. Considerando que as mudanças sazonais de *H. emarginata* foram relacionadas às características locais, estudos adicionais sobre pradarias crescendo sob diferentes condições ambientais são necessários para avaliar seu estado de conservação.

Palavras-Chaves: Rio Pacoti, pradarias marinhas, angiospermas marinhas, gênero *Halodule*, angiospermas marinhas brasileiras

Introduction

Halodule emarginata is a poorly known seagrass species endemic to the Brazilian coast. It was described by den Hartog (1970), based on specimens collected on the coast of the state of São Paulo, within Brazil's south-east region. It is characterized by having relatively short and wide leaves, with either emarginated or obtuse apices (Oliveira-Filho 1983, Barros *et al.* 2016). These morphological traits differentiate it from *H. wrightii*, another common seagrass species occurring on the Brazilian coast (Hartog 1972, Oliveira-Filho *et al.* 1983, Barros *et al.* 2016).

Due to the lack of studies, the species is still classified as "data deficient" by the *International Union for the Conservation of Nature* – IUCN. However, some authors have considered a possible reclassification in the near future, if the relatively small distribution of the species and the existence of threats are confirmed (Short *et al.* 2011).

The species range was originally documented from around latitude 24ºS to 13ºS, between the states of São Paulo and Bahia (Oliveira-Filho *et al.* 1983), although it apparently have also been observed further north, approximately at 10ºS, in the state of Alagoas (Karine Magalhães *pers. comm.*[1]). Nevertheless, a small meadow of *H. emarginata* was recently discovered around latitude 3ºS, in the state of Ceará, increasing its range of occurrence 1500 km northward of the former northernmost point (Barros *et al.* 2016, Copertino *et al.* 2016). The existence of this previously unknown meadow further evidences the need of new studies on the species.

Despite the worldwide decline of seagrass beds since the end of the 20th century (Short *et al.* 2011), efforts to map and monitor Brazilian meadows are still scarce. Only recently, a network of researchers has elaborated methods to obtain a long-term data on the seagrass occurring along this coastline (Copertino *et al.* 2015). But regarding to *H. emarginata*, since even the location and the extension of its meadows remain unknown, data on basic aspects of its ecology are still lacking. Few studies have provided information on the type of substrate preferred by the species (Oliveira-Filho *et al.* 1983, Barros *et al.* 2016) and on some of the ecological relationships that it establishes with other organisms (Oliveira-Filho *et al.* 1983, Oliveira 1991, Barros *et al.* 2016). But so far none has addressed, for example, the existence of seasonal fluctuations in plant morphology or meadow size.

In times of global environmental changes, studies on the susceptibility of seagrass meadows to variations on local environmental features are needed to draw future scenarios for these ecosystems (Barros *et al.* 2013). Nevertheless, despite the availability of information on Brazilian seagrass meadows (e.g. Costa *et al.* 1997, Colares & Seeliger 2006, Short *et al.* 2006, Siqueira *et al.* 2011, Barros *et al.* 2014), data specific for *H. emarginata* beds are still lacking.

This study aims to record temporal variations of characters of the *H. emarginata* meadow recently recorded in an estuary on the semiarid coast of Brazil (Barros *et al.* 2016), assessing its relationships with selected environmental factors, thus contributing to the knowledge of this species.

Materials and Methods

1Profa. Dra. Karine Matos Magalhães, Universidade Federal Rural de Pernambuco, Av. Dom Manoel de Medeiros, S/N. Dois Irmãos. Recife-Pernambuco. Email: karinemmagalhaes@gmail.com

Study site: The studied meadow of *Halodule emarginata* Hartog (a voucher specimen can be found at Profa. Francisca Pinheiro Herbarium of the Federal University of Ceará – HMAR/ UFC, nº 2520) is located in an estuary on the Ceará state coast (X: 564.297; Y: 9.576.181 UTM or 3°49.5'S; 38°25'W; Figure 1), within the Environmental Protection Area of the Pacoti river, which comprises the municipalities of Fortaleza, Eusébio and Aquiraz (Ceará 2000). This estuary has an area of 362 km^2, encompassing about 160 hectares of mangroves, riparian and tableland forests, saltmarshes, and seagrass meadows, all of which are considered of great ecological and economic importance to the local environmental setting (Irving *et al.* 1988, Gorayeb *et al.* 2005, Lacerda *et al.* 2007, Barros *et al.* 2016).

Located next to the equator, the regional climate is predominantly hot semi-arid, typically exhibiting high temperatures that vary little along the year. Two climatic periods are usually observed: a relatively warmer rainy season between February and May; and a relatively cooler dry season spanning most of the second semester. In the latter period, wind speeds are typically higher, particularly between August and October (Moura 2012).

