

# Floral visitors and potential pollinators of a rupicolous bromeliad (Pitcairnioideae) in the Brazilian semiarid

## Visitantes florais e potenciais polinizadores de bromélia rupícola (Pitcairnioideae) no semiárido brasileiro

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### Abstract

There have been few studies about the pollinators of bromeliads of the genus *Encholirium*. Considering this lack of information, this study comes to fill a gap in the literature on the floral visitors and potential pollinators of *E. spectabile*. In order to perform this study, we observed the inflorescence of this species between 2011 and 2014 (four years of observation), in the semiarid region of Santa Maria municipality (Rio Grande do Norte state, north-eastern Brazil). Floral visitors were observed through focal method. The observations were made during the day, starting at 06h a.m. until 06h p.m., and at night from 07h until 11h59 p.m. In about 1,800 hours of observations, 24 species were recorded visiting *E. spectabile* flowers, including 4 species of moths (Lepidoptera: Sphingidae and Geometridae), 3 species of bees (Hymenoptera: Apidae), 4 species of hummingbirds (Aves: Trochilidae) and 2 species of bats (Chiroptera: Phyllostomidae), among others. Based on these results, we propose that the *macambira* bromeliads (*E. spectabile*) should be considered as key elements in the conservation of various taxonomic groups in the semiarid region, through the umbrella species theory as already proposed for other species of Bromeliaceae.

**Keywords:** associated fauna, caatinga biome, macambiras, *Encholirium spectabile*, biodiversity.

### Resumo

Existem poucos estudos a respeito dos polinizadores de bromélias do gênero *Encholirium*. Dessa forma, este estudo vem preencher a lacuna na literatura sobre os visitantes florais e potenciais polinizadores de *E. spectabile*. Para sua realização, observamos a inflorescência dessa espécie no período de 2011 a 2014 (quatro anos de observações), na região semiárida, no município de Santa Maria, Rio Grande do Norte, Brasil. Os visitantes florais foram registrados por meio do método focal. As observações foram conduzidas durante o dia, começando às 06h da manhã e seguindo até às 18h e, à noite, das 19h às 23h59min. Em cerca de 1.800 horas de observação, 24 espécies foram registradas visitando a inflorescência de *E. spectabile*, incluindo 4 espécies de mariposas (Lepidoptera: Sphingidae e Geometridae), 3 espécies de abelhas (Hymenoptera: Apidae), 4 espécies de beija-flores (Aves: Trochilidae) e 2 espécies de morcegos (Chiroptera: Phyllostomidae), entre outros. Com base nesses resultados, e subsidiados pela teoria das espécies guarda-chuva, sugerimos que as bromélias *macambiras* (*E. spectabile*) sejam consideradas como elementos chave na conservação de vários grupos taxonômicos de região semiárida.

**Palavras-chave:** fauna associada, bioma caatinga, macambiras, *Encholirium spectabile*, biodiversidade.

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## Introduction

The family Bromeliaceae has a significant ecological importance to the ecosystem where it is inserted due to the high number of interdependence relations that other organisms establish with species of this family, as well as the bromeliads with such organisms (Waser and Price, 1983; Romero and Vasconcellos-Neto, 2005; Gonçalves *et al.*, 2011). Bromeliads are an important component in maintaining biological diversity (Siqueira Filho and Machado, 2001; Rios *et al.*, 2010; Santana and Machado, 2010), since they provide shelter, serve as a substrate for foraging and even as a breeding site for many organisms (Ramalho *et al.*, 2004; Romero and Vasconcellos-Neto, 2005; Andrade *et al.*, 2009). They are also a food resource for floral visitors (Siqueira Filho and Machado, 2001; Kaehler *et al.*, 2005; Rios *et al.*, 2010).

A floral visitor is any animal that visits the floral parts of the plant, searching for food (nectar, pollen, wax and other compounds provided by the plant), even if it does not perform pollination (Rios *et al.*, 2010). Some factors, such as the adequacy of animal body parts that will touch the plant, floral morphology, type of visitor approach and time spent in this approach, are mandatory for the occurrence of pollination (Waser and Price, 1983).

Bromeliads provide food resources for a wide variety of organisms (Sazima *et al.*, 1989; Nara and Weber, 2002). Most bromeliad species present ornithophily syndrome, whereas some others show entomophily or chiropterophily (Sazima *et al.*, 1989; Benzing, 2000; Rios *et al.*, 2010). Hummingbirds are considered the most important bromeliad pollinators (Bawa, 1990; Nara and Weber, 2002; Canela and Sazima, 2003; Santana and Machado, 2010; Christianini *et al.*, 2013).

