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Orchid Bees (Hymenoptera: Apidae: Euglossini) in Seasonally Dry Tropical Forest (Caatinga) in Brazil

LS Carneiro[1], WM Aguiar[1,2], CML Aguiar[1] & GMM Santos[1]

1 - Departamento de Ciências Biológicas, Universidade Estadual de Feira de Santana, Bahia, Brazil

2 - Instituto do Meio Ambiente e Recursos Hídricos, Salvador-BA, Brazil

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Corresponding author
Lázaro da S. Carneiro
Departamento de Ciências Biológicas
Universidade Estadual de Feira de Santana
Av. Transnordestina, s/nº, Novo Horizonte
CEP 44036-900, Feira de Santana-BA, Brasil.
E-Mail: lazarocarneiro16@gmail.com

Abstract

Euglossini bees are important Neotropical pollinators, but there is a lack in the knowledge about this fauna in dry tropical environments. The aims of this study were to evaluate the richness and abundance of euglossine bees in two fragments of seasonally dry tropical forest (Caatinga), as well as to assess the distribution of euglossine species richness in the Caatinga environment. Males were collected along 12 consecutive months, using traps with aromatic baits. The species richness (S=5) was lower than in rainforests and savannas. *Euglossa cordata* (L.) was the dominant species in the assemblage, representing 70% of the individuals. The highest abundance occurred in the rainy season. Euglossini fauna presents low local species richness in Caatinga areas, however the beta diversity is higher, since assemblages in different habitats have differences in species composition.

Introduction

Euglossini bees are also known as "orchid bees" due to the intimate interactions with Orchidaceae (Dressler, 1982), whose flowers are used by males to collect fragrances that they probably use for the court (Dodson et al., 1969; Eltz et al., 2005). Other floral sources are exploited to collect fragrances, resins, pollen and nectar (Whitten et al., 1993; Cortopassi-Laurino et al., 2009; Perger, 2015). These bees are pollinators of plants included in approximately 40 botanical families (Ramírez et al., 2002).

This taxon is distributed in the Neotropical region (Dressler, 1982; Moure et al., 2012), and higher species richness is found in tropical rainforests (Roubik & Hanson, 2004), but there are populations settled in arid areas, as in the seasonally dry tropical forest (Caatinga) (Lopes et al., 2007; Andrade-Silva et al., 2012). Studies focusing on Euglossini assemblages in the Caatingas' dominium are scarce and geographically restricted. Some works were carried out in different phytophysiognomies located near the Caatinga vegetation, such as riparian forests of the São Francisco River (Neves & Viana, 1999; Moura & Schlindwein, 2009), while few studies focused on the euglossine assemblages in the typical xerophytic vegetation of Caatinga (Lopes et al., 2007; Andrade-Silva et al., 2012).

Habitat fragmentation has been recognized as one of the main causes of biodiversity loss (Fahrig, 2003; Krauss et al., 2010; Haddad et al., 2015), while changes in abundance and species richness related to land use pressures also have been observed (Laurence et al., 2011; Newbold et al., 2015). The Caatinga is a xerophilous vegetation in the Northeast of Brazil that occupies an area of approximately 750.000 km², reduced to almost half of its original area (IBGE, 2015). The fragmentation these ecosystems is related to the proximity of cities and road construction (Santos & Tabarelli, 2002), livestock, slash and burn agriculture and use of wood for coal production (Leal et al., 2005; Holanda et al., 2015). The scarcity of knowledge on euglossine assemblages in

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dry environments, and the high level of degradation of the seasonally dry tropical forest (Caatinga) (Leal et al., 2005; IBGE, 2015) motivated the planning of this study, which aimed to characterize the euglossine assemblage in two fragments of Caatinga, as well as to evaluate the distribution of Euglossini species richness in the Caatinga.

