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Diversity and distribution of epiphytic bromeliads in a Brazilian subtropical mangrove

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ABSTRACT

It is not unusual to find epiphytic bromeliads in mangroves, but most studies on mangrove vegetation do not record their presence. This study aimed to evaluate the diversity and distribution of epiphytic bromeliads in a subtropical mangrove. The richness, abundance and life form (atmospheric and tank) of bromeliads were recorded and compared among host tree species and waterline proximity. The effects of diameter and height of host trees on the abundance of bromeliads were also assessed. The mangrove was composed of *Avicennia schaueriana*, *Laguncularia racemosa* and *Rhizophora mangle*. We recorded seven bromeliad species of the genera *Tillandsia* and *Vriesea*. The waterline proximity did not affect the abundance or diversity of bromeliads, but atmospheric forms were predominant near the waterline, whereas tank bromeliads were more frequent in the interior of the mangrove. The three mangrove species hosted bromeliads, but *L. racemosa* was the preferred host. The species composition showed that the distribution of bromeliads is more related to the host species than to the distance from the waterline. Bromeliad abundance increased with tree size. Bromeliads can be biological indicators of ecosystem health; therefore, inventories and host tree preferences are necessary knowledge for an adequate management of sensitive ecosystems as mangroves.

Key words: Bromeliaceae, bromeliad-host relationship, species richness, waterline distance.

INTRODUCTION

Vascular epiphytes can be found in diverse habitats, on host plants with architectural and phenological features that are favorable for their establishment (Graham and Andrade 2004, Zotz and Schultz 2008, Cach-Pérez et al. 2013). Since epiphytes are sensitive to human impact and climate change, the structure of epiphytic communities has been

used as a conservation index (Nadkarni and Solano 2002, Wolf 2005, Hayasaka et al. 2012).

The Bromeliaceae is a rich family of vascular plants, with about 3160 species, of which more than 60% are epiphytes (Zotz 2013). The composition and distribution of epiphytic bromeliads are influenced by the characteristics of hosts. The substrate offered by each host tree promotes specificity to the epiphyte-host relationship (Zotz and Vollrath 2003, Zotz and Schultz 2008, Benavides et al.

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2011). Epiphytic bromeliads can show two life forms: tank bromeliads, whose leaves are arranged in a rosette where they accumulate water and organic debris; and atmospheric bromeliads, whose leaves are narrow and do not serve as a reservoir (Benzing 1990, Givnish et al. 2007). Each life form shows specific requirements that also influence their distribution pattern (Benzing 1990). Tank bromeliads also play an important ecological role, increasing the local diversity, since many invertebrates and vertebrates use their reservoir for shelter, breeding and feeding (Mestre et al. 2001, Lopez et al. 2005, Ngai and Srivastava 2006).

The spatial distribution of epiphytic bromeliads depends on the relationship between their particular requirements (for reproduction, fixing, germination, growth and survival) and biotic (availability of host trees, dispersers and pollinators) and abiotic factors (temperature, luminous intensity and atmospheric humidity) (Nieder et al. 2000, Zotz and Vollrath 2003, Benavides et al. 2011). Vertically, the composition and abundance of species can vary between the different heights of the host trees, depending on the strategy of nutrient acquisition, time of substrate availability and microclimatic conditions (Bonnet and Queiroz 2006). Horizontally, the distribution of epiphytic vegetation along ecosystems varies according to the relative humidity, the forest structure and the host species arrangement (Nieder et al. 2000, Zotz and Schultz 2008, Cach-Pérez et al. 2013).