Despite the great diversity of floral visitors reported for Bromeliaceae, mainly in the genera *Aechmea*, *Tillandsia*, *Vriesea* and *Puya* (Sazima *et al.*, 1989; Siqueira Filho and Machado, 2001; Nara and Weber, 2002; Mendonça and Dos Anjos, 2003; Rios *et al.*, 2010), little is known about the floral visitors of the genus *Encholirium*. An exception is the study performed on *Encholirium spectabile* MART. EX SCHULT. & SCHULT. F. (Queiroz *et al.*, 2016) in the Sertão region of the caatinga biome. *Encholirium spectabile* (Pitcairnioideae) is an endemic bromeliad of Brazil, the distribution of which is restricted to the rocky outcrops in semiarid regions of northeastern Brazil (Ramalho *et al.*, 2004). Popularly known as “macambira” or “macambira-de-flecha” (literally “arrow macambira”), *E. spectabile* it is one of the species that characterizes the typical landscapes of the Caatinga biome. Due to the rustic, thorny appearance of its leaves, it is called “macambira” in Tupi, which Bessa (1982) translated into Portuguese as “molho pungente” or “spiny sheaf or bundle”. This species is distributed throughout most of the Northeast geopolitical

region of Brazil, especially in the Caatinga biome, sometimes reaching the coastline (Forzza, 2005). *Encholirium spectabile* may be considered a key species for local biodiversity due to its associations with several other organisms, mainly due to the shape of their clumps that form large tangles on rocky outcrops, creating a refuge protected by the hard and abundant thorns present on the bromeliad’s leaves (Jorge *et al.*, 2014; Jorge, 2015; Sales *et al.*, 2015).

Considering that the single study about the floral visitors of *E. spectabile* was carried out in the Sertão region of the caatinga biome (Queiroz *et al.*, 2016), we aimed to study the floral visitors and potential pollinators of *E. spectabile* in the Agreste region, characterized by higher rainfall and milder temperatures than in the Sertão proper (Rizzini, 1997). This study has the following objectives: (i) to describe the floral visitors of *E. spectabile* and its potential pollinators; and (ii) to understand the relationship between the species involved.

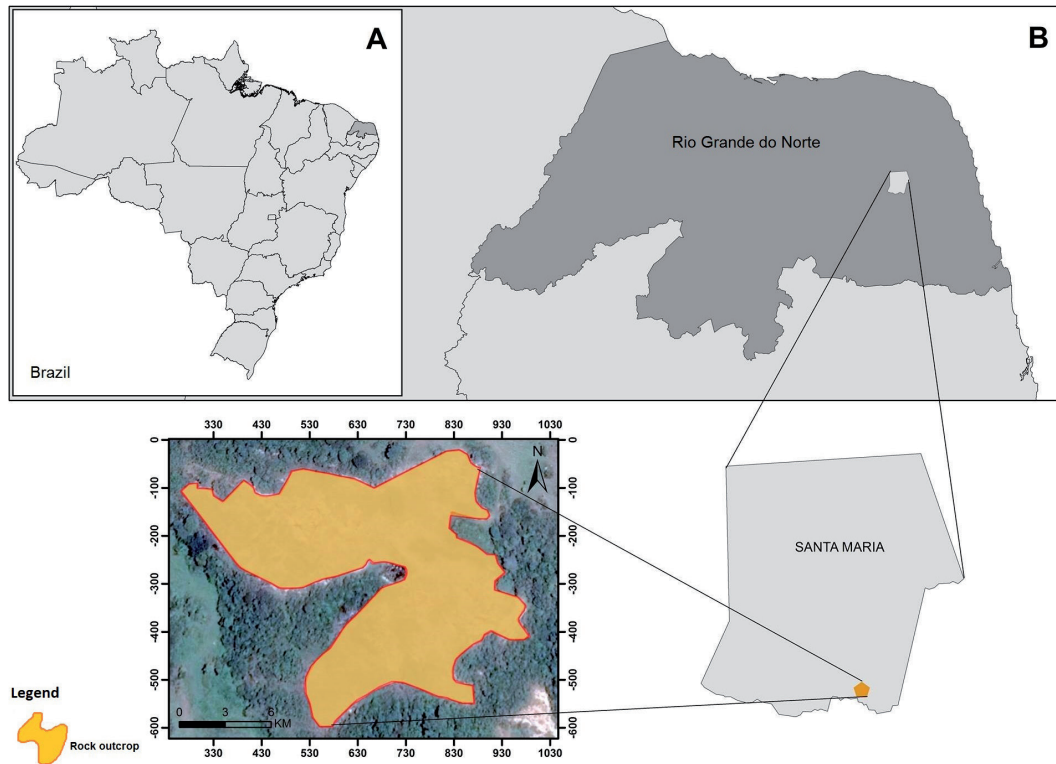
## Materials and methods

### Study area

The study area is part of the Caatinga, the only exclusively Brazilian biome, occupying about 800,000 Km<sup>2</sup>, more than 10% of the national territory (Ab’Saber, 1977; Velloso *et al.*, 2002). According to Rizzini (1997), the term “caatinga” is a generic name used to designate a complex of deciduous and xerophile vegetation composed by woody plants and somewhat rich in cactuses and rigid bromeliads, whose dominance depends on climate dryness and substrate composition. Two climatic periods are recognized for this region: the rainy season, from December to June, and the dry season, from July to November. In some regions, the dry season is extremely severe with droughts that can last for years.