Fieldwork and Laboratory Processing: A total of eight samplings were performed to characterize the studied meadow, four in each season (one per month, from February to May and from June to September of 2015), considering the seasonal fluctuations known to occur in seagrass beds on the semiarid coast of Brazil. Previous studies observed denser seagrass meadows with taller and heavier plants during the rainy months, while in the dry season the plants are stressed by an increase of solar radiation, windy and wave actions, presenting patched meadows and less developed plants (Barros & Rocha-Barreira 2014, Barros *et al.* 2016, *unpublished observations*).

The sampling design was based on Burdick & Kendrick (2001) for patched seagrass beds. Two central points approximately 30m apart were established on the studied meadow, defining sampling areas I and II. Four peripheral points were then placed around each center, up to 10m away from the central point, oriented in the directions of the river bed (RB), river margin (RM), river upstream (RU), and river

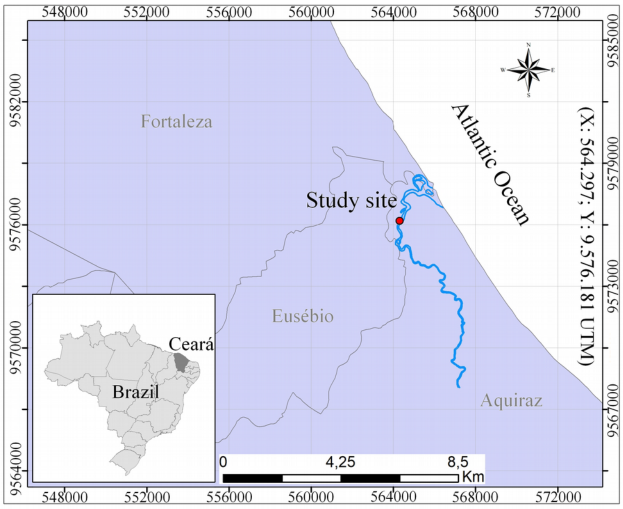


Figure 1. Location of the studied *Halodule emarginata* meadow in the Pacoti river (red point), Ceará State, semiarid coast of Brazil.

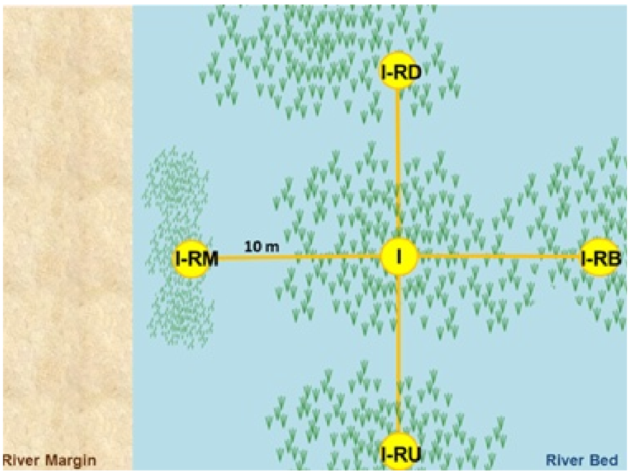


Figure 2. Experimental design in one of the areas monthly sampled in the semiarid coast of Brazil. Legend: I – Point of origin; I-RB – river bed; I-RM – river margin; I-RU – river upstream; I-RD – river downstream. Source: Adapted from Copertino *et al.* (2015).

downstream (RD). Thus, a total of 10 sampling points were established in each month (Figure 2).

In each point, plant samples were collected using a PVC corer with 10 cm in diameter, buried at 15 cm depth. The samples were washed in the river water using a 1 cm sieve in order to remove the excess of sediment. Thereafter, the plants were deposited in tagged plastic bags, frozen, and transported to the Instituto de Ciências do Mar (Labomar/UFC), where they were processed.

In the laboratory, it was recorded the number of shoots per sample. Then a digital caliper and a millimeter blade with precision of 0.1mm was used to obtain five measurements of each of five morphological features: (1) root length, (2) vertical rhizome (i.e. the rhizomes growing from the main rhizome) length, (3) entire (with apexes) leaf length, (4) leaf width and (5) distance between shoots. Thereafter, shoots (aboveground) and roots/rhizomes (belowground) were dried at 60°C by 24 hours to obtain the biomasses in grams per dry weight per square meter (g dw m^{-2}).

During each field sampling, only one sediment sample was collected for granulometric analysis, since previous experiments using three random samples did not find differences in the sediment classification in a same sampling for the Pacoti River (*Pers. Obs.*). Additionally, monthly values (from February to September of 2015) of total rainfall (mm), number of rainy days, mean maximum temperature (ºC), mean minimum temperature (ºC), temperature range (maximum - minimum) and mean wind speed (m/s) were retrieved from the database for teaching and research of the Brazilian Institute of Meteorology – BDMEP (INPE 2015).

