

ECOLOGICAL CONSIDERATIONS ON *Xeronycteris vieirai*: AN ENDEMIC BAT SPECIES FROM THE BRAZILIAN SEMIARID MACROREGION

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ABSTRACT. We provide information on distribution, shelter use, food consumption, and reproductive biology of the nectar-feeding bat *Xeronycteris vieirai*. Six adult bats were mist netted near the caves and bromeliad *Encholirium splendidum* in a transition area between Caatinga and Cerrado biomes in Brazil. Bats were leaving the caves and were observed feeding on that bromeliad species. Our results suggest that distribution of *X. vieirai* may not be restricted to the Caatinga, but may occupy the entire Brazilian semiarid macroregion. *Echolirium splendidum* is an important resource for bats in karstic regions and its distribution might be related to the distribution and reproduction of *X. vieirai*.

RESUMO. Considerações ecológicas sobre *Xeronycteris vieirai*, uma espécie de morcego endêmica da macrorregião semiárida brasileira. Fornecemos informações sobre a distribuição, uso de abrigo, consumo alimentar e biologia reprodutiva do morcego nectarívoro *Xeronycteris vieirai*. Seis morcegos adultos foram capturados com redes próximas às cavernas e à bromélia *Encholirium splendidum* em uma área de transição entre os biomas Caatinga e Cerrado no Brasil. Os morcegos estavam saindo das cavernas e foram observados se alimentando daquela espécie de bromélia. Nossos resultados sugerem que a distribuição de *X. vieirai* talvez não esteja restrita somente à Caatinga, mas talvez ocupe toda à macrorregião semiárida brasileira. *Echolirium splendidum* é um importante recurso para os morcegos em regiões cársticas e sua distribuição deve estar relacionada à distribuição e reprodução de *X. vieirai*.

Key words: Cave. Distribution. Food consumption. Nectar-feeding bat. Reproduction.

Palavras chave: Caverna. Consumo alimentar. Distribuição. Morcego nectarívoro. Reprodução.

INTRODUCTION

Neotropical nectar-feeding bats belong to the subfamilies Glossophaginae and Lonchophyllinae (Family Phyllostomidae) and range from southwestern United States to northern Argentina and Chile (Griffiths & Gardner 2008a; b). They are important in ecosystem functioning via pollination (Fleming et al. 2009), and extensive conservation efforts have been conducted due to the tendency of several species to present restricted geographical distributions, specific roost requirements, and small populations (Arita & Santos-Del-Prado 1999; Santos & Arita 2002; Aguiar et al. 2010). In a recent compilation of the endemic mammals for the Caatinga and Cerrado biomes, four bat species were recorded; two of these are nectar-feeding bats which belong to the subfamily Lonchophyllinae: *Lonchophylla inexpectata* Moratelli & Dias, 2015 and *Xeronycteris vieirai* Gregorin & Ditchfield, 2005 (Gutiérrez & Marinho-Filho 2017).

Xeronycteris vieirai remains as a poorly known species even after thirteen years after its description, which was based on four specimens collected in three localities in northeastern Brazil (Gregorin & Ditchfield 2005). Nine years after the species description, an emended diagnosis using morphological characters was also based on only four specimens collected in only three localities (Nogueira et al. 2014). Currently, there are only 90 records of individuals sampled in eight localities (Gregorin & Ditchfield 2005; Astúa & Guerra 2008; Nogueira et al. 2015; Cordero-Schmidt et al. 2017). Although this species is currently classified as endemic to the Caatinga (Gutiérrez & Marinho-Filho 2017), it was predicted to occur along the diagonal of open and dry biomes crossing the Brazilian territory (Gregorin & Ditchfield 2005), with Jaíba, in the northern region of the state of Minas Gerais, being the nearest locality to the Cerrado biome (Nogueira et al. 2015). All other localities where *X. vieirai* was found are located in the northeastern region of Brazil: in the states of Bahia, Paraíba, Pernambuco, Rio Grande do Norte and Sergipe (Gregorin & Ditchfield 2005; Astúa & Guerra 2008; Cordero-Schmidt et al. 2017).