It is not unusual to find epiphytic bromeliads in mangroves, which are important ecosystems in tropical and subtropical coastlines (Vannucci 2001). Mangroves have great functional diversity and high productivity (Ashton and Macintosh 2002, Bhomia et al. 2016). They are recognized by being great organic matter transformers and sources of income and services, such as minimizing the effects of coastal disturbance and climate change (Alongi 2008, Lima and Colpo 2014). However,

mangroves are very sensitive to human activities, and are in decline around the world due to the exploitation of their areas and natural resources (Penha-Lopes et al. 2011, Santos et al. 2011). Mangrove degradation causes the decrease and fragmentation of biodiversity (Ebrahimi-Sirizi and Riyahi-Bakhtiyari 2012, Bayen 2012). Therefore, describing and monitoring the biodiversity in mangroves could be a valuable tool for the conservation and management of this ecosystem (Hayasaka et al. 2012).

Most studies describing the flora of mangroves assess the diversity and community structure of trees but do not record the presence of epiphytes (Ashton and Macintosh 2002, Colpo et al. 2011, Bhomia et al. 2016, MacKenzie et al. 2016, Chen et al. 2016). Although epiphytes are very abundant in dense mangroves, few studies have assessed the richness of epiphytic species or specifically of bromeliads (Robertson and Platt 2001, Zotz and Reuter 2009, Cach-Pérez et al. 2013). To understand the distribution patterns of epiphytes and to preserve them, it is important to know not only the diversity, but also the bromeliad-host relationships (Magalhães and Lopes 2015).

Due to the lack of studies and information about epiphytic bromeliads in mangrove forests, and considering that the diversity of these sensitive species can be a tool for mangrove conservation, this study aimed to assess the diversity of epiphytic bromeliads in a subtropical mangrove, evaluating their distribution and relationship with their host trees.

MATERIALS AND METHODS

The study area was a mangrove fragment of the Itapanhaú river (23° 49' 07" S, 46° 09' 07" W), located in Bertioga, central coast of the State of São Paulo, Brazil. This area is located in the Serra do Mar State Park. The average annual temperature is approximately 27°C, the air relative humidity is

greater than 80%, and the annual rainfall is 3,200 mm (Maia et al. 2008).

Two transects were established in the study area: one at the mangrove-river interface (edge transect) and the other at 100 m from the mangrove-river interface (interior transect) (experimental design modified from Ashton and Macintosh 2002, and MacKenzie et al. 2016). This distance was established because the transition-mangrove zone starts at about 150 m from the waterline, with the presence of non-mangrove species. In each transect, we randomly demarcated 10 quadrats of 25 m². In each quadrat, all trees with circumference larger than 5 cm were registered, identified, measured (DBH = diameter at breast height, in cm) and inspected regarding the presence of bromeliads. The height of host trees was also measured with a clinometer.

The bromeliads in each host tree were identified, counted, photographed and characterized as tank or atmospheric bromeliads. With exception of *Tillandsia usneoides*, the actual abundance of each species of bromeliads could be recorded, since it was possible to identify and record each ramet. Abundance of *T. usneoides* was estimated as the degree of cover in the host tree on a scale from 0 to 4, according to Bonnet et al. (2007). The proportion of individuals of each bromeliad species in the three host species was also calculated.

The structure of the mangrove forest in the study area was evaluated by a two-way ANOVA, which compared the density of each tree species (fixed and orthogonal factor with three levels: *Avicennia schaueriana*, *Laguncularia racemosa* and *Rhizophora mangle*) between transects (fixed and orthogonal factor with two levels: edge and interior). The proportion of trees with and without bromeliads in each transect was compared by chi-square test.

The effects of host species (fixed and orthogonal factor with three levels: *A. schaueriana*, *L. racemosa* and *R. mangle*) and transects (fixed

and orthogonal factor with two levels: edge and interior) on the abundance of bromeliads were evaluated by a two-way ANOVA. The Cochran test assessed the homogeneity of variances. Chi-square tests were used to compare the proportion of tank and atmospheric bromeliads in each transect. The proportion of each bromeliad on each host species was also determined.

Variations in the composition of bromeliad species between transects and host tree species were evaluated by cluster analysis, which was carried out based on a Bray Curtis similarity index. We also performed a multiple regression analysis (GLM) to test the effects of DBH and height of host trees (predictor variables) on the abundance of bromeliads (dependent variable).