Statistical analyses: After the assessment of normality (via Kolmogorov-Smirnov & Lilliefors tests) and homocedasticity (via Levene tests) of variables, their seasonal variations were compared using either a Kruskall-Wallis (non-parametric data), Analysis of Variance – ANOVA (parametric data) or chi-squared (sediment composition percentages) tests.

A Principal Component Analysis (PCA) of the standardized (to zero mean and unit variance) biological features was performed to identify major sources of variation. It was expected that the first component, which explained most of the biological variation, represented the overall meadow development. The interpretation of other components was based on the coefficients of the individual population variables (Jolliffe 2002).

A Bio-environmental analysis (BIO-ENV) assessed which of the climatic and sedimentary variables were correlated to variations in meadow characteristics. The test standardizes environmental variables and their variations were presented in a dissimilarity matrix as the Euclidian distance between months, measured with the standardized values of the biological features. Equivalent matrices were constructed for all possible subsets of the environmental variables, aiming to find the subset with the highest Pearson correlation with the biological variations. Finally, a Mantel test was used to assess the significance of this relationship.

The environmental variables selected by the BIO-ENV were then used to construct linear models of the first principal components produced by the PCA (i.e. the overall meadow development), via ordinary least squares. This analysis aimed to assess more explicitly how these aspects of biological variation are related to environmental features.

Results of granulometric analysis were obtained using ANASED® 5j, 5.0 version. All statistical tests were performed in R 3.3.2, with the BIO-ENV and Mantel tests requiring the package Vegan 2.3-5 (Oksanen 2016).

Results

Variations of Halodule emarginata in the Pacoti river: In general, the means of the studied *H. emarginata* characters indicated a greater development of the meadow during the rainy season, when it was densest, and presented longer leaves, roots and vertical rhizomes (Table I), although some peaks during the both considered seasons were found (Figure 3). With the exception of leaf width, all significant differences were observed in features associated with the below ground fraction of the population (Table II). The shoot density and the biomass had a clear tendency to decrease as the dry season advanced (Figure 3).

The belowground biomass ranged from 51.7% (September) to 76% (March) of the total biomass, which was significantly greater during the rainy season, as well as the length of vertical rhizome. In contrast, the width of the leaves was significantly greater during the dry season (Table I).

The first two principal components of the biological features explained 78.3% of the meadow variance (Table III). As expected, the first component (PC1) can be interpreted as the overall meadow development, since all features presented the same sign. The second component (PC2) may be regarded to the lifecycle of below ground and above ground of the vegetation during the year (Figure 4).

Considering PC1, there was a clear overall decline in the population along the months, as the season changed from rainy to dry (Figure 5A). The same trend can be seen in most individual biological features (Figure 3), irrespective of the significance of their differences between seasons. On the other hand, PC2 did not show a temporal patterns (Figure 5B), suggesting that the decline was general, and not restricted to a single aspect of the population.

Table I. Minimum (Min), maximum (Max), mean and standard deviation (SD) values, during the dry and rainy seasons.

Variables	Rainy Season				Dry Season			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Distance between shoots (cm)	0.30	4.20	1.38	0.74	0.30	4.30	1.38	0.77
Length of vertical rhizomes (cm)	0.40	5.40	2.45	1.15	0.50	4.60	1.92	0.96
Shoot density (shoots m^{-2})	127	605	1685	1173	127	3312	1346	757
Length of the roots (cm)	0.90	10.60	4.29	1.92	0.80	11.70	4.10	1.78
Length of the leaves (cm)	1.11	10.99	4.66	1.98	1.38	10.01	4.53	2.04
Width of the leaves (mm)	0.26	0.74	0.5	0.09	0.16	0.83	0.59	0.11
Belowground biomass (g dw m^{-2})	0.38	78.22	15.47	14.56	0.76	30.45	8.59	6.93
Aboveground biomass (g dw m^{-2})	0.25	21.66	5.30	4.63	0.38	12.10	3.78	2.55
Total biomass (g dw m^{-2})	0.64	99.87	20.77	18.77	1.53	37.83	12.37	8.64

Table II. Results of the analysis of variance that compared the means of the characters of a *Halodule emarginata* meadow from the semiarid coast of Brazil, during the dry and rainy seasons. Legend: F – ANOVA index; df – degree of freedom; p – significance. (*)Means significantly different.

Variables	ANOVA		
	F	df error	p
Distance between shoots (cm)	0.010	268	0.919
Length of vertical rhizomes (cm)	14.242	229	0.000*
Shoot density (shoots m^{-2})	2.309	76	0.133
Length of the roots (cm)	0.765	297	0.383
Length of the leaves (cm)	0.380	325	0.538
Width of the leaves (mm)	48.276	325	0.000*
Belowground biomass (g dw m^{-2})	7.276	78	0.009*
Aboveground biomass (g dw m^{-2})	3.320	78	0.072
Total biomass (g dw m^{-2})	6.612	78	0.012*

Environmental Variations and Interactions with Halodule emarginata: Environmental parameters varied as expected during the study (Table IV), with rainfall and temperature being higher in the rainy season, and wind speed being higher in the dry season (Figure 6).