Throughout its range, the Caatinga is divided into two vegetation zones corresponding to two distinct types of landscape: the *Sertão* and the *Agreste*. The *Sertão* corresponds to the backlands, being the most characteristic region of the biome; it shows relatively low humidity, less frequent and more concentrated rainfall and an arid landscape (Rizzini, 1997). Rizzini (1997) defines the *Agreste* as an area of higher humidity due to its proximity to the sea, deeper soil, higher and denser vegetation and more frequent rainfall, making up a transition zone between the Atlantic Forest and the *Sertão* itself.

Fieldwork for this study was conducted in the *Agreste* region, precisely in the “Fazenda Tanques” located in the Santa Maria municipality (Rio Grande do Norte, Brazil). The observations were carried out on a rocky outcrop of about 9,000 m<sup>2</sup> (5.854°S, 35.701° W; WGS84 datum, 137m elev.) about 2 miles southwest from downtown Santa Maria (Figure 1). In this location, there is



**Figure 1.** Location of the study area, highlighting the location of *Tanques* Farm, in Santa Maria, state of Rio Grande do Norte, northeastern Brazil.

a high density of *E. spectabile* ramets, which grow on rocky outcrops forming clumps or tussocks. They flower throughout most of the year, consequently attracting pollinators and others floral visitors.

## Methods

The observations of this study were made between 2011 and 2014, four years of observation, as part of a project that aimed to analyze the fauna associated with the rupicolous bromeliad *E. spectabile* in the Brazilian semi-arid region. During this period, observation and collection of species that were associated with the bromeliads were performed on a monthly basis as well as focal observations of floral visitors.

The activities of floral visitors were monitored several times for three consecutive days in each month during the survey period. During floral anthesis, the focal method (Dafni, 1992) was employed to observe bromeliad visitors. Observations were performed during the day (between 6h a.m. and 6h p.m.) and at night (between 7h p.m. and 11h59 p.m.). The floral visitors were observed directly, without the use of optical equipment. The time in which the species started and finished visitation activities were recorded and the total number of individuals visiting the flowers were

counted. Specimens were not collected, and, thus, it is possible that a same individual may have been recorded more than once.

Four clumps were randomly chosen each month for observations. Each clump had twelve bromeliads with six flowerings each on average. After focal observations, each inflorescence was analyzed in search of smaller animals (invertebrates) inside the flowers.

During focal observations, researchers kept at the distance of approximately ten meters from the bromeliads in order to avoid interference in visitor activities, especially birds and bats. Each sighting was registered in a field book and each individual was photographed for later identification by experts for each group. Photographic record of the individuals was done through digital apparel and when necessary, specimens were collected, and later returned to its place of origin.

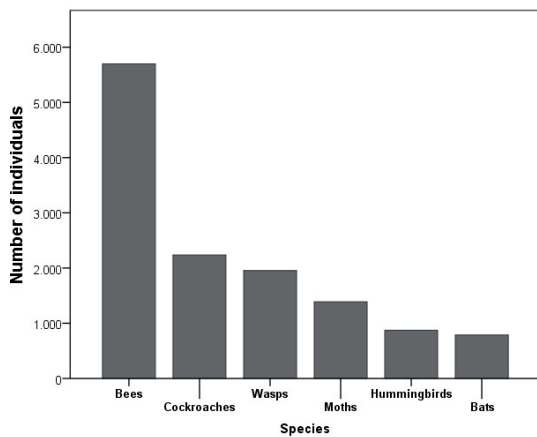
## Results

In the study area *Encholirium spectabile* blooms during most of the year, with some short periods of no flowering. Some individuals bloom before others (asynchronous flowering), which guarantees flowering for the species throughout the year.

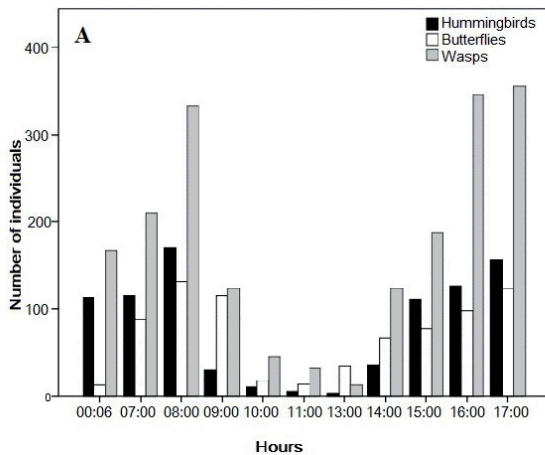
### Floral visitors

Approximately 24 species were observed in association with *E. spectabile* flowers. Among these, there were 4 species of moths (Lepidoptera: Sphingidae and Geometridae), 3 species of bees (Hymenoptera: Apidae), 4 species of hummingbirds (Trochilidae) and 2 species of bats (Phyllostomidae) (Table 1, Figures 2 and 3). In addition, the following taxonomic groups were observed visiting *E. spectabile* flowers: a beetle (Coleoptera: Elateridae), a wasp (Hymenoptera: Vespidae), a butterfly (Lepidoptera: Lycaenidae) and an unidentified cockroach (Blattaria) (Table 1, Figure 2).