RESULTS

The mangrove forest in the study area was composed of three tree species: *Avicennia schaueriana* Stapf and Leechman, *Laguncularia racemosa* C.F. Gaertn and *Rhizophora mangle* L. The density of trees showed no differences between the edge ($5,400 \pm 2,185$ trees.ha⁻¹) and the interior ($4,040 \pm 1,091$ trees.ha⁻¹) transects, but the density of *A. schaueriana* was lower than that of the other species in the forest (Table I and Figure 1). Most of the trees were free of bromeliads (Chi-square: $p < 0.001$). Only 23% of trees in the edge and 32% in the interior were used by epiphytes (Figure 2).

We recorded seven bromeliads species of the genera *Tillandsia* and *Vriesea*. In each transect, we found six bromeliad species. A total of 1,165 individuals, of which 47.9% were seedlings were registered in the studied mangrove. Furthermore, the sum of degree of cover of *T. usneoides* was at 60 (Table II). *Tillandsia gardneri* was the most abundant species, which was found in all host species, while *V. gigantea* was the rarest species, only one individual were recorded in *L. racemosa* (Table II). The abundance of bromeliads

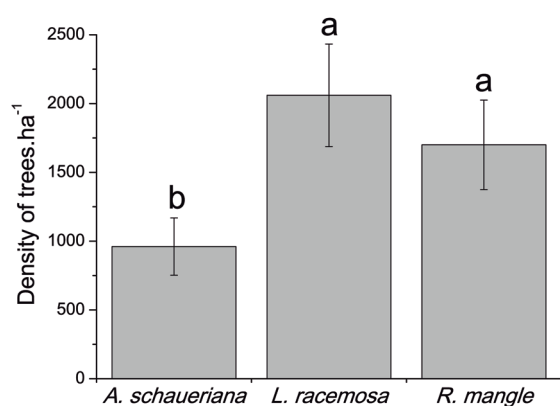


Figure 1 - Density of each tree species (mean and standard error in ha⁻¹) in Itapanhaú mangrove.

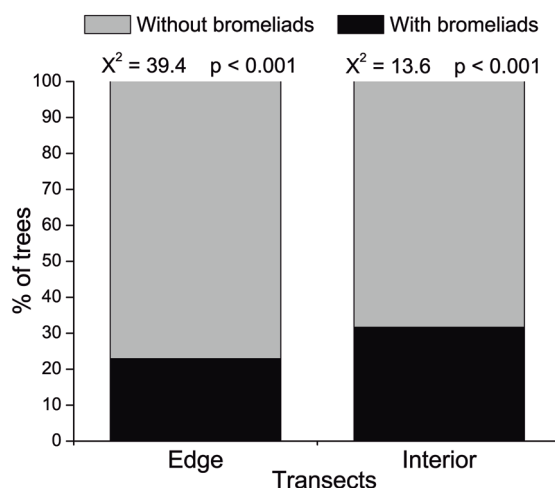


Figure 2 - Proportion of trees without and with bromeliads in the edge and interior transects of Itapanhaú mangrove. Chi-square results.

TABLE I

Summary of the two-way ANOVA comparing A: the density of each tree species between transects and B: the abundance of bromeliads in each species of host tree between transects. Transects is a fixed and orthogonal factor, with two levels: edge and interior. Tree species is a fixed and orthogonal factor, with three levels: *Avicennia schaueriana*, *Laguncularia racemosa* and *Rhizophora mangle*.