On the other hand, the substrate did not change significantly during the study (χ^2 = 0.46, *p* = 0.8), despite the averages of gravel percentage increased non-significantly during the rainy season, and the averages of sand and fine sand percentages, during the dry season. It could be classified as poorly selected, according the selection of the grain, and as medium lithoclastic sand, according the Larsonneur classification (Table V).

Regarding the relationship of environmental and biological features, the BIO-ENV analysis indicated that the differences among months in terms of plant characteristics were significantly correlated to number of rainy days, temperature range and percentage of gravel (*Mantel r* = 0.56, *p* = 0.02).

Considering these three environmental variables (Figure 7), only the model relating PC1 and the number of rainy days produced significant coefficients ($F_{1,6}$ = 11.4, *p* = 0.01). The inclusion of any other variables rendered the model p-value >0.05. In the case of PC2, no variable produced

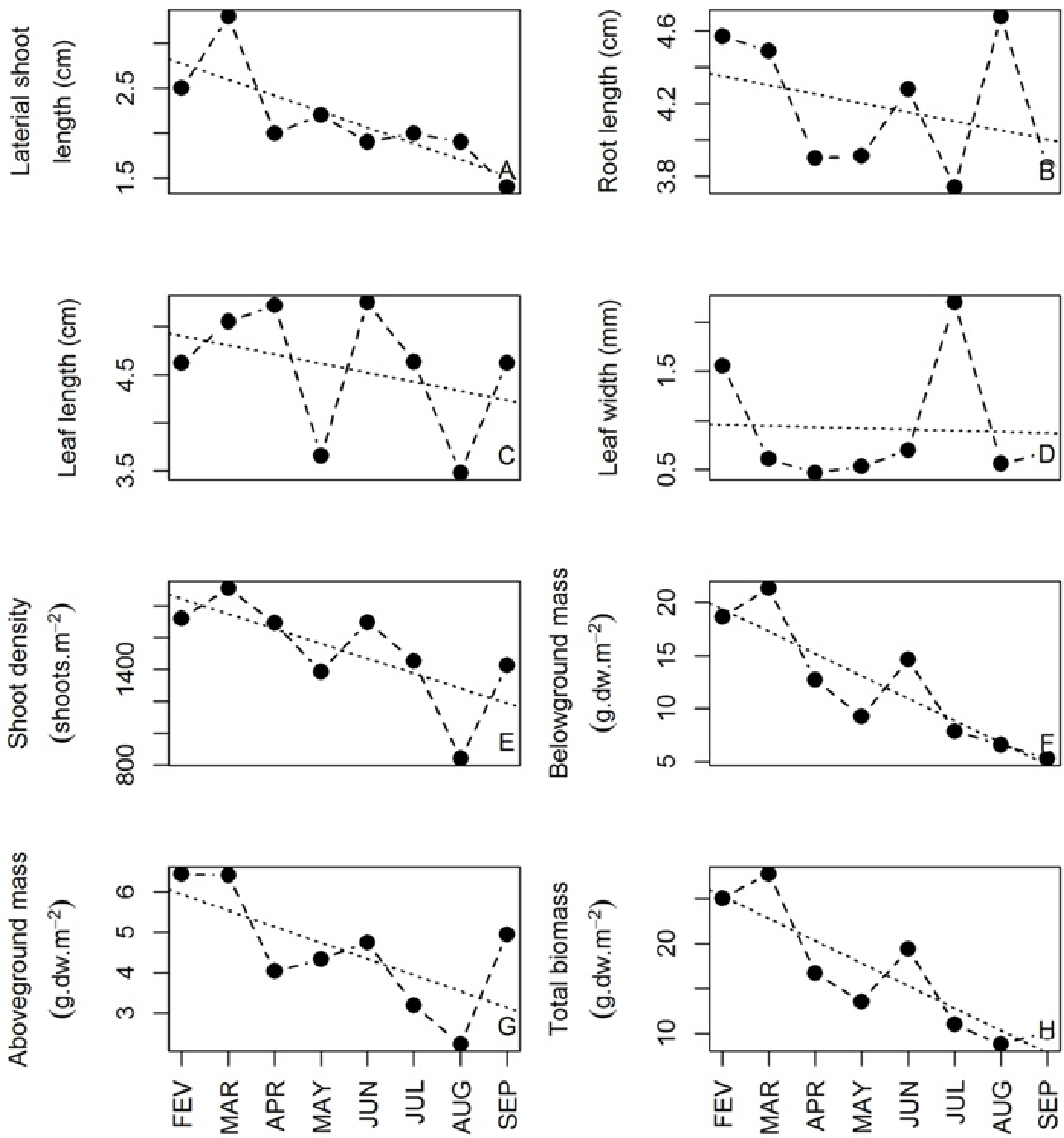


Figure 3. Temporal variations in biological features of a *Halodule emarginata* meadow from the Brazilian semiarid coast.

significant results.

