

Bat fauna of the Cerrado savanna of eastern Maranhão, Brazil, with new species occurrences

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OLÍMPIO, A.P.M., VENTURA, M.C.S., MASCARENHAS, M.J.O., NASCIMENTO, D.C., ANDRADE, F.A.G., FRAGA, E.C., BARROS, M.C. **Bat fauna of the Cerrado savanna of eastern Maranhão, Brazil, with new species occurrences.** *Biota Neotropica*. 16(3): e20150089. <http://dx.doi.org/10.1590/1676-0611-BN-2015-0089>

Abstract: In Brazil, 179 bat species have been recorded to date, representing 68 genera and nine families. Few data are available on the bat fauna of the state of Maranhão, so the present study was based on a survey of the bat fauna of the Inhamum Municipal Environmental Protection Area (APA Inhamum) in the Cerrado savanna of the eastern extreme of the state. This inventory provides new records of bat species for the state of Maranhão and the Cerrado biome. A total of 31 species (four families) were collected, representing 39% of the bat species known to occur in Maranhão and 28.71% of the species described for the Cerrado. The family Phyllostomidae was the most diverse, with 23 species (74.20% of the total), and also the most abundant, with 86.09% of the specimens collected. The Molossidae (four species) was the second most diverse, followed by the Vespertilionidae (three species) and the Emballonuridae (one species). *Carollia perspicillata* was the most abundant species (28%). The records of *Artibeus fimbriatus* and *Platyrrhinus fusciventris* are the first for the Cerrado and were also recorded in Maranhão for the first time. The cumulative species curve did not reach an asymptote. The species *Dermanura gnoma*, *Lasiurus blossevillii*, *Lasiurus ega*, *Micronycteris schmidtorum*, *Molossops temminckii*, *Platyrrhinus cf. recifinus*, *Phylloderma stenops* and *Trachops cirrhosus*, were also recorded in Maranhão for the first time demonstrating the value of for mammal inventories and emphasizing the need for further surveys in this poorly-known region.

Keywords: Bats, Faunal survey, APA Inhamum, Maranhão, New records, Chiroptera.

OLÍMPIO, A.P.M., VENTURA, M.C.S., MASCARENHAS, M.J.O., NASCIMENTO, D.C., ANDRADE, F.A.G., FRAGA, E.C., BARROS, M.C. **Quiroptero fauna do cerrado leste maranhense, Brasil, com ocorrência de novos registros.** *Biota Neotropica*. 16(3): e20150089. <http://dx.doi.org/10.1590/1676-0611-BN-2015-0089>

Resumo: Atualmente são registrados para o Brasil, nove famílias, 68 gêneros e 179 espécies de morcegos. No Maranhão, poucas são as informações sobre a fauna de morcegos, portanto objetivou-se realizar um levantamento faunístico e reportar os novos registros de morcegos para o Cerrado leste maranhense na Área de Proteção Ambiental Municipal do Inhamum. Foram coletadas 31 espécies, distribuídas em quatro famílias representando 39% das espécies de morcegos registradas no Maranhão e 28,71% das espécies descritas para o Cerrado. A família Phyllostomidae apresentou a maior riqueza (23 espécies - 74,20%) e abundância (86,09%). A família Molossidae (quatro espécies) foi a segunda mais representativa, seguida de Vespertilionidae (três espécies) e Emballonuridae (uma espécie). *Carollia perspicillata* foi a espécie mais abundante (28%). As espécies *Artibeus fimbriatus* e *Platyrrhinus fusciventris* constituem novos registros para o Cerrado e o primeiro registro para o Maranhão. A curva de acumulação de espécies mostrou-se não estabilizada. As espécies *Dermanura gnoma*, *Lasiurus blossevillii*, *Lasiurus ega*, *Micronycteris schmidtorum*, *Molossops temminckii*, *Platyrrhinus cf. recifinus*, *Phylloderma stenops* e *Trachops cirrhosus* constituem novos registros para o Maranhão. As espécies coletadas na APA do Inhamum correspondem a novos registros para o Cerrado do leste maranhense evidenciando-a como uma área de extrema importância para levantamentos mastozoológicos, mostrando que a região necessita de mais estudos.