The most representatives groups of visitants were bees, hummingbirds, bats, moths, cockroaches and wasps (Figure 2). The majority of the individuals observed showed



**Figure 2.** Total number of visits recorded for the flowers of *E. spectabile* during the years of 2011 to 2014, Santa Maria, Rio Grande do Norte, northeastern Brazil.



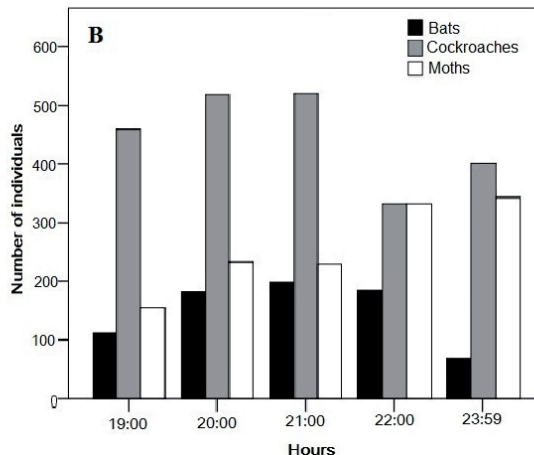
nocturnal habits, and were recorded between 08h-10h p.m. (Figure 3).

Hummingbirds, bees, wasps and butterflies began their activities early, at 06h30 a.m. they were already actively visiting the flowers. Their foraging activities decreased around 11h-12h a.m., returning at 03:00 p.m. and extending up to 6h p.m. The bats *Lonchophylla mordax* and *Glossophaga soricina* initiated activities around 7h30 p.m. with a peak of activity starting at 8h p.m. that extended through the night, as did the moths, cockroaches and the beetle *C. zonatus*.