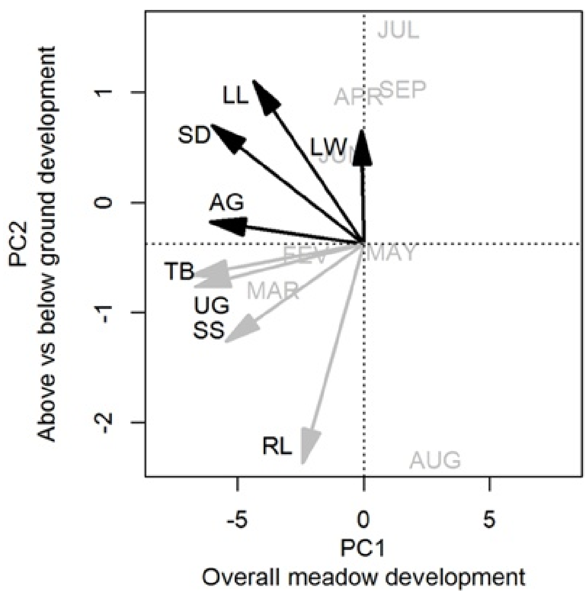
Discussion

The morphological features measured in the present study fell within the range of available descriptions of the species (den Hartog 1970, Oliveira-Filho 1983, den Hartog 1972), with the leaves being consistently shorter and wider than those recorded for *H. wrightii* (Oliveira-Filho *et al.* 1983, Creed 1997, Magalhães 1997, Oliveira *et al.* 1997, Sordo *et al.* 2011, Barros & Rocha-Barreira 2014, França *et al.* 2014), and shorter and narrower than the verified for *H. beaudettei* (Magalhães & Barros 2017). In *Halodule* species, features such as leaf size are usually subject to changes due to variations in environmental conditions, which do not occurs with their leaf tips (Bujang *et al.* 2008).

Despite some authors have questioned the status of *Halodule emarginata* as a distinct species, which is largely based on leaf tip morphology (Oliveira-Filho 1983, Kuo & Hartog 2001), the consistency of this character, in spite of the large geographic distance separating the studied meadow from other *H. emarginata* beds, suggests that *H. emarginata* is a distinguishable taxonomic unit. Hence, from a conservationist point of view, this species urgently needs more focused investigations to assess if and how it is being threatened by local and global environmental changes.

Table III. Coefficients (eigenvectors) and proportion of explained variance (eigenvalues) of the principal component of 8 biological features of a *Halodule emarginata* meadow from the semiarid coast of Brazil. Legend: PC – Principal Components.

Variables	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**
Length of vertical rhizomes (cm)	-0.37	-0.28	-0.22	0.47	0.52	0.49	0.02	0.00
Length of the roots (cm)	-0.17	-0.66	-0.11	-0.59	-0.17	0.17	0.35	0.00
Leaf length (cm)	-0.3	0.48	0.21	-0.57	0.26	0.44	-0.21	0.00
Width of the leaves (mm)	-0.01	0.31	-0.93	-0.13	-0.11	0.00	0.01	0.00
Shoot density (shoots m^{-2})	-0.41	0.35	0.11	0.10	0.04	-0.22	0.8	0.00
Belowground biomass (g dw m^{-2})	-0.45	-0.13	-0.05	-0.09	0.16	-0.5	-0.31	-0.63
Aboveground biomass (g dw m^{-2})	-0.41	0.06	0.08	0.26	-0.77	0.34	-0.15	-0.15
Total biomass (g dw m^{-2})	-0.46	-0.09	-0.02	-0.02	-0.03	-0.35	-0.29	0.76
Proportion of variance	0.582	0.200	0.119	0.053	0.039	0.005	0.000	0.000
Cumulative proportion	0.582	0.782	0.902	0.955	0.994	1.000	1.000	1.000