		A				B			
		Density of trees.ha ⁻¹				Abundance of bromeliads			
		Cochran test				Cochran test			
		C = 0.321		p = 0.210		C = 0.450		p = 0.967	
	df	MS	F	p	MS	F	p		
Transects	1	138.4	0.477	0.4926	1.86	0.188	0.6663		
Tree species	2	1138.2	3.926	0.0256	114.57	11.559	0.0001		
Trans vs. Tree	2	519.7	1.793	0.1763	9.21	0.929	0.4009		
Error	54	289.9			9.91				

in the edge (73 ± 79.2 bromeliads.25m⁻²) and the interior (48.8 ± 46.1 bromeliads.25m⁻²) transects was similar (Table I). In the edge transect, 88.7% of bromeliads were atmospheric ($\chi^2 = 431.5$; $p < 0.0001$), whereas in the interior transect, tank bromeliads predominated (54.7%) ($\chi^2 = 4.301$; $p = 0.0425$) (Figure 3). The three mangrove species hosted bromeliads, but the abundance and richness of bromeliads in each host species were different.

Laguncularia racemosa seemed to be the preferred host because greater abundance (Figure 4) and richness (Table II) of bromeliads were recorded in this tree. Four bromeliads species were recorded in *R. mangle* and only *T. gardneri* was found in *A. schaueriana* (Table II).

According to the composition of bromeliad species, the cluster analysis grouped the host tree species (especially *L. racemosa* and *R. mangle*)

TABLE II
Richness, life form, and abundance of bromeliads recorded in the mangrove of the Itapanhaú river. Proportion of each bromeliad species in the host trees. * degree of cover as abundance estimation.

Bromeliad species	Life form	N	Proportion of each bromeliad in the species of host tree (%)		
			<i>A. schaueriana</i>	<i>L. racemosa</i>	<i>R. mangle</i>
<i>Tillandsia gardneri</i>	Atmospheric	582	9.3	78.2	12.5
<i>Tillandsia geminiflora</i>	Atmospheric	156	0	90.4	9.6
<i>Tillandsia globosa</i>	Atmospheric	61	0	100	0
<i>Tillandsia stricta</i>	Atmospheric	63	0	100	0
<i>Tillandsia usneoides</i>	Atmospheric	60*	0	25	75
<i>Vriesea gigantea</i>	Tank	1	0	100	0
<i>Vriesea rodigasiana</i>	Tank	302	0	65.9	34.1

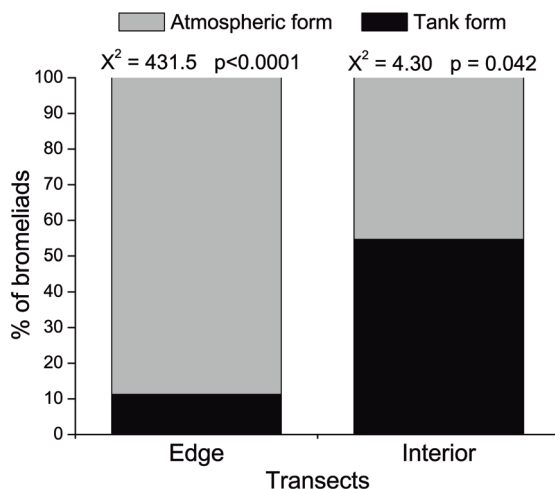


Figure 3 - Proportion of atmospheric and tank bromeliads in the edge and interior transects of Itapanhaú mangrove. Chi-square results.

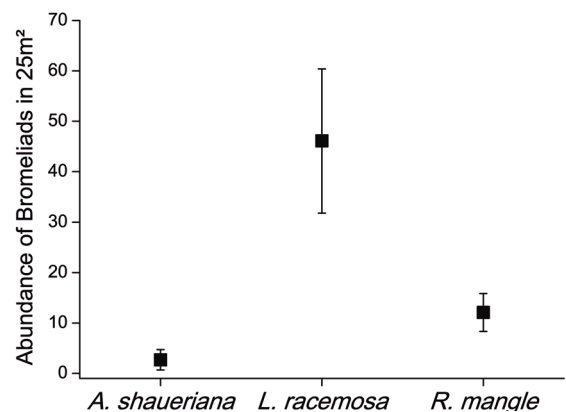


Figure 4 - Abundance of bromeliads (mean and standard error in 25m²) in each host tree species recorded in Itapanhaú mangrove.

at 58% similarity (Bray Curtis coefficient) but not the transects (edge and interior) (Figure 5). This result suggests that the distribution of epiphytic bromeliads in the mangroves is more associated with the host tree than with the distance from the waterline. The DBH of the host tree showed a positive effect on bromeliad abundance, while the height was not related (Table III). Therefore, larger DBH of host trees is associated with greater abundance of bromeliads.