In comparison with other nectar-feeding bats, which are generalists that also feed on flowers, insects, flower parts and fruits, *X. vieirai* was considered to feed strictly on liquid food (nectar) (Gregorin & Ditchfield 2005; Bolzan et al. 2015). However, recent evidence has shown that its diet can also include pollen and leaves (Cordero-Schmidt et al. 2017). Information on the consumed food items by this nectar-feeding species is still limited. Furthermore, there are few data considering several characteristics of the natural history of this species (Griffiths & Gardner 2008b), such as the reproduction and roost use (see Cordero-Schmidt et al. 2017). The species is considered as threatened in the Vulnerable category of the Brazilian Red List (Governo Federal do Brasil 2014), and also as a data-deficient in the Red List of the International Union for the Conservation of Nature (IUCN) (Solari 2015), requiring more in-depth investigation. Herein, we provide data on distribution, roost use, food consumption, and reproductive biology of *X. vieirai*.

MATERIALS AND METHODS

Study area

This study was conducted in the municipality of São Félix do Coribe, located in the western portion of the state of Bahia in the northeastern Brazil. The study area (13°25' S - 44°11' W, 533 m altitude) is located in the transition zone between the Caatinga and Cerrado biomes (Gonzaga et al. 2013) and it is inserted in the Brazilian semiarid macroregion (Governo Federal do Brasil 2005) (Fig. 1). The predominant vegetation in the municipality is Seasonal Forest (SEIA 2014), also known as dry limestone forests, which are plant formations that occur on limestone outcrops in the Cerrado biome (Ribeiro & Walter 1998). The study region is characterized by highly karstic outcrops that allow the existence of many caves. According to the Köppen-Geiger classification, the climate in São Félix do Coribe is Aw, with higher rainfall index in the summer than in the winter, and with a dry winter (Alvares et al. 2013). The mean annual temperature in the region is 25 °C. October is the warmest month with a maximum mean of 33 °C and July the coldest month with a minimum mean of 16 °C. The mean annual rainfall is 823 mm. The months with the highest precipitation are comprised from November to March, with December being the