Palavras-chave: Morcegos, Levantamento faunístico, APA do Inhamum, Maranhão, Novos registros, Chiroptera.

Introduction

Bats constitute an important component of the mammal communities of all Neotropical ecosystems in terms of species richness and ecological diversity. In some areas, bats contribute a significant proportion of total diversity, representing up to 40-50% of the total number of species in mammalian communities (Bianconi et al. 2004). In Brazil, the reviewed list includes nine families, 68 genera, and 179 species (Nogueira et al. 2014, Feijó et al. 2015).

The Brazilian state of Maranhão covers a total of 21,656,866 hectares (Neres & Conceição 2010) and is located centrally on the country's northern coast, in a strategic position at the convergence point of the Amazon, Cerrado and Caatinga biomes (Dias et al. 2009), which is reflected in the state's considerable diversity of animals and plants, and makes it potentially important for the inventory of mammals (Oliveira et al. 2008). Despite this richness of ecosystems and biological diversity, few studies are available on the bat fauna of the state, with the exception of the recent efforts of Cruz et al. (2007), Dias et al. (2009), Santos et al. (2009) and Bernard et al. (2011). Most of these studies have focused on sites in the north and west of the state, with few data available from its other regions. In this context, the present study is based on an inventory of the bat fauna of an area of Cerrado in eastern Maranhão, providing new records of the occurrence of species in this region, and other important data on the characteristics of this important group of mammals.

Material and methods

1. Study area

The bat specimens were collected during three field excursions to the Inhamum Municipal Environmental Protection Area (APA Inhamum) in April and September 2014, and January 2015. The APA Inhamum (04°53'30"S, 43°24'53"W) is located in the municipality of Caxias, in eastern Maranhão, Brazil (Figure 1), and has a total area of approximately 3,500 ha, which is covered primarily by Cerrado savanna, with two distinct types of vegetation (shrubby-arboreal and grassland) on the flatter terrain, with stands of buriti palms being associated with the watercourses, located in depressions (Neres & Conceição 2010).

2. Specimen collection and data analysis

The collection of specimens during this study was authorized by the federal Chico Mendes Institute for Conservation Biology (ICMBio) through special license IBAMA/SISBIO 42670-1. The bats were captured between 18:00 h and 23:00 h using mist-nets of different sizes (12 m x 3 m, 9 m x 3 m, and 6 m x 3 m), which were set in areas adjacent to food sources and probable flight paths, at different locations within the APA Inhamum. All specimens collected have been deposited provisionally in the Genetics and Molecular Biology Laboratory (GENBIMOL) at CESC/UEMA, where they were photographed, identified, sexed, weighed, and measured using a digital caliper (300mm - 12"). The specimens will be deposited in the UFMA vertebrate collection on the Chapadinha campus (Maranhão).

The life stage of each specimen was classified as juvenile or adult based on morphological traits. Adult females were examined through the palpation of the abdomen and teats to determine whether they were lactating or gestating, while the testicles of the males were recorded