Material and Methods

Study area

The study was carried out in two fragments of Caatinga located in the municipality of Pé de Serra, state of Bahia, Brazil. These fragments are 4 km apart and are surrounded by a predominant pasture matrix. Fragment I (11°54' S; 39°31' W) has approximately 50 ha, consisting of a shrub Caatinga vegetation (SEMA, 2014) in regeneration, and there is some goat and sheep farming in this site. Fragment II (11° 57' S 39° 32' W) has approximately 220 ha, is covered by arboreal and shrub caatinga (SEMA, 2014). The local vegetation is generally dense, although the site has already suffered burnings.

The area of study has dry climate of type BSh according to classification of Köppen. The rainy season lasting from November to March and annual rainfall around 658 mm (SEI, 2014). Annual rainfall was 495 mm during this study, which is below the expected average. Rainfall data were obtained from the Instituto Estadual do Meio Ambiente (INEMA).

Methods

Males were collected monthly from November 2015 to October 2016, totalizing 216 h of sampling effort per site. Sampling was carried out on sunny days and without rain. In each fragment, a sampling point was selected, where seven bait traps were hung from a height of 1.5 m above the ground, at least 2 m from each other. Seven aromatic compounds (benzyl acetate, β-ionone, methyl cinnamate, eucalyptol, eugenol, methyl salicate and vanillin) were soaked in cotton and inserted into traps made from plastic bottles, in which three lateral openings were made to insert funnels, following a model proposed by Aguiar and Gaglianone (2008).Traps were installed between 7:30 a.m. and 8:00 a.m., remaining exposed for two days. The bees caught on the first day of sampling were removed from the traps at the beginning of the second day, immediately before reapplication of the baits.

The specimens were identified according to the taxonomic keys (Nemésio, 2009; Faria Jr & Melo, 2012) and confirmed by bee taxonomy specialist. We followed the Moure's Bee Catalog (Moure et al., 2012) for species nomenclature.

Data analysis

We have used the Rank-Abundance Plot, where the relative abundance of species is determined in descending order (Whittaker, 1965), to evaluate the distribution of species abundance in each fragment. Additionally, the Shannon-Wiener index (H') was used to calculate diversity of species, following the algorithm H'= - Σpi x ln pi, where *pi* is the proportion of individuals of the species *i* represented in the sample and ln = neperian logarithm (Magurran, 2004). Pielou index (J') was used to calculate the uniformity of abundance, following the algorithm J'= H' / log2S, where H'= Shannon diversity index and Log2S = logarithm in base two of species richness (Magurran, 2004). Dominance was evaluated using Berger-Parker index (d), defined as d = Nmax/N, where Nmax = Number of individuals of the most abundant species, N = total sample number. A linear correlation of Sperman's was performed to investigate the relation between abundance and rainfall. These indexes were calculated in the PAST 2.17c program (Hammer et al., 2001).

In order to evaluate if the sampling effort was enough to sample the species richness in each fragment, we used richness estimators (Chao 1 and Jackknife 1), calculated in the EstimateS 9.1 software (Cowell, 2015). To analyze the distribution of Euglossini species richness in different areas of the Caatinga, we reviewed data published in studies on Euglossini assemblages in which aromatic baits were used to attract males, totalizing nine sites sampled: 1. Site Parque Estadual Pedra da Boca (Zanella & Martins, 2005); 2. Site Cacimba de Dentro (Zanella & Martins, 2005); 3. Site 1 (Lopes et al., 2007); 4. Site 2 (Lopes et al., 2007); 5. Site 3 (Lopes et al., 2007); 6. Site 4 (Lopes et al., 2007); 7. Site Pindoba (Andrade-Silva et al., 2012); 8. Site Cambuí (Andrade-Silva et al., 2012); 9. Site Braúna (Andrade-Silva et al., 2012). From these data, we elaborated a table presenting the distribution of species by Caatinga phytophysiognomy (arboreal or shrub) and species accumulation curves in function of the sample effort, given by the number of localities sampled.

