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Short Communication

Edge effect on vascular epiphytic composition in a fragment of Atlantic Forest in northeastern Brazil

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ABSTRACT

Epiphytes are common in the canopy of temperate and tropical forests, where they substantially contribute to species diversity and to key ecosystem processes. However, little is known about the effects caused by deforestation on this group of species, especially in northeastern Brazil, an area experiencing intense anthropogenic pressure. This study aimed to evaluate the effect of environmental variables on the structure of assemblies of vascular epiphytes in a fragment of open ombrophilous forest, Areia, northeastern Brazil. Sixty 10 × 10 m sampling plots were installed to cover different environments within the fragment. The relationship between environmental variables and species composition was evaluated by means of a generalized linear mixed model. The composition of assemblies of epiphytes differed with respect to distance from the edge and luminosity. In the study area, deforestation led to a change in the composition of epiphytic species both at the edge and the interior of the fragment.

Keywords: *brejo de altitude*, community ecology, epiphytism, environmental factors, forest fragmentation

Vascular epiphytes comprise around 10% of all known vascular plants, approximately 29,000 species, representing an important component of the biological diversity in tropical forests (Gentry & Dodson 1987). This group of species plays an important role in the supply of nutrients in ecosystems, because they capture nutrients from the atmosphere (instead of the soil stock) in an efficient manner, making them available in the soil later, by means of the decomposition process of organic matter (Oliveira 2004). The contribution is particularly noticeable in the increased content of P, Ca, and C and decreased acidity (Pereira *et al.* 2005). Epiphytes are also an important source of nutrients for canopy animals, providing pollen, nectar, fruit, and water, and even, sites for nesting birds in some cases (Benzing 1990).

Because of the mandatory presence of phorophytes for their establishment, epiphytes are among the first life forms affected by deforestation (Sodhi *et al*. 2008). However, research on the major drivers of deforestation (e.g., forest fragmentation, edge effect) has focused on tree species (Meira-Neto & Martins 2003) and little attention has been paid to their effect on epiphytes. Few studies evaluated the edge effect on vascular epiphytes (Bataghin *et al*. 2008, 2010; Köster *et al*. 2009; Bernardi & Budke 2010; Bianchi & Kersten 2014), and only one examined the edge effect on species composition (Bianchi & Kersten 2014). In northeastern Brazil, no study has addressed the consequences of environmental changes caused by deforestation for the community of vascular epiphytes. Considering the importance of epiphytes in the ecosystem, investigating and assessing

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the ecology of these species may be useful to understand and manage conservation.

Thus, this study aimed to evaluate the effect of environmental variables on the community structure of vascular epiphytes in a fragment of open ombrophilous forest, Paraíba, northeastern Brazil. The study area is located in the Center for Agricultural Sciences, Campus II, Federal University of Paraíba (UFPB), Areia (06°57'46"S and 35°41'31"W), within the microregion of Brejo Paraibano. Local altitude is approximately 600 m, the average annual temperature is 22°C, the relative humidity is approximately 85%, and the average annual rainfall is 1,450 mm (Mayo & Fevereiro 1982). Because of the orographic effect of the eastern slope of the Borborema plateau, the vegetation is open ombrophilous forest, also named *brejo de altitude* (Veloso *et al*. 1991).

The study was conducted in a 50-ha fragment where 60 10 × 10 m sampling plots were installed, corresponding to 1.2% of the total fragment area. The distribution of plots was planned in order to cover six distinct geographical regions in the fragment: Upper Edge 1: the most peripheral region in the fragment, northbound; Upper Edge 2: region 20 m away from UE 1; Center of the Fragment 1: upper central region of the fragment; Center of the Fragment 2: lower central region of the fragment; Lower Edge 1: the most peripheral region in the fragment, southbound; and Lower Edge 2: region 20 m away from LE 1. In each of the geographic regions, 10 plots were installed.

For the study, all shrub and tree individuals with a circumference at breast height (CBH) ≥ 10 cm observed in each plot were analyzed. Within these sampling units, we determined all vascular epiphytic individuals. The material collected was herborized and subsequently registered in the herbarium JPB of UFPB and in the herbarium Jaime Coelho de Moraes of UFPB. The classification system follows APG III (2009) for angiosperms and Smith *et al*. (2006) for lycophytes and monilophytes.

To evaluate the effect of environmental variables on the composition and structure of epiphyte assemblies, the following variables were measured: (I) radiation index (RI): the radiation of each plot was measured with the aid of a light meter (Light Meter LD©–209); the relative luminosity index was calculated using the obtained values (Paiva & Poggiani 2000); (II) distance from edge (DE): at each plot the distance from the closest edge was measured using a measuring tape; (III) density of shrub and tree individuals (DST): the total number of shrub and tree individuals with CBH ≥ 10 cm was determined for each plot; and (IV) total basal area of shrub and tree individuals (BA): CBH of shrub and tree individuals with CBH ≥ 10 cm was measured in each plot and the formula for basal area was applied (Mueller-Dombois & Ellemberg 1974).

The species composition of vascular epiphytes in each plot was summed up through non-metric multidimensional scaling (NMDS). For these analyses, we selected only the plots where epiphytes and species with more than five individuals were present. The ranking was based on the dissimilarity between samples calculated by means of the Bray–Curtis index (Austin 2013).

The relation between environmental variables and species composition was evaluated using a generalized linear mixed model. None of the measured variables was correlated. We used geographic regions in the fragment (GR) as random variable. Therefore, our model was evaluated as follows: $NMDS = a + b(RI) + b(DE) + b(DST) + b(BA) + b(1|GR)$. For statistical analyses, we used the software *R* (R Core Team 2014).