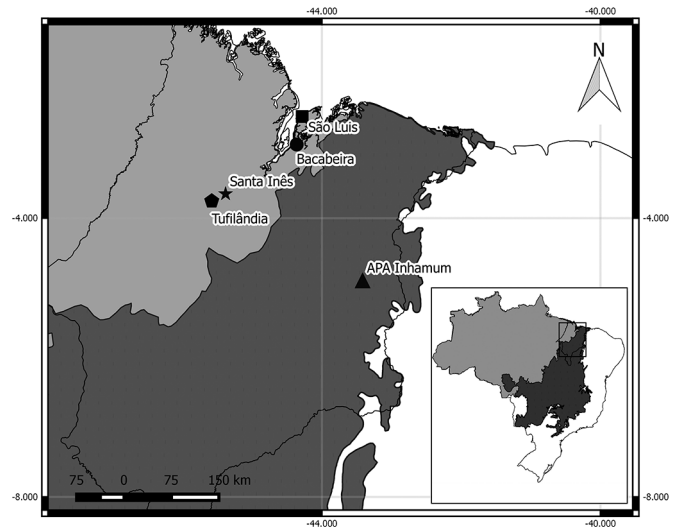


Figure 1. Map of Brazil and the state of Maranhão, showing the study area: the Inhamum Municipal Environmental Protection Area (APA Inhamum). Sites of previous surveys (Amazon biome - Bacabeiras, Santa Inês, Tufilândia and São Luís) and the present study (Cerrado biome - APA Inhamum) of state of Maranhão.

as abdominal or external. Some of the specimens were anesthetized and sacrificed to provide vouchers and were stored in containers with cotton wool soaked in ether. These specimens were fixed in a standard position with 10% formaldehyde and then conserved in 70% ethanol.

Morphometric data were also collected, including the right (RF) and left forearms (LF), ear (E), tragus (TG), foot (F), and tail (TL). The identification of the taxa was based on the classification keys of Gregorin & Taddei (2002) and Gardner (2008), and subsequently confirmed by specialists. Sampling effort was calculated using the formula proposed by Straube & Bianconi (2002). The cumulative species curve was determined using the Jackknife 1 estimator run in EstimateS, version 9.0.0 (Colwell 2012).

Results

1. Species diversity

With a total sampling effort of 24,030 m²/h, 226 specimens were captured, of 31 species representing four families - Phyllostomidae, Molossidae, Vespertilionidae and Emballonuridae (Figure 2). The family Phyllostomidae was the taxonomically richest, with 23 species (74.20% of the total) distributed in 15 genera, as well as being the most abundant, with 86.09% of the total number of netted individuals (Table 1). The family Molossidae was the second most diverse, being represented by four species in four genera, followed by the Vespertilionidae with three species in two genera, and the Emballonuridae, with a single species.

Carollia perspicillata was the most abundant, representing 28% of the captures. Despite the fact that the species recorded in the APA Inhamum represent 39% of the total number known to occur in Maranhão and 28.71% of the species described for the Cerrado, *Artibeus fimbriatus* and *Platyrrhinus fusciventris* represent new records for this biome and together with *Dermanura gnoma*, *Lasiurus ega*, *Lasiurus blossevillii*, *Micronycteris schmidtorum*, *Molossops temminckii*, *Phylloderma stenops*, *Platyrrhinus cf. recifinus* and *Trachops cirrhosus* constitute new records for the state of Maranhão. The species curve

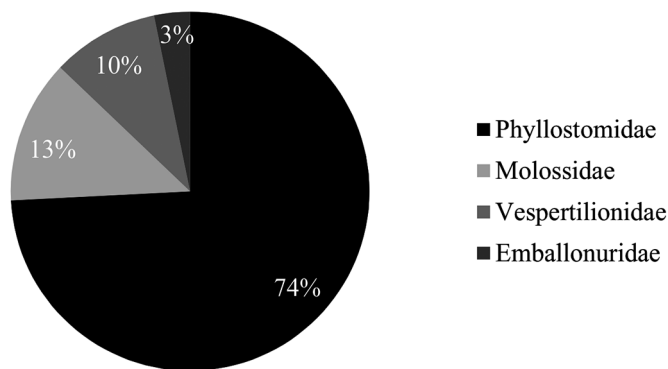


Figure 2. Bat species richness recorded in the APA Inhamum by chiropteran family. The numbers represent the species of families.