Results

The Euglossini assemblage sampled was composed by five species (Table 1). The species richness expected was the same as that observed in fragment I (Chao1= 2.00±0.17; Jackknife1=2.92±0.92) while in fragment II, the species richness expected was higher than that observed (Chao1=6.09±2.41; Jackknife=6.86±1.72). Abundance was also higher in fragment II than in fragment I. *Euglossa cordata* (Linnaeus) was the most abundant species, representing 70% of the males collected, contributing to the highest relative abundance in both fragments (Fig 1). Three *Euglossa* species were recorded only in fragment II. Although diversity was higher in fragment II (H'= 0.977) compared to fragment I (H'= 0.636), the values did not differ significantly (t= -1.311, p= 0.245). The uniformity was higher in fragment I (J'= 0.92) than in fragment II (J'= 0.607) (Table 1).

The highest abundance of Euglossini was found in January (Fig 2), a rainy month, influenced by the abundance of *Eg. cordata*. In Fragment II, a number of males was in activity in March/2016, a month with low precipitation (Fig 2).

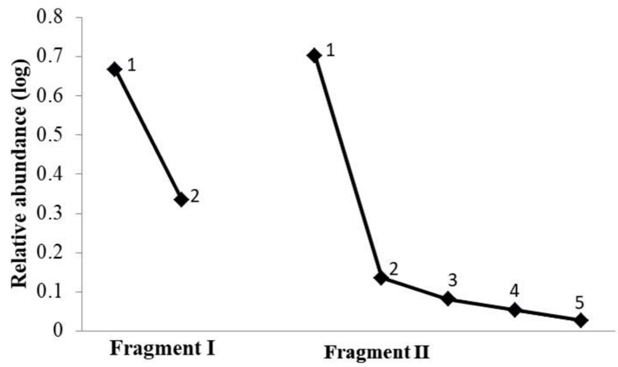

Fig 1. Rank abundance plot for Euglossini species in two fragments of Caatinga (1 = *Eg. cordata*; 2 = *El. nigrita*; 3 = *Euglossa* sp; 4 = *Eg. fimbrita*; 5 = *Eg. securigera*).

Table 1. Composition, Species Richness, Diversity, Uniformity and Dominance in Euglossini assemblages in two fragments of Caatinga.

Species	Fragment I	Fragment II	Total
Euglossa cordata (Linnaeus)	2	26	28
Euglossa securigera Dressler	0	1	1
Euglossa fimbriata Moure	0	2	2
Euglossa sp.	0	3	3
Eulaema nigrita Lepeletier	1	5	6
Abundance	3	37	40
Species Richness	2	5	5
Diversity (H')	0.636	0.977	0.970
Uniformity (J')	0.918	0.607	0.603
Dominance (d)	0.666	0.702	0.700

Eg. cordata was recorded in fragment I only in months with the highest rainfall (January and October), but in fragment II it occurred in both rainy and dry months. *Eulaema nigrita* Lepeletier was recorded only in January, the rainiest month. There was no correlation between monthly abundance and rainfall (r = 0.411, p = 0.183).

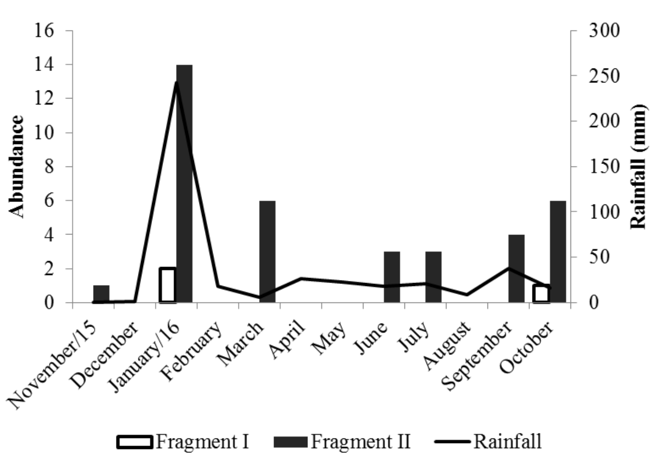

Fig 2. Rainfall and monthly flutuaction in abundance of Euglossini bees in fragments of Caatinga.