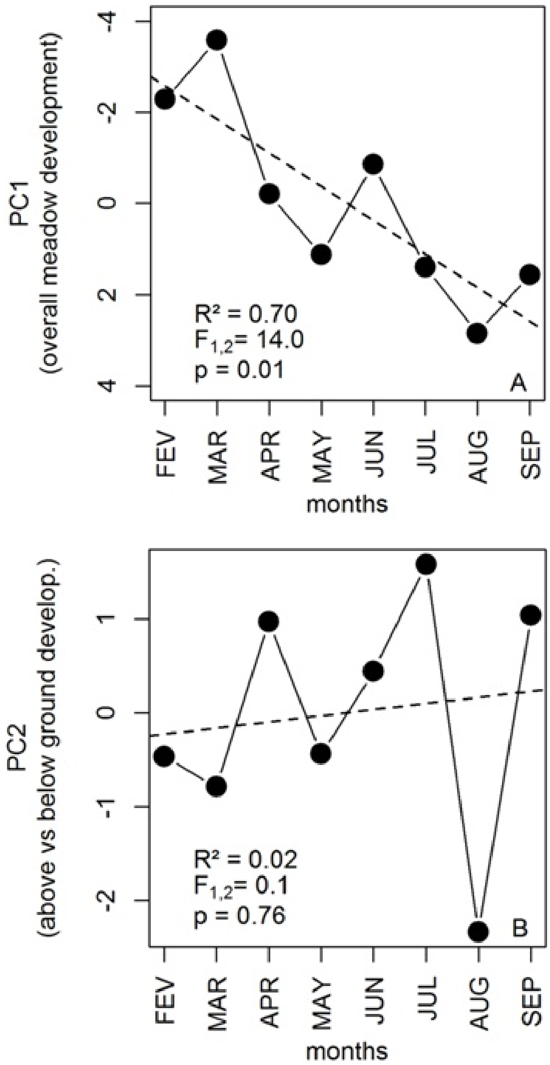


Figure 4. Principal component analysis considering variations of the *Halodule emarginata* characters obtained in the Brazilian semiarid coast. Legend: PC – Principal Component Axis; LW – leaf width; LL – leaf length; SD – shoot density; AG – aboveground biomass; TB – total biomass; UG – belowground biomass; SS – length of vertical rhizomes; RL – root length.

Considering the other morphological features (except leaf tip) summarized into two principal components of the PCA obtained, the first component (PC1) was readily interpreted as the level of plant development, since it grouped all morphological variables together.

Figure 5 (previous page). Temporal fluctuations in the first two principal components of variation of a *Halodule emarginata* meadow from the semiarid coast of Brazil. Legend: **A.** temporal changes of the first principal component, representing the overall meadow development; **B**. temporal changes of the second principal component, representing above vs below ground development.

On the other hand, the interpretation of the second component was more complex. PC2 separated canopy characteristics as aboveground biomass, leaf length, leaf width and shoot density from the underground, as root length, vertical rhizome length and total biomass (which was more influenced by the underground biomass, due to the latter's relatively high values). Therefore, PC2 could signal periods in which plants were more developed above, or instead, below the ground, contrasting the level of maturation of these two strata of the population, a distinction that was not possible from PC1 alone. It is, however, noteworthy that we could not find any unambiguous temporal pattern for PC2, maybe indicating that this component is more related to the life cycles of the plants than to some externality.

On the other hand, the data obtained along the study showed that the studied *Halodule emarginata* meadow had an overall development in terms of biomass and morphometry in the rainy season. The same pattern has been also observed for *H. wrightii* along the Brazilian semiarid coast, even in meadows located outside estuarine areas (Barros *et al.* 2014, *unpublished observations*). This result, however, contrasts with finds for *H. wrightii* meadows located on the generally more humid Brazilian eastern coast, whose greater development was observed to occur in the dry season (Magalhães *et al.* 1997, Oliveira *et al.* 1997, Sordo *et al.* 2011). On one hand this indicates that at least some seasonal patterns may be generalizable for the entire genus. On the other hand it suggests that the relationship of the Brazilian seagrass beds with environmental features is complex, and probably non-linear. Therefore, the effects of global environmental changes should be evaluated locally, and more regional surveys of *H. emarginata* are needed to assess possible threats to the species along the entire Brazilian coast (Barros *et al.* 2013).

In the Brazilian semiarid meadows of *H. wrightii*, the reductions on plant and meadow characters observed in the dry season were largely correlated to wind speed, which apparently affects these beds by changing the sedimentary dynamics in their area of occurrence (Barros *et al.* 2014). However, in the present study, despite possible effects of sediment composition and temperature range, the variations in *H. emarginata* characteristics were more correlated to rainfall (particularly the number of rainy days). Being located within an estuary, in a wave protected area, the balance of continental and coastal waters may be determinant to this particular *H. emarginata* population. Due to semidiurnal tidal fluctuations, the area seems to be under a highly hydrodynamic regime, which is also suggested by the year-round presence of poorly selected sediments largely composed by medium lithoclastic sands (Martins & Mendes 2011).

Table IV. Minimum, maximum, seasonal mean values, and results of the variance analysis of environmental variables obtained during the rainy and dry seasons in a *Halodule emarginata* area from the semiarid coast of Brazil. Legend: H – Kruskall-Wallis index; p – significance; (*) Means significantly different.