Table 1. Bat species recorded in the APA Inhamum, Caxias, Maranhão (Brazil). The species marked with an asterisk were recorded in Maranhão for the first time.

| Taxon |
|---|
| Family Emballonuridae |
| Subfamily Emballonurinae |
| <i>Rhynchonycteris naso</i> (Wied-Neuwied, 1820) |
| Familia Phyllostomidae |
| Subfamily Desmodontinae |
| <i>Desmodus rotundus</i> (E. Geoffroy, 1810) |
| <i>Diaemus youngii</i> (Jentink, 1893) |
| Subfamily Glossophaginae |
| <i>Glossophaga soricina</i> (Pallas, 1766) |
| Subfamily Phyllostominae |
| <i>Lophostoma brasiliense</i> Peters, 1866 |
| <i>Lophostoma silvicola</i> d’Orbigny, 1836 |
| <i>Micronycteris minuta</i> (Gervais, 1856) |
| <i>Micronycteris schmidtorum</i> Sanborn, 1935* |
| <i>Gardnerycteris crenulatum</i> (E. Geoffroy, 1803) |
| <i>Phylloderma stenops</i> Peters, 1865* |
| <i>Phyllostomus discolor</i> Wagner, 1843 |
| <i>Phyllostomus hastatus</i> (Pallas, 1767) |
| <i>Trachops cirrhosus</i> (Spix, 1823)* |
| Subfamily Carollinae |
| <i>Carollia perspicillata</i> (Linnaeus, 1758) |
| <i>Rhinophylla pumilio</i> Peters, 1865 |
| Subfamily Stenodermatinae |
| <i>Artibeus fimbriatus</i> Gray, 1838* |
| <i>Artibeus lituratus</i> (Olfers, 1818) |
| <i>Artibeus obscurus</i> (Schinz, 1821) |
| <i>Artibeus planirostris</i> (Spix, 1823) |
| <i>Dermanura cinerea</i> (Handley, 1987) |
| <i>Dermanura gnoma</i> Handley, 1987* |
| <i>Platyrrhinus fusciventris</i> Velazco, Gardner & Patterson 2010* |
| <i>Platyrrhinus cf. recifinus</i> (Thomas, 1901)* |
| <i>Sturnira lilium</i> (E. Geoffroy, 1810) |

Continued Table 1.

| Taxon |
|---|
| Family Molossidae |
| <i>Cynomops abrasus</i> (Temmincki, 1827) |
| <i>Molossops temminckii</i> (Burmeister, 1854)* |
| <i>Molossus rufus</i> E. Geoffroy, 1805 |
| <i>Nyctinomops laticaudatus</i> (E. Geoffroy, 1805) |
| Family Vespertilionidae |
| Subfamily Vespertilioninae |
| <i>Lasiurus blossevillii</i> ([Lesson, 1826])* |
| <i>Lasiurus ega</i> (Gervais, 1856)* |
| Subfamily Myotinae |
| <i>Myotis nigricans</i> (Schinz, 1821) |

had not reached the asymptote by the end of the study (Figure 3). This indicates that further sampling would be required to record the total number of bat species that occur in the study area.

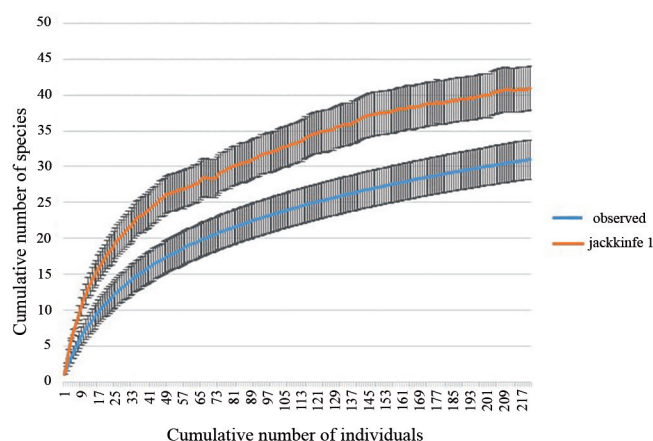


Figure 3. Cumulative species curve for the bats recorded in the APA Inhamum, Caxias, Maranhão, Brazil.