DISCUSSION

The conditions of light, air humidity, temperature, and physical variants provided by host trees create microenvironments that affect the spatial distribution patterns and settlement of epiphytic bromeliads in a forest (Zotz and Vollrath 2003, Padmawathe et al. 2004, Zotz and Schultz 2008, Hayasaka et al. 2012, Cach-Pérez et al. 2013). In the mangrove of Itapanhaú river, the distribution of bromeliads was more affected by the characteristics

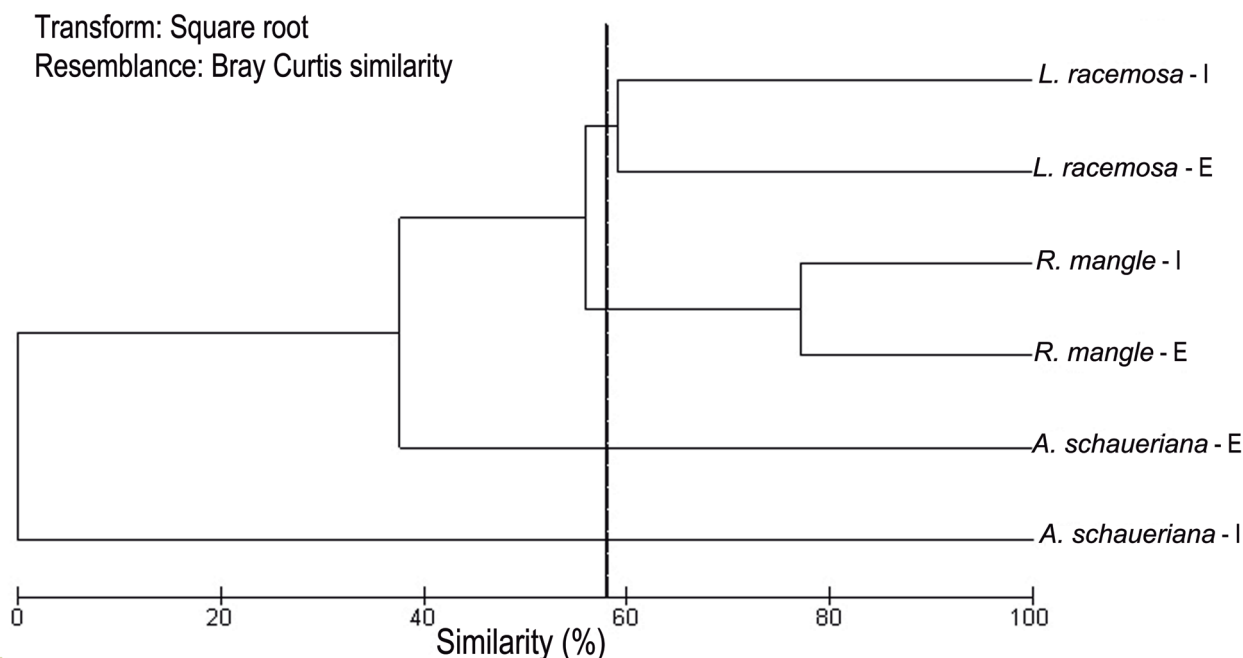


Figure 5 - Cluster analysis based on bromeliad abundances recorded in each host tree species and in each transect (E = edge, I - interior). The Bray Curtis coefficient grouped the host species (*L. racemosa* and *R. mangle*) at 58% of similarity, independently of the transect.

TABLE III

Summary of multiple regression analysis (GLM), testing the relationship between predictor variables (diameter at breast height – DBH - and height of host trees) and dependent variable (abundance of bromeliads).