In the survey, 1,277 shrub and tree individuals were sampled, with 65 phorophytic individuals. In total, 197 occurrences of vascular epiphytes were recorded, representing 12 species in 12 genera and five families (Tab. 1). For statistical analyses, seven species and 32 plots were used, because there were species with a low number of individuals and plots with no epiphytes.

The configuration produced on the NMDS axis was sufficient to explain 43.81% of the variance. The generalized linear mixed model using the NMDS axis (dependent variable) and environmental factors (independent variable) explained 27.79% of the variation in species composition ($NMDS = -4.228^{-17} - 3.573^{-1}\,RI - 3.294^{-1}\,DE + 2.615^{-1}\,DA + 5.363^{-2}\,AB$; $\chi^2 = 12.295$; $R^2 = 0.2779$; $P = 0.01$). The variables that significantly contributed to the model were RI ($t = -2.195$; $P = 0.03$) and DE ($t = 2.05$; $P = 0.05$) (Tab. 2).

The fragment studied here has a high degree of disturbance, considering there is no difference in the relationship between the distance from the edge and the incidence of radiation ($R^2 = 2.89^{-3}$; $P = 0.76$). In some cases (especially in disturbed forests), even without this relation, other environmental factors (e.g., wind speed, humidity) may vary depending on the distance from the edge (Bataghin *et al.* 2008). Although there is no relation between luminosity and distance from the edge, the composition of epiphyte communities differed with regards to the gradient from edge to interior, something that suggests that other environmental factors acting on the periphery of the fragment (in addition to the variables under analysis) may have an effect on composition of epiphytes.

Studies conducted with vascular epiphytes showed no effect of distance from the edge on richness, abundance, or diversity index (Bataghin *et al*. 2008; 2010; Köster *et al*. 2009; Bernardi & Budke 2010). Preliminary analyses also revealed the absence of an effect of distance from edge on the abundance ($R^2 = 3.15^{-3}$; $P = 0.75$) and richness ($R^2 = 7.02^{-3}$; $P = 0.64$) in the fragment focus of this study, reinforcing the idea that (independently of the location of study) the edge effect does not affect the abundance and richness of vascular epiphytes. However, a recent study has found differences in species composition along an edge–interior gradient (Bianchi & Kersten 2014). Thus, although the distance from the edge has no effect on the richness and abundance of epiphytes, species occurring on

Table 1. List of vascular epiphytic species collected in plots installed in the woods in the Center for Agricultural Sciences of UFPB. [1] Species used for analysis (by having sufficient number of subjects); [2] Species excluded from analysis (by having insufficient number of individuals); Voucher: registration number.

Family/species	Nº Ind.	Voucher
ARACEAE		
Philodendron imbe Schott ex Endl.[1]	29	15,529*
BROMELIACEAE		
Aechmea stelligera L.B. Sm.[1]	14	15,531*
Vriesea procera (Mart. ex Schult.f.) Wittm.[1]	7	15,528*
Tillandsia polystachya (L.) L.[2]	2	15,540*
CACTACEAE		
Rhipsalis floccosa Salm-Dyck ex Pfeiff.[1]	22	14,431*
ORCHIDACEAE		
Alatiglossum barbatum (Lindl.) Baptista[2]	1	14,428*
Catasetum macrocarpum Rich. ex Kunth[2]	2	15,536*
Epidendrum difformes Jacq.[2]	1	14,432*
Polystachya concreta (Jacq.) Garay & H.R. Sweet[2]	1	14,429*
Vanilla schwackeana Hoehne[1]	6	15,535*
POLYPODIACEAE		
Microgramma vacciniifolia (Langsd. & Fisch.) Copel.[1]	76	43,550**
Pleopeltis macrocarpa (Bory ex Willd.) Kaulf.[1]	36	43,551**

* Species registered in the herbarium "Jaime Coelho de Moraes".
** Species registered in the herbarium "JPB".

Table 2. Results of fixed effects in generalized linear mixed model analyses for the analyzed fixed variables.

Fixed Effects	Estimate	Std. Error	t value	P value
Intercept	-4.228^{-17}	1.577	-	-
radiation index (RI)	-3.573^{-1}	1.628	– 2.195	0.03*
distance from edge (DE)	-3.294^{-1}	1.607	– 2.05	0.05*
density of shrub and tree individuals (DST)	2.615^{-1}	1.82	1.437	0.16
total basal area of shrub and tree individuals (BA)	5.363^{-2}	1.826	0.294	0.77

the edge are not the same as in the interior (or they do not occur with the same number of individuals). Some species were widely distributed along the entire edge–interior gradient, such as *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel., and *Pleopeltis macrocarpa* (Bory ex Willd.) Kaulf. Other species, in turn, were more strongly associated with edges such as *Philodendron imbe* Schott ex Endl. and *Vriesea procera* (Mart. ex Schult.f.) Wittm. The species *Rhipsalis floccosa* Salm-Dyck ex Pfeiff. was more strongly associated with distance from the edge. Luminosity can also cause the same effect, where areas with higher radiation may show a different composition (based on the abundance) when compared with areas with lower luminosity. Some species were widely distributed along the entire light gradient, such as *M. vacciniifolia* and *P. macrocarpa*. *Aechmea stelligera* L.B. Sm. was more strongly associated with high light intensity, whereas *P. imbe* and *V. procera* were more strongly associated with low luminosity.

Epiphytes are clearly sensitive to changes in environmental factors (e.g., altitude —Hietz & Hietz-Seifert 1995) and anthropogenic disturbance (Wolf 2005). For the study area, the fragmentation caused by deforestation resulted in a change in species composition of epiphytes in relation to the edge and the interior of the fragment. Given the importance of epiphytes in the ecosystem, further studies must be conducted using replicable metrics, which can contribute to a conservation plan for these species in swamp areas in northeastern Brazil.

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