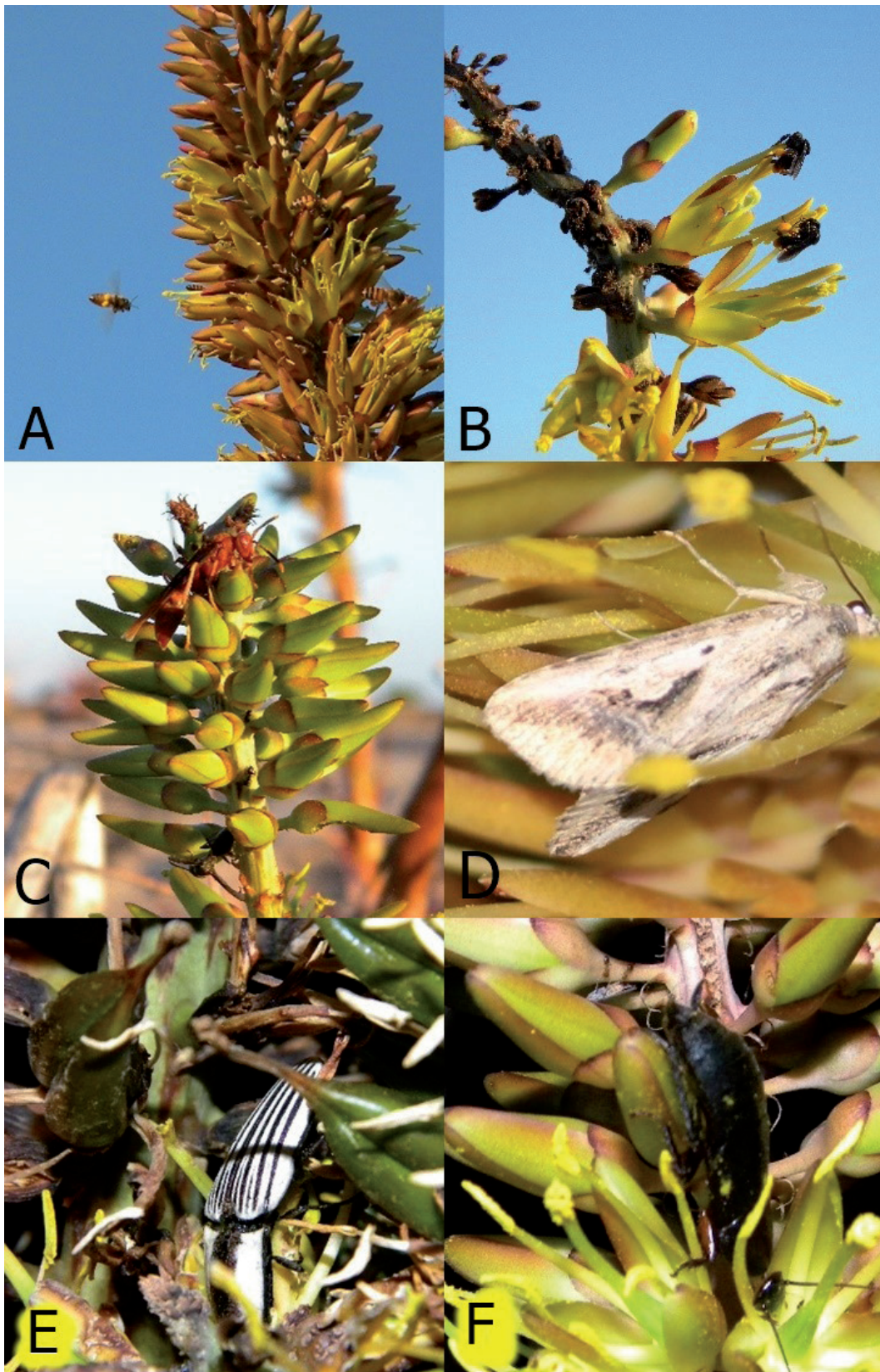
### Additional interactions

In addition to the reported floral visitors, other taxa, including ants and bugs, were recorded in *macambira* flowers (Figure 4). Three species of ants (Hymenoptera: Formicidae) were recorded in activity in bromeliad floral scape. The recorded genera were *Crematogaster* (Hymenoptera: Formicidae) with one species and *Camponotus* (Hymenoptera: Formicidae) with two species: *Camponotus* spp. 1 and 2. These species were observed during the day and night walking among the flowers and foraging in the nectaries. Individuals of *Crematogaster* sp. build their nests on bromeliad leaves, frequently moving between the leaves and flowers. There was interaction between individuals of *Crematogaster* sp. and butterfly larvae of the family Lycaenidae. It is also noted that the workers of *Crematogaster* sp. were observed feeding on the exudates released by leafhoppers (Hemiptera: Cicadellidae) (Figure 4).

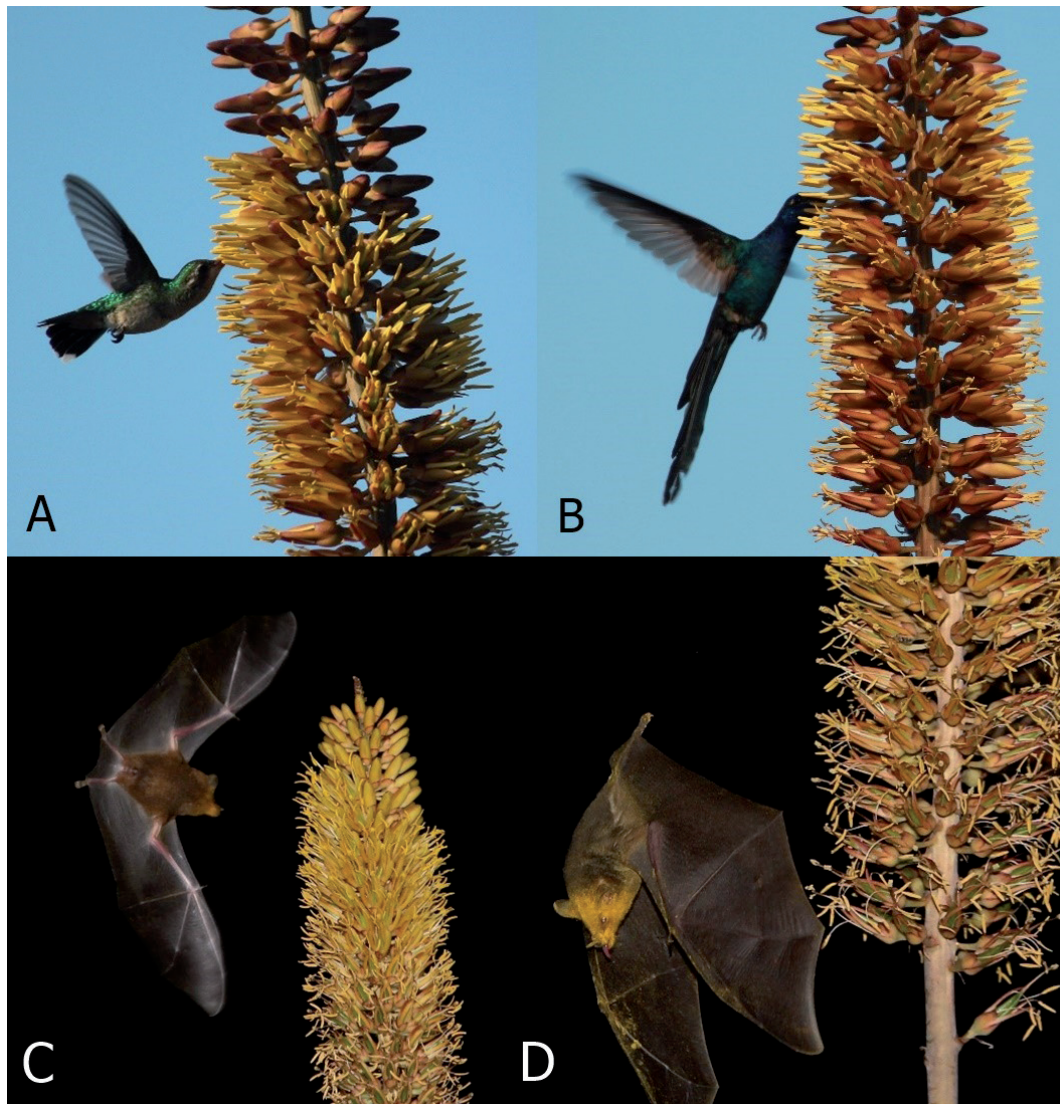
Bugs (Hemiptera: Reduviidae) were observed feeding on nectar of already pollinated flowers. Dipterans of the Ulidiidae family were often observed on newly opened flowers (Figure 4).