Comparing Euglossini species richness in different areas of Caatinga, we observed that arboreal Caatinga have a richer Euglossini fauna (up to 14 species per assemblage) than shrub Caatinga, in which only two species have been recorded (*El. nigrita* and *Eg. cordata*) (Table 2). The number of species registered in the site 9 (Braúnas) (S = 14) was significantly higher than in the other sites (mean = 4.45; standard deviation = 3.70), and this assemblage had four exclusive species. Species accumulation curves did not stabilize, including or excluding site 9 from the analysis (Fig 3).

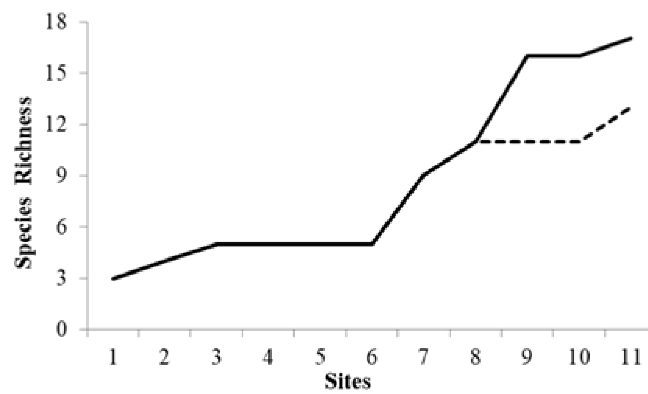

Fig 3. Species accumulation curves in function of the number of localities sampled in Caatinga vegetation. The solid line represents the curve based on all the sites (n = 11) sampled in the Caatinga, and the dotted line the curve excluding the site 9 (Braúnas). 1. Site Parque Estadual Pedra da Boca (Zanella & Martins, 2005); 2. Site Cacimba de Dentro (Zanella & Martins, 2005); 3. Site 1 (Lopes et al., 2007); 4. Site 2 (Lopes et al., 2007); 5. Site 3 (Lopes et al., 2007); 6.Site 4 (Lopes et al., 2007); 7. Site Pindoba (Andrade-Silva et al., 2012); 8. Site Cambuí (Andrade-Silva et al., 2012); 9. Site Braúna (Andrade-Silva et al., 2012); 10. Fragment I (this study); 11. Fragment II (this study).

Discussion

The species richness and abundance of euglossine bees found were similar to that observed in most areas covered by seasonally dry tropical forest (Caatinga). The euglossine assemblages in the Caatinga are commonly composed of two to five species (Lopes et al., 2007; Zanella & Martins, 2005; this study), but there are some assemblages with higher species richness. A single assemblage in arboreal Caatinga was composed of more than eight species (Andrade-Silva et al., 2012). The assemblages with the highest species richness were found in arboreal Caatinga with canopy 5 to 12 m in high, located in areas with higher humidity, in the Chapada Diamantina highlands, a region characterized by a mosaic of different types of vegetation (semideciduous forest, riparian forests, savanna and caatinga), located at relatively close distances between each other, forming a complex landscape (Juncá et al., 2005).

The total number of Euglossini species recorded in Caatinga vegetation is fifteen, with a single endemic species, *Eufriesea nordestina* (Moure) (Zanella & Martins, 2005) and one undescribed species of *Eulaema* (Andrade-Silva et al.,

Table 2. Composition and species richness in Euglossini assemblages in different Caatinga phytophysiognomies. 1. Site Parque Estadual Pedra da Boca (Zanella & Martins, 2005); 2. Site Cacimba de Dentro (Zanella & Martins, 2005); 3. Site 1 (Lopes et al., 2007); 4. Site 2 (Lopes et al., 2007); 5. Site 3 (Lopes et al., 2007); 6. Site 4 (Lopes et al., 2007); 7. Site Pindoba (Andrade-Silva et al., 2012); 8. Site Cambuí (Andrade-Silva et al., 2012); 9. Site Braúna (Andrade-Silva et al., 2012); 10. Fragment I (this study); 11. Fragment II (this study).