Predictor variables	df	Bromeliad abundance		
		MS	F	p
DBH of host trees	1	3239.8	7.681	0.0076
Height of host trees	1	85.8	0.203	0.6536
Error	56	421.8		

of the host tree than by the distance to the waterline. In the study area, *L. racemosa* and trees with greatest diameter provided better conditions for the colonization of bromeliads.

The topography, type of substrate, frequency of tides, availability of freshwater and nutrients influence the diversity and structure of mangrove forests (Schaeffer-Novelli et al. 1990). *Avicennia schaueriana*, *L. racemosa* and *R. mangle*, the tree species recorded in this study, are common

in subtropical Brazilian mangroves (Colpo et al. 2011). The arrangement of trees in the forest is an important factor that affects the distribution of epiphytes, since each host species provides different substrates, conditions and microclimates for epiphytic development (Benzing 1990, Bonnet and Queiroz 2006). However, in the present study, we found no differences in the density of each tree species or in the proportion of trees with bromeliads between the edge and interior transects. This homogeneous structure of forest possibly promoted the similar abundance and richness of bromeliads in both transects. In this sector of the Brazilian coast, the coastal plains are small, and consequently the mangrove areas are less extensive (Colpo et al. 2011). Therefore, it is probable that the distance between the river and the interior of the forest was insufficient to reveal differences in mangrove structure or in bromeliad diversity and abundance.

In this study, the most important difference found between transects was the proportion of atmospheric and tank bromeliads. Atmospheric bromeliads, with more intermittent water supply but better photoprotection (Benzing 2000, Pierce 2007, Cach-Pérez et al. 2016), predominated in the edge transect, whereas tank bromeliads, which have their own water reservoir and show lower capacity of dissipation of excess radiation (Arruda and Costa 2003, Woods et al. 2015, Cach-Pérez et al. 2016), were more abundant in the interior of the mangrove. In mangroves, air humidity and incident radiation near the river are greater than in the forest interior (Bonnet et al. 2007). In the studied mangrove, probably these environmental factors differed between transects and apparently provided the distribution pattern of atmospheric and tank bromeliads.

Based on the composition of bromeliad assemblages, our results suggest that the distribution of these epiphytes is more related to the host tree species than to the distance from the waterline. Many epiphytes show preferences for specific characteristics of the host trees (Benzing 2000, Benavides et al. 2011, Wagner et al. 2015). Therefore, phylogenetically analogous trees or those that share morphology or functional traits may host similar species of epiphytes (Chaves et al. 2016). The bark structure of the tree is an important feature that affects the preference of bromeliads, since the bark influences the microclimate near the trunk (Callaway et al. 2002, Vergara-Torres et al. 2010, Wagner et al. 2015). Increased roughness of the bark provides greater capacity of retention of organic matter and humidity, promoting the germination of seeds and the development of epiphytes (Benzing 1990, Laube and Zotz 2006, Tewari et al. 2009, Chomba et al. 2011, Wagner et al. 2015). In the present study, all bromeliad species were found on *L. racemosa*, which is the mangrove species with greatest bark roughness (Marcelli 1992, Schaeffer-Novelli 1995). Therefore, we can

assume that this tree species is the most favorable host for bromeliad establishment in this Brazilian subtropical mangrove. Besides the bark traits, the size of attachment area and the time available for colonization positively influence the settlement and development of bromeliads (Flores-Palacios and García-Franco 2006). We found that mature trees with larger trunks (DBH) show greater abundance of bromeliads.

Epiphyte colonization depends on the conditions and support provided by the host tree; therefore, epiphytes can be considered useful biological indicators of ecosystem health (Hayasaka et al. 2012, Sáyo et al. 2013). We can predict a rich bromeliad flora in mangroves with good development and conservation status, especially in mangrove forests with great abundance of mature specimens of *L. racemosa*. In many regions, the deterioration of mangroves is faster than the production of information. Therefore, bromeliad species inventories and assessment on host tree preferences are necessary knowledge for an adequate management of mangroves.

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