The survey of bats in Maranhão closest to the APA Inhamum was conducted by Dias et al. (2009) in the municipality of Bacabeira (Figure 1). In this case, the results of the present study extend by more than 241 km to the east, the geographic ranges of *Artibeus planirostris*, *A. lituratus*, *A. obscurus*, *C. perspicillata*, *Diaemus youngii*, *Desmodus rotundus*, *Glossophaga soricina*, *Lophostoma silvicola*, *Lophostoma brasiliense*, *Phyllostomus discolor*, *Sturnira lilium*, *Mimon crenulatum*, *Micronycteris minuta* and *Phyllostomus hastatus*. These same authors also conducted surveys in the municipalities of São Luís, Santa Inês and Tufilândia. The results of the present study also represent an extension of 274 km to eastern Maranhão, of the ranges of *Dermanura cinerea*, *Rhinophylla pumilio*, *Rhynchonycteris naso* and *Myotis nigricans*, previously known to occur only as far east as São Luís (Cruz et al. 2007). The species *Molossus rufus*, *Nyctinomops laticaudatus*, and *Cynomops abrasus* have been recorded previously in Maranhão although the localities have not been documented. Recent studies in the state have all focused on the Amazon biome, and the records from the APA Inhamum represent the first data for the Cerrado biome in Maranhão.

2. Characterization of the new records of bat species for the Brazilian state of Maranhão

Family Phyllostomidae

Artibeus fimbriatus

An adult male specimen (body weight 53 g) was captured at 20:50 h on 18 September 2014 and a non-gestating adult female (body weight 59 g) at 22:10 h on 22 January 2015. Forearm length in the male was 69.16-70.98 mm, and 69.07-69.56 mm in the female. The specimens present gray pelage with white-based hairs.

Dermanura gnoma

Two specimens were collected, a male weighing 14 g, at 21:33 h on 10 June 2015, and an adult female weighing 11.5g at 18:25 h on 8 June 2015. Forearm length was 40.19 - 41.16 mm in the male and 40.35-39.83 mm in the female. The dorsal pelage is light chestnut, with the ventral pelage slightly lighter in color, and face with incipient light striping.

Miconycteris schmidtorum

An adult female (non-gestating) weighing 6 g was collected at 20:30 h on 23 January 2015. Right forearm length 32.8 mm, left forearm 32.78 mm. Brown dorsal coloration with ventral coloring in tones of light yellow.

Platyrrhinus fusciventris

Juvenile female weighing 11 g was collected at 19:27 h on 24 January 2015. Right forearm length 37.36 mm, left forearm 39.28 mm. Brown coloration.

Platyrrhinus cf. recifinus

An adult male was captured at 21:24 h on 18 September 2014. Body weight 12.5 g, right forearm 37.32 mm and left forearm 38.22 mm. Coloration predominantly gray, with a continuous white stripe extending from the top of the head to near the uropatagium, as well as yellowish extremities to the ears and tragus.

Phylloderma stenops

An adult male weighing 40.4 g was collected at 18:25 h on 8 June 2015. Right forearm length 70.19 mm, left forearm 69.1 mm. Light brown coloration.

Trachops cirrhosus

An adult male was captured at 18:22 h on 2 May 2014. Body weight 29 g, forearms 62.42-63.22 mm, and tail of 19.52 m. Pelage coloration in varying shades of gray, lips with warts, and ears large.

Family Molossidae

Molossops temminckii

This species was rare, with a single non-gestating adult female being captured at 18:32 h on 1 May 2014. Body weight 4.5 g. Right forearm 30.05 mm, left forearm 29.98 mm. The dorsal pelage ranged from medium to dark chestnut, with the ventral fur light chestnut to cream, with white-based hairs.

Family Vespertilionidae

Lasiurus ega

Four adult males and a juvenile were captured after 19:15 h on 1 May 2014, all with their testicles in an abdominal position. Body weights varied from 9 g to 12 g, and forearm lengths from 43.92 mm to 48.44 mm, and tails of 41.02 mm to 57.19 mm. The specimens were buffy-yellowish in color, with a lighter-colored venter, and a striping pattern on the wings.