**Figure 3.** Number of visits recorded throughout the day in *E. spectabile* flowers in one-hour intervals. A - Diurnal specimens; B - Nocturnal specimens (except bees).



**Figure 4.** Invertebrate floral visitors of *Encholirium spectabile* in Santa Maria, Rio Grande do Norte, northeastern Brazil. A - *Apis mellifera*; B - *Trigona spinipes*; C - *Polistes canadensis*; D - Lepidoptera; E - *Chalcolepidius zonatus* (Coleoptera, Elateridae); F - Cockroach (Blattaria).



**Figure 5.** Vertebrate pollinators of *Encholirium spectabile* in Santa Maria, Rio Grande do Norte, northeastern Brazil. A - Female *Chlorostilbon lucidus*; B - *Eupetomena macroura*; C - Aspect of the approach of *Lonchophylla mordax* to the *Encholirium* inflorescence; D - Note the accumulation of pollen on the snout and face of *Lonchophylla mordax*.

## Discussion

The flowering of *Encholirium spectabile* throughout the year provides a great advantage for the pollinators in the dry season, ensuring food supply in this period of shortage. These results differ from those found by Queiroz *et al.* (2016), in an area of dry Caatinga, where the authors reported flowering occurring from June to September, sometimes until October. The floral characteristics of *E. spectabile* have the same flower pattern as other species of the genus (Forzza, 2005): brush type flowering, with the presence of many flowers and tall inflorescences (up to two meters), yellow and/or pale-green flowers, stamens and style placed outwards, a large corolla and

high nectar production throughout the day (Queiroz *et al.*, 2016).

In the area where this study was conducted, *E. spectabile* is visited by a large range of species, possibly allowing for pollination by more than one taxonomic group, unlike other species of the genus that have been studied so far. Sazima *et al.* (1989) and Christianini *et al.* (2013) observed that hummingbirds are pollinators of *Encholirium heloisae* (L.B. SM.) FORZZA & WAND. However, only bats pollinate the flowers of *Encholirium vogelii* RAUH. Our results suggest that *E. spectabile* is pollinated by more than one taxonomic group, as reported in Queiroz *et al.* (2016).

Hummingbirds were the group with largest species richness that visited *Encholirium spectabile* flowers in the

**Table 1.** Floral visitors of the “macambira-de-flecha” *Encholirium spectabile* in the Santa Maria municipality, Rio Grande do Norte, north-eastern Brazil, during the period 2011 - 2014. D = daytime; N = night.

Order	Family	Species	Habit
<b>Hymenoptera</b>	Apidae	<i>Apis mellifera</i> (LINNAEUS 1758)	D
		<i>Trigona spinnipes</i> (FABRICIUS 1793)	D
		<i>Centris</i> sp.	D
	Vespidae	<i>Polistes canadensis</i> (LINNAEUS 1758)	D
	Formicidae	<i>Crematogaster</i> sp. 1, sp. 2	D/N
		<i>Camponotus</i> sp.	D/N
<b>Coleoptera</b>	Elateridae	<i>Chalcolepidius zonatus</i> (ESCHSCHOLTZ 1829)	N
<b>Diptera</b>	Ulidiidae	-	D
<b>Hemiptera</b>	Reduviidae	-	D/N
	Cicadellidae	-	D/N
<b>Blattaria</b>	-	-	N
<b>Lepidoptera</b>	Sphingidae	-	N
	Geometridae	-	N
	Lycaenidae	<i>Strymon serapio</i> (GODMAN & SALVIN 1887)	D
<b>Vertebrates</b>			
<b>Apodiformes</b>	Trochilidae	<i>Amazilia leucogaster</i> (GMELIN 1788)	D
		<i>Chrysolampis mosquitus</i> (LINNAEUS 1758)	D
		<i>Chlorostilbon lucidus</i> (SHAW 1812)	D
		<i>Eupetomena macroura</i> (GMELIN 1788)	D
<b>Chiroptera</b>	Phyllostomidae	<i>Lonchophylla mordax</i> (THOMAS 1903)	N
		<i>Glossophaga soricina</i> (PALLAS 1766)	N