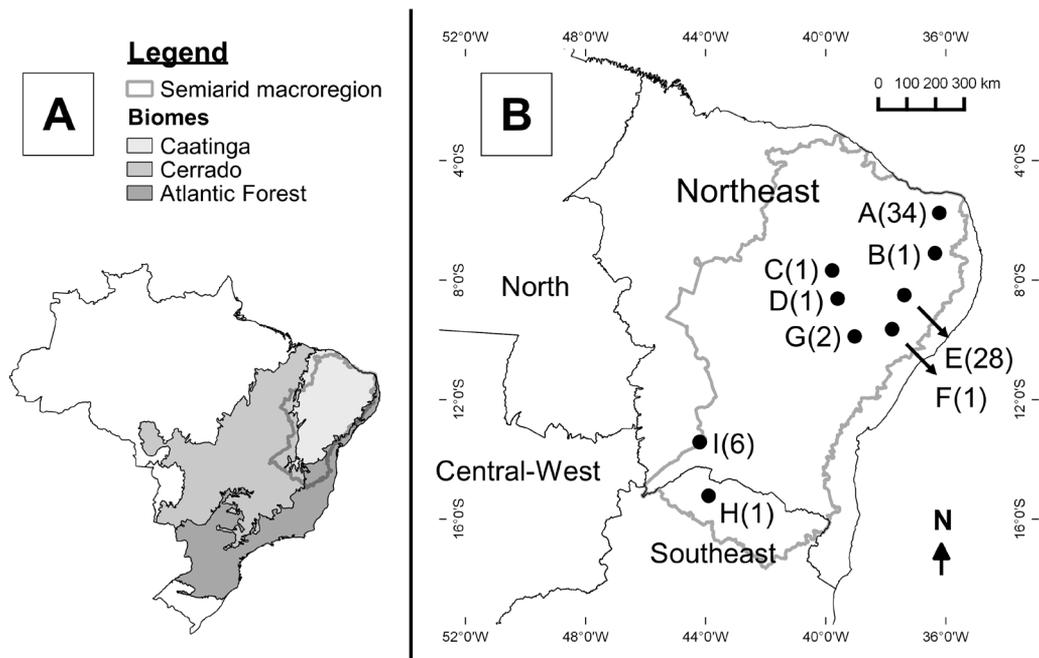


Fig. 1. A) Distribution of the Atlantic Forest, Caatinga, and Cerrado biomes, and the Brazilian semiarid macroregion. B) Localities (●) of all records of *Xeronycteris vieirai*. Numbers in parentheses indicate the number of captured individuals in such a locality. A = Municipality of Lajes, state of Rio Grande do Norte (Cordero-Schmidt et al. 2017); B = Municipality of Soledade, state of Paraíba (Gregorin & Ditchfield 2005); C = Municipality of Exu, state of Pernambuco (Gregorin & Ditchfield 2005); D = Municipality of Orocó, state of Pernambuco (Astúa & Guerra 2008); E = Municipality of Buíque, state of Pernambuco (Cordero-Schmidt et al. 2017); F = Municipality of Canindé de São Francisco, state of Sergipe (Astúa & Guerra 2008); G = Municipality of Canudos (“Cocorobó”), state of Bahia (Gregorin & Ditchfield 2005); H = Municipality of Jaíba, state of Minas Gerais (Nogueira et al. 2015); and I = Municipality of São Félix do Coribe, state of Bahia (this study).

wettest month (181 mm) and June the driest month (0 mm) (WorldClim, Hijmans et al. 2005).

Recently, São Félix do Coribe has been the target of several taxonomic efforts that have resulted in descriptions of new plant (Carvalho-Sobrinho & Queiroz 2010; Forzza & Leme 2015) and invertebrate species, such as beetles (Galileo & Martins 2010). As for bat species, only *Phyllostomus hastatus* (Pallas, 1767), *Glossophaga soricina* (Pallas, 1766), *Carollia perspicillata* (Linnaeus, 1758), *Artibeus planirostris* (Spix, 1823), *Artibeus obscurus* (Schinz, 1821) and *Platyrrhinus lineatus* (É. Geoffroy St.-Hilaire, 1810) were previously recorded for this municipality (Lapenta & Bueno 2015), which is considered a poorly investigated region for bats (Bernard et al. 2011).

Bat sampling

Sampling was carried out from June 11th to 28th, 2014 (dry season) and from March 15th to 28th, 2015 (rainy season) using mist nets set on carbonaceous outcrops near the entrances and skylights of caves, and also

near the inflorescences of *Encholirium splendidum* Forzza (Bromeliaceae). The mist nets remained open from sunset to midnight. Captured bats were placed in cotton bags for later identification, body measurements (mass [g] and forearm [mm]), as well as classification of age through ossification of the epiphyses (Anthony 1988), and reproductive stage. The reproductive stage of the individuals was determined according to Zortéa (2003): males are considered as non-reproductive when the testicles are in the abdominal cavity or reproductive when the testicles are evident in the scrotal sac; and females are considered as non-reproductive when signs of pregnancy or lactation are absent, pregnant when a fetus is detected through abdominal inspection, lactating when nipples are evident with secretion, or post-lactating when nipples are evident but without secretion. In order to avoid recaptures, individuals were released near the sampling sites only after mist nets were closed. On June 20th, 2014, two specimens were collected to serve as voucher material. This date

was prior to the publication of the list of endangered Brazilian fauna that includes *X. vieirai* (December 18th, 2014, Governo Federal do Brasil 2014). The voucher specimens are deposited in the Adriano Lucio Peracchi collection (collection number: ♀ ALP10695 and ♂ ALP10718), located at the Federal Rural University of Rio de Janeiro, Seropédica, Rio de Janeiro, Brazil. Individuals were identified using the species description studies of Gregorin & Ditchfield (2005) and Nogueira et al. (2014). Samplings were authorized by IBAMA through the license number 469/2014 that allowed to capture, collect and transport the bats. Besides mist netting, bats were also photographed and visually observed feeding on flowers in order to know their feeding behavior.