	Arboreal Caatinga								Shrub Caatinga		
	1	**2**	**3**	**6**	**7**	**8**	**9**	**11**	**4**	**5**	**10**
Eufriesea nordestina (Moure)	_	X	_	_	_	_	_	_	_	_	_
Eufriesea auriceps (Friese)	_	_	_	_	X	X	X	_	_	_	_
Euglossa townsendi[1] Cockerell	_	_	_	_	_	_	X	_	_	_	_
Euglossa cordata[2] (Linnaeus)	X	X	X	X	X	X	X	X	X	X	X
Euglossa fimbriata Moure	_	_	_	_	_	_	X	X	_	_	_
Euglossa leucotricha Rebêlo & Moure	_	_	_	_	X	_	X	_	_	_	_
Euglossa melanotricha Moure	_	_	_	_	X	X	X	_	_	_	_
Euglossa pleosticta Dressler	_	_	_	_	_	X	X	_	_	_	_
Euglossa securigera Dressler	_	_	X	_	X	X	X	X	_	_	_
Euglossa sp.	X	_	_	_	_	_	_	_	_	_	_
Euglossa sp.1	_	_	_	_	_	_	_	X	_	_	_
Euglossa stellfeldi Moure	_	_	_	_	_	_	X	_	_	_	_
Euglossa truncata Rebêlo & Moure	_	_	_	_	_	_	X	_	_	_	_
Eulaema cingulata[3] (Fabricius)	_	_	_	_	X	X	X	_	_	_	_
Eulaema nigrita Lepeletier	X	_	X	X	X	X	X	X	X	_	X
Eulaema sp.	_	_	_	_	_	X	X	_	_	_	_
Exaerete dentata (Linnaeus)	_	_	_	_	_	_	X	_	_	_	_

[1]cited as *Euglossa aratingae* by Andrade- Silva et al. (2012); [2]cited as *Euglossa carolina* by Andrade- Silva et al. (2012); [3]cited as *Eulaema marcii* by Andrade-Lima et al. (2012).

2012). However, due to the small number of studies, it is still difficult to measure the gamma diversity of Euglossini bees. The species accumulation curves did not have tendency towards stabilization, indicating that sampling at other sites should reveal other species of Euglossini bees living in the Caatinga.

The change from shaded vegetation to open vegetation seems to influence Euglossini assemblages, leading to a decrease in the species richness, both in the Brazilian savanna (Cerrado) (Nemésio & Faria Jr., 2004; Alvarenga et al., 2007; Silveira et al., 2015), and Caatinga (Neves & Viana, 1999; Lopes et al., 2007; Andrade-Silva et al., 2012). Andrade-Silva et al. (2012) showed that temperature was the most important environmental variable to explain variations on composition and abundance of Euglossini in three Caatinga fragments. Moura and Schlindwein (2009) pointed out that although some species of Euglossini bees from the Atlantic forest use riparian forests of the São Francisco river as habitat corridors, there is a decrease in the number of species towards the interior of the Caatinga biome.

Additionally, the change from arboreal to shrubby vegetation in the Caatinga seems to limit the occurrence of most species of Euglossini. Several species of Euglossini bees appear to have restricted geographical distribution in the Caatinga, while few species, such as *Eg. cordata* and *El. nigrita* has greater ecological valence and wider distribution in these xeric areas. These species are tolerant to dry and open environments, and under anthropic influence (Peruquetti et al., 1999; Tonhasca et al., 2002), which may explain its occurrence in xerophilous Caatinga environments. The uniformity and dominance indexes reflected differences in species abundance, since that a single dominant species (*Eg. cordata*) was represented by many individuals in the assemblage, as reported in other Euglossini assemblages (Alvarenga et al., 2007; Aguiar & Gaglianone, 2008; Rocha-Filho & Garófalo, 2013; Silveira et al., 2015; Vilhena et al., 2017). This study reinforces the idea of low species richness of orchid bees in xerophilous Caatinga vegetation. Additional studies focusing on the influence of habitat loss and fragmentation on these bee assemblages in the seasonally dry tropical forest are required to plan conservation strategies for these bee populations, since there is a high level of degradation of the Caatinga environment.

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