study area, with four registered species. Hummingbirds began their activities early, seeing that at 7h a.m. they were already actively visiting the flowers. At around 11h a.m. the foraging activities decrease, starting over at 03h p.m. and extending up to 06h p.m. This was also reported by Queiroz *et al.* (2016) and explained through the results of nectar production by *E. spectabile*, which peaks during the late afternoon, extends throughout the night and goes on until 11h a.m. of the next day (Queiroz *et al.*, 2016), coinciding with the results of hummingbird visits in this study.

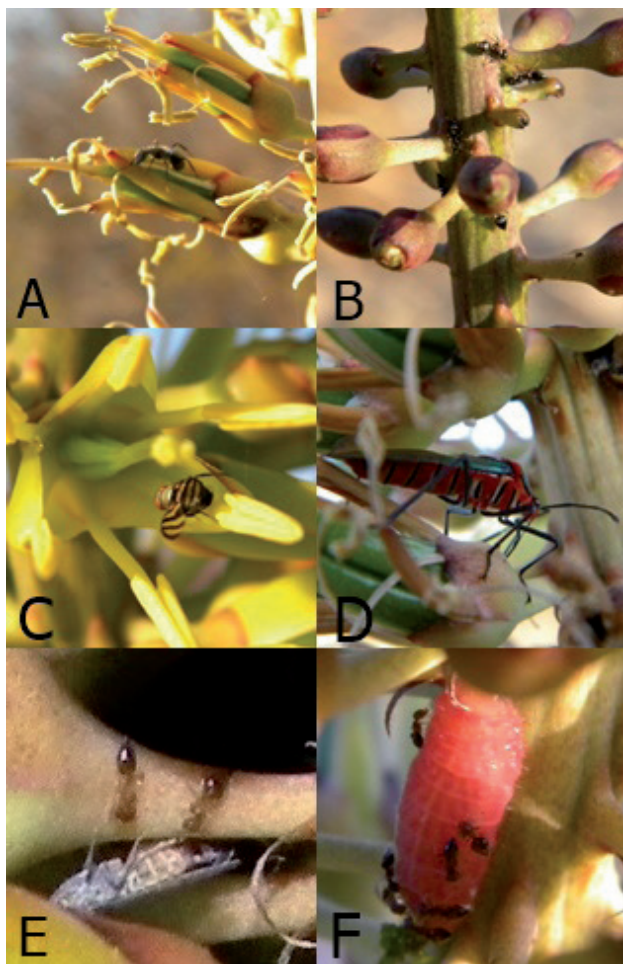
The bats *Lonchophylla mordax* and *Glossophaga soricina* presented peak activity at 8h p.m. These species initiated activities around 7h30 p.m. and extended it through the night, making quick visits to flowers and then heading to another bromeliad, as reported by Sazima *et al.* (1989) for other species of *Encholirium*. Nogueira (1998) mentions the possibility of *E. spectabile* as a food resource for *L. mordax* specimens in the Caatinga of north Minas Gerais, which was confirmed in this study and also recorded by Queiroz *et al.* (2016). Christianini *et al.* (2013) also reports that *L. mordax* specimens visit the flowers of *Encholirium glaziovii* MEZ. However, *G. soricina* has already been documented as a pollinator of several bromeliad species in southeast Brazil (Willig, 1983; Sazima *et al.*, 1999). Queiroz *et al.* (2016) also recorded the nighttime activity of *G. soricina* and *L. mordax*, as well as *Phyllostomus discolor* (WAGNER, 1843) and the marsupial *Didelphis albiventris* (LUND, 1840), as pollinators of *E. spectabile*

growing on rocky outcrops in the Caatinga of the private nature reservation “Fazenda Almas” in state of Paraíba, northeastern Brazil.

Queiroz *et al.* (2016), while studying floral phenology, nectar production, as well as the diversity and frequency of *E. spectabile* pollinators in the Caatinga, hypothesized that pollination is made primarily through chiropterophily. However, the floral phenology of this species favors a mixed pollination strategy, involving birds and mammals, which results in high reproductive success (Queiroz *et al.*, 2016). Our results also suggest that in *E. spectabile*, pollination is of a mixed type and some taxonomic groups (hummingbirds, bats and some invertebrates) may have a certain influence on the pollination of this species.