RESULTS

We captured a total of six adult individuals of *X. vieirai* (Fig. 2A) in the study area, which consequently ranks third in number of specimens observed in a single study (Fig. 1). On June 20th, 2014 (dry season), we captured three individuals in mist nests placed one meter from a cave. The first specimen, a lactating female, was captured around 18:00 h. The other two, a non-reproductive female and a reproductive male, were captured around 20:30 h. On March 27th, 2015 (rainy season), a mist net was set up in front of a skylight of a cave, located 1.5 m far from the cave sampled in the dry season. Near the skylight of the cave, many inflorescences of *E. splendidum* were visited by bats. On that day (March 27th), a female of *X. vieirai* in an advanced stage of pregnancy and an individual of *Micronycteris sanborni* Simmons, 1996 were captured leaving this skylight around 18:40 h. In the same mist net, two other specimens of *X. vieirai* were captured near the inflorescences around 21:00 h, a female in an advanced stage of pregnancy and a non-reproductive female. We also captured the nectarivorous species *Lonchophylla* sp. and *G. soricina*, and frugivorous *C. perspicillata* from mist nets positioned near *E. splendidum*. In the dry season, we did not observe inflorescences of that bromeliad at the sampling sites; nor did we observe bats with pollen, as in the rainy season.

On March 15th, 2015 from 21:00 h to 21:30 h, we observed frequent bat visits to the inflorescences of *E. splendidum*. Using photographs,

we distinguished nectar-feeding and fruit-eating bats, like *Carollia*, that were feeding on the flowers. Among the nectar-feeding bats (*Lonchophylla* and *Glossophaga*), *X. vieirai* was observed hovering in front of one of the flowers for less than two seconds. We did not observe bats visiting more than one flower in the inflorescence during the same visit. During some of these visits, we registered some clearly pregnant females of *X. vieirai* (Fig. 2B). All bats that fed on nectar touched the snout on the anthers of the flowers and had their heads covered by *E. splendidum* pollen. Pollen on *X. vieirai* was distributed from the distal tip of the snout to the neck and behind the ears (Fig. 2B).

DISCUSSION

Distribution

Despite its restricted occurrence in the Caatinga biome (Gutiérrez & Marinho-Filho 2017), our record of *X. vieirai* in the Caatinga-Cerrado ecotone and the record of Nogueira et al. (2015) close to a Cerrado area support the hypothesis that this species may possibly occur in the Cerrado biome, as already indicated by Nogueira et al. (2007). However, we believe that if *X. vieirai* occurs in the Cerrado, it is likely to occupy only those areas of the Cerrado which belong to the Brazilian semiarid macroregion, such as enclaves of this biome located in the Caatinga (e.g. Araújo et al. 2005; Costa & Araújo 2007) and areas bordering the Caatinga. This macroregion is characterized by frequent droughts and the spatio-temporal variation of irregular rains, that yearly reach more than 1000 mm on areas near the coastal and less than 500 mm on interior areas (Brasil 2005; Correia et al. 2011). The semiarid region covers 900 000 km² and is composed of a mosaic of vegetation from the Caatinga (82%), Cerrado and Atlantic Forest (Giulietti et al. 2006). Spatially, those vegetation types shelter different microclimates that can influence the maintenance of animal populations during the year. For example, during periods of drought in the Caatinga, small mammals persistently inhabit mesic vegetation formation, such as forest enclaves (Mares et al. 1985).