Variables	Min	Max	Mean Rainy	Mean Dry	Kruskall-Wallis	
					H	p
Rainfall (mm/month)	12.7	377.7	224.9	60.4	3.000	0.083
Nº of rainy days (days/month)	2.0	4.0	20.7	20.5	4.802	0.028*
Wind speed (m/s)	1.8	3.9	2.2	3.3	5.333	0.020*
Temperature range (°C)	6.9	8.1	7.2	7.7	4.083	0.043*
Air temperature (°C)	30.4	31.7	31.2	30.7	0.857	0.354
Water temperature (°C)	28.0	30.3	29.6	28.6	4.083	0.043*
Salinity	12.3	39.0	30.4	36.6	0.750	0.386
Gravel (%)	1.0	5.4	3.5	2.0	2.083	0.148
Sand (%)	89.7	93.1	90.7	92.0	2.083	0.148
Fines (%)	4.8	7.6	5.8	6.0	0.333	0.563

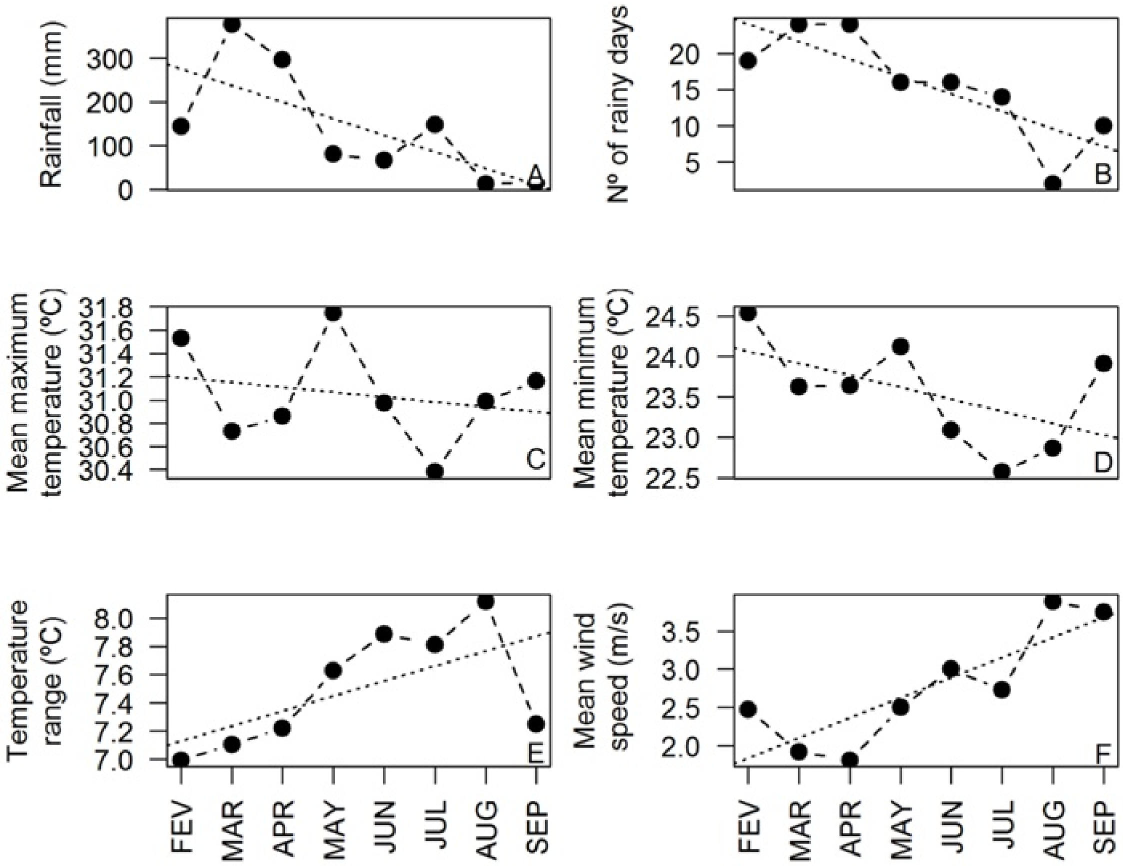


Figure 6. Temporal variations in 6 climatic parameters during the study of a *Halodule emarginata* meadow from the semiarid coast of Brazil.

Table V. Granulometric analysis of the sediment collected along the study in a *Halodule emarginata* meadow from the semiarid coast of Brazil. Legend: F & W – Folk & Ward classification; Shep. – Sheppard classification.

Samples	F&W- Mean	F&W- Median	F&W- Gr_Selection	Larsonneur	Shep.
February	Fine Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
March	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
April	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
May	Medium Sand	Medium Sand	Very Poorly Selected	Medium Lithoclastic Sand	Sand
June	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
July	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
August	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand
September	Medium Sand	Medium Sand	Poorly Selected	Medium Lithoclastic Sand	Sand

However, a larger continental runoff may increase nutrient availability, facilitate the removal of excessive sand, and diminish the risk of air exposure in the rainy season, hence benefiting the plants (Romero *et al.* 2006). New studies are needed to assess this specific hypothesis. Nevertheless our results suggest that, even if the overall seasonal fluctuations may appear similar, the ecological functioning of this estuarine *H. emarginata* meadow may be different from nearby *H. wrightii* marine beds.