The bees *Apis mellifera* (LINNAEUS, 1758) and *Trigona spinipes* (FABRICIUS, 1793) probably promote self-pollination, providing that they forage in many flowers within the same inflorescence. The largest impact of the bee’s pillage behavior must be in pollen collection because they are generally considered efficient when removing pollen from the anthers. Bees are the most important pollinating insects for angiosperms and form the group with greatest diversity involved in the pollination of many plant species (Zanette *et al.*, 2005), also playing an important role in the pollination of bromeliads (Benzing, 2000; Schmid *et al.*, 2011).

Records of cockroaches visiting inflorescences of Bromeliaceae are already known in the literature (Schmid *et al.*, 2011), but this information remains unexplored and incon-



**Figure 6.** Additional floral visitors of *Encholirium spectabile* in Santa Maria, Rio Grande do Norte, Brazil. A - *Camponotus* sp. 2.; B - *Crematogaster* sp.; C - Diptera, Ulidiidae; D - Hemiptera, Reduviidae; E - Interaction between *Crematogaster* sp. and Hemiptera, Cicadellidae; F - Interaction between *Crematogaster* sp. and Lycaenidae larvae (Lepidoptera).

sistent. The species recorded in this study commonly visits bromeliad flowers during the night, when individuals are actively seeking nectar and consequently end up plundering pollen and carrying it on their bodies. These cockroaches are wingless and move around by walking on the flowering stem, which may possibly lead to pollination among flowers of the same bromeliad, although little can be speculated about the influence of this group on actual pollination.

The Lepidoptera recorded in this study visited the flowers mainly during the night, although specimens of *Strymon serapio* (GODMAN & SALVIN, 1887) were daytime visitors. These individuals made quick visits without directly touching the flowers, indicating that they only use the nectar. Since we did not collect individuals for body analysis and because of the speed with which these individuals visit the flowers, little can be speculated about

the influence of this group on the actual pollination of *Encholirium spectabile*'s flowers, as seen in Marques *et al.* (2015). Pollination by Lepidoptera (psychophilia) is not common in Bromeliaceae (Benzing, 2000), although it has been recorded in the subfamilies Bromelioideae (Siqueira Filho and Machado, 2001) and Tillandsioideae (Gardner, 1986; Varassin and Sazima, 2000). Queiroz *et al.* (2016) also reported sporadic visits of Sphingidae moths to *E. spectabile* inflorescences in the Caatinga.

Though recorded for other species of bromeliads (Schmid *et al.*, 2010), the association between ants of the genus *Crematogaster* and Lycaenidae butterflies observed in the present study is the first record of this type of interaction taking place in *Encholirium* bromeliads. The ants collected the substances exuded by caterpillars while actively defending them, which is consistent with the observations of Pierce *et al.* (2002) for Formicidae-Lepidoptera associations; however further observations are required to arrive at a conclusion on the type of relationship between these groups in *E. spectabile*.

All the taxonomic groups recorded in the present study play a crucial role in the pollination system of the Caatinga biome, some exercising more or less influence according to the species of the studied plant (Machado and Lopes, 2004). Machado and Lopes (2004) conducted a study on the pollination system in the Caatinga biome and found that insect pollination was the most frequent, occurring in (69.9%) of the studied species, followed by hummingbird (15%) and bat pollination (13%), bees are mainly responsible for pollination in this biome. According to Machado and Lopes (2004), hummingbirds are mainly responsible for pollination in the families Acanthaceae, Bromeliaceae, Cactaceae, Leguminosae, Passifloraceae, and Sterculiaceae.

Like hummingbirds, bats are also important for the maintenance of the pollination system in the Caatinga biome. *Glossophaga soricina* is a species that pollinates hundreds of plant species, especially in the Bignoniaceae, Bombacaceae, Bromeliaceae, Gentianaceae, Gesneriaceae, Leguminosae, Lythraceae, Myrtaceae, Passifloraceae, and Tiliaceae (Nogueira *et al.*, 2007). Also, *Lonchophylla mordax* presents a strong influence on the pollination of the Bromeliaceae, Cactaceae, Bombacaceae and Convolvulaceae (Queiroz *et al.*, 2015), showing the importance of this species in the structuring of plant communities in the caatinga biome.

In the area where this study was conducted, *Encholirium spectabile*, aside from providing shelter, refuge against predators, area for foraging and thermoregulation for a range of animal species, as reported by Jorge *et al.* (2014) and Jorge (2015), is also an important source of food, nectar and pollen for a significant amount of species. These bromeliads seem to be very important for these groups, especially in the dry season, where food avail-



ability is scarce in the Caatinga, and therefore may be key elements in maintaining biological diversity. Thus, based on the umbrella species theory, we suggest that *macambira* bromeliads (*E. spectabile*) should be considered a key element in the conservation of various taxonomic groups in the Caatinga, as already proposed for other bromeliads (Rocha *et al.*, 2004).

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