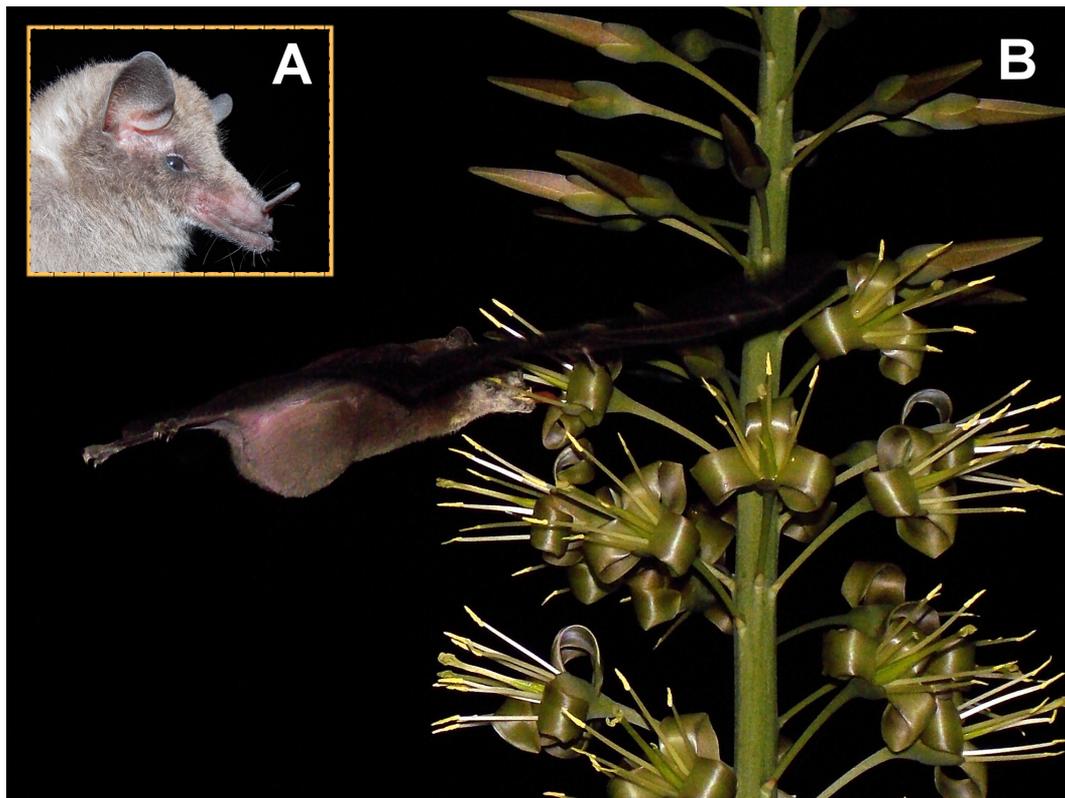


Fig. 2. A) Nectar-feeding bat *Xeronycteris vieirai* and B) a pregnant female in hovering feeding on nectar of bromeliad *Encholirium splendidum* Forzza in São Félix do Coribe, state of Bahia, Brazil. Photos: (A) Andrea C. S. Maas and (B) Luiz A. C. Gomes.

Because nectar-feeding bat species can occur in diverse physiognomies of vegetation of the Brazilian semiarid, as in areas with xerophytic vegetation of the Caatinga, vegetation enclaves of the Cerrado and the Atlantic Forest, and transition zones between biomes (Sá-Neto & Marinho-Filho 2013), we suggest that *X. vieirai* is not only endemic to the Caatinga, but to the entire Brazilian semiarid macroregion. Additional sampling efforts along this macroregion, mainly in enclaves of the Cerrado and the Atlantic Forest, and ecotone areas of biomes, are needed in order to confirm our suspicion.

Roost use

Cordero-Schmidt et al. (2017) first recorded the use of caves by *X. vieirai*, and our data reinforce their finding. Cave is a shelter type commonly used by many nectar-feeding species in the Neotropical region (Arita & Santos-

del-Prado 1999; Guimarães & Ferreira 2014). In the present study, the observation of the insectivorous *M. sanborni* leaving the same cave as *X. vieirai* suggests that our focal species shared the shelter with other bat species with different food habits. This situation had already been observed with other phyllostomids, such as the frugivorous *A. planirostris*, the nectarivorous *G. soricina*, the gleaner *Tonatia bidens* (Spix, 1823), and the insectivorous *Peropteryx macrotis* (Wagner, 1873) (Emballonuridae) and *Furipterus horrens* (Cuvier, 1828) (Furipteridae) in a cave in the state of Rio Grande do Norte, northeastern region of Brazil (Cordero-Schmidt et al. 2017). We did not observe *X. vieirai* using the cave as a daytime shelter; however, this bat uses caves also during the daytime (Cordero-Schmidt pers. comm.). Therefore, *X. vieirai* can be considered as having a cave-dwelling habit. According to Guimarães & Ferreira (2014), a

cave-dwelling habit is characteristic of bats that roost in caves both during the daytime and night. Usually, bats use caves to protect themselves from weather and to escape from potential predators (Kunz 1982).