In the last decades, despite the legal protection, the Pacoti river have faced considerable anthropogenic impacts (Silva et al. 2016). More striking, the mangrove area doubled in approximately 50 years (Lacerda *et al.* 2007). This

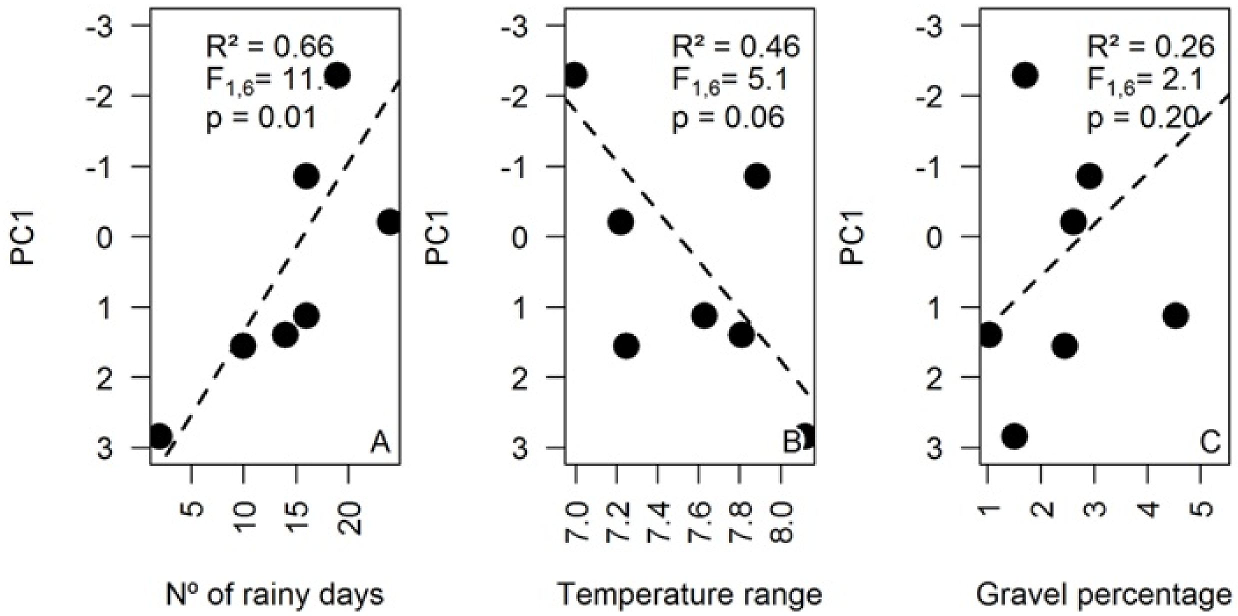


Figure 7. Relationship between the variables pointed out by the BIO-ENV (number of rainy days, temperature range and gravel percentage) and the first principal component (PC1) of variation of a *Halodule emarginata* meadow from the semiarid coast of Brazil. This component may be regarded as a measure of the overall plant development.

increase, despite an unexpected outcome of human impacts, was mainly attributed to a combined effect of deactivation of salt pond areas before occupied by salt marsh meadows, reduction in freshwater supply and sediment accumulation due to river damming (Lacerda *et al.* 2007). Considering our results, these factors may be a significant threat to the small *H. emarginata* population under study. And their effects should be worsen if the expected reduction in rainfall in this area due to global climatic changes is confirmed (Marengo 2008). In short time scales, the burial of the meadow seems to be a probable result of these impacts. In the long run, the appearance of new sandbanks along the river margin, combined with a larger intrusion of seawater, may increase the number of habitats available to the species. However, if siltation is not contained, even this augmented population may eventually disappear.

The above mentioned threats become even more serious considering that this particular *H. emarginata* population so far appears isolated on the Brazilian coast. Therefore, new studies are urgently needed to assess the existence of other nearby meadows– including in the Pacoti river itself. Only after these surveys it will be possible to evaluate the risks of local extinction faced by this apparently unique estuarine seagrass meadow.

It is therefore necessary to increase the knowledge about this species, by acquiring data on meadows growing under different environmental conditions and recording possible threats in other sites of the Brazilian coast, so that we can assess the actual state of conservation of the species, and also to predict future scenarios considering global environmental changes. Specifically regarding the studied meadow, its apparent isolation and the recent changes in the local environmental settings, particularly river damming, pose risks to the population. Surveys at broader spatial and temporal scales are then urgently needed to evaluate the magnitude and duration of these threats.

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