Food habit

In the present study, *X. vieirai* and other bats (*Lonchophylla* sp., *G. soricina* and *C. perspicillata*) were mist netted near the inflorescences of *E. splendidum* and observed feeding on its nectar. This bromeliad species was recently described with material obtained from São Félix do Coribe (Forzza & Leme 2015). Bromeliaceae is known to be a ubiquitous food resource for bats in karst areas (Sazima et al. 1989; Bredt et al. 2012; Christianini et al. 2013; Queiroz et al. 2016). However, the only previously known species of bromeliad consumed by *X. vieirai* is *Encholirium spectabile* Martius ex Schultes f. (Cordero-Schmidt et al. 2017). In the study area, *E. splendidum* has been shown to be an important food source for bats in the rainy season. The use of *E. splendidum* as food resource is recorded for the first time for *X. vieirai*, and also for other bat species, such as *C. perspicillata*, *G. soricina*, and *Lonchophylla* sp. Also, the observation of pollen of *E. splendidum* adhered to head of *X. vieirai* is a strong indication that this bat species is a potential pollinator for that bromeliad. Some species of *Echolirium*, such as *E. splendidum*, are xerophytic and have distribution restricted to rocky outcrops (Sazima et al. 1989; Forzza & Leme 2015). This characteristic of the soil is very common in the Brazilian semiarid macroregion (Correia et al. 2011), suggesting that the distribution of these bromeliads might be interconnected with the distribution of *X. vieirai*. The correspondence between bat and plant species distributions has been observed for other species of nectar-feeding bats and plants, such as cacti and agaves, in the arid and semiarid regions of Venezuela and Mexico (Valiente-Banuet et al. 1996; Nassar et al. 2003).

Reproduction aspects

Tropical bats tend to give birth during the period with greatest food resource availability

(Fleming et al. 1972; Moreno-Valdez et al. 2004) and *X. vieirai* seems to follow this pattern. Pregnant females of *X. vieirai* were already observed on July and October (dry months) and lactating females on January, March, July, November, and December in Catimbau National Park, state of Pernambuco, and in Lajes, state of Rio Grande do Norte (Cordero-Schmidt et al. 2017). In the study area, two pregnant females were captured in March (end of the rainy season), the month when *E. splendidum* bloomed. Forzza (pers. comm.) observed this plant with inflorescences during April and July (dry season) in São Félix do Coribe. Although we did not observe blooming of *E. splendidum* on June in the study area, we captured a lactating female and a reproductive male in this month, indicating that *X. vieirai* also uses other plants, as Cactaceae species (see Cordero-Schmidt et al. 2017), besides this bromeliad. In view of this, our data suggest that *X. vieirai* births might be synchronized with the availability of flowers. For example, Moreno-Valdez et al. (2004) observed that the period of birth and lactating females of *Leptonycteris nivalis* (Saussure, 1860) coincides with the blooming period of *Agave* in an arid region of Mexico. Currently, the reproductive pattern for *X. vieirai* is considered as seasonally monoestrous with a reproductive peak occurring in the second half of the year (Cordero-Schmidt et al. 2017). Additional data are necessary to confirm if the reproduction of this species maintains this pattern of fluctuation with the blooming of xerophilous plant species.

Measures for conservation

Information on the biology and ecology of *X. vieirai* applicable to conservation is still limited. The use of caves as a possible shelter by *X. vieirai* is worrisome since this environment is a target for destruction in efforts to control and manage hematophagous bats (Santos & Arita 2002; Aguiar et al. 2010). According to Guimarães & Ferreira (2014), one way to preserve bats using caves is to protect this kind of shelter. Another way to protect endangered nectar-feeding bats would be to protect large areas containing the plants they use (Moreno-Valdez et al. 2004). *Encholirium splendidum* is

distributed around the base of the São Francisco River and has been suggested as a threatened species because it occurs strictly on limestone outcrops which have been degraded for cement manufacturing (Forzza & Leme 2015). In this sense, protecting large areas which contain this bromeliad would be advantageous to protect both plant and bat species that are threatened with extinction. Lastly, knowing that the abundance of nectar-feeding bats is related to the flowering period of the plants and the nectar they consume (Valiente-Banuet et al. 1996; Moreno-Valdez et al. 2004), it is possible that the presence of blooming bromeliads of the genus *Encholirium*, such as *E. splendidum*, be a sign of the occurrence of *X. vieirai* in areas of the Brazilian semiarid macroregion.

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