Lasiurus blossevillii

Two adult males with abdominal testicles were collected at 18:46 h on 19 September 2014 and a non-gestating female at 19:16 h on 22 January 2015. Body weights varied from 6 g to 7 g for males and 8 g for female. Forearm length varied from 36.64 mm to 40.41 mm, and tails from 30.00 mm to 45.55 mm. Coloration was reddish buffy, with white-tipped hairs, and a lighter-colored venter in yellowish tones.

Discussion

Only 10% of surveys have focused on sites in the northeastern region of the country, which includes Maranhão (Feijó et al. 2011). The results of the present study indicate that the APA Inhamum is characterized by a considerable diversity and abundance of bats, with ten new species recorded for the state and two for the Cerrado biome. In their survey of the bats of the Amazon biome of Maranhão, Bernard et al. (2011) recorded 21 species, of which seven were also found in the present study of the state's Cerrado. In the light of the results of the studies of Olimpio et al. (2015), Nascimento et al. (2015) and Costa et al. (2012) the present study presents evidence of the occurrence in the APA Inhamum of species typical of the state's different biomes, in addition to species endemic to the Cerrado, emphasizing the importance of this site for the understanding of the distribution patterns of the region's chiropterans.

In the opinion of Feijó et al. (2011), inventories such as that reported in the present study are important for the understanding of the diversity and distribution of the fauna of a given region, permitting the resolution of taxonomic questions and the identification of priorities for biogeographic and ecological studies. In addition, Bernard et al. (2011) concluded that this type of study can contribute to the evaluation of environmental impacts and provide important data for decision-making in the management of natural environments.

The inventory of the bat fauna of the APA Inhamum represents 39% of the species known to occur in Maranhão. The phyllostomids were the most diverse of these species, with 74.20% of species richness and 86.09% of total abundance. This predominance of phyllostomids is typical of the chiropteran fauna of Brazil (Bolzan 2011) and may also be accounted for by the collection of specimens using only mist-nets, a selective method (Muyllaert et al. 2014).

The genus *Platyrrhinus* is diagnosed from other genera of the subfamily Stenodermatinae by a combination of three characters: two accessory cusps on the posterior face of P4, presence of three upper molars, and presence of a fringe of hair along the trailing margin of

the uropatagium. Although other genera also have these characters, no other genera possess all three at the same time (Carvalho. & Fabián, 2011). According to Gardner (2007) little is known about *P. recifinus* and Jones and Carter (1976) suggested that *P. recifinus* may prove to be a junior synonym of *P. lineatus*. The status specific of the specimen remains “*Platyrrhinus cf. recifinus*”.

The Cerrado biome covers almost a quarter (23%) of Brazil and is characterized by rich, but still poorly-understood biological diversity, which includes 101 bat species, corresponding to 60% of the total number known to occur in the country. These species belong to 42 genera, distributed in eight families (except Natalidae), of which the Phyllostomidae is the most diverse (55 species), followed by the Molossidae (20) and Vespertilionidae with 12 (Sousa et al. 2013). A similar pattern of diversity was recorded in the present study, given that the predominant family was the Phyllostomidae, with 23 species, followed by the Molossidae (four species) and Vespertilionidae, with three species. With the exception of the Emballonuridae (one species), none of the other families known to occur in the Cerrado were recorded in the APA Inhamum. *Artibeus fimbriatus* and *P. fusciventris* represent new records for the Cerrado.

Despite these new records, the number of species captured, and the overall sampling effort, the cumulative species curve did not stabilize, indicating the need for further sampling efforts based on additional, complementary techniques. The results of the present study were consistent with those of Cunha et al. (2011), Ávilla-Cabadilla et al. (2014), and Muylaert et al. (2014) in the Cerrado, in which the cumulative species curves also failed to reach an asymptote. This may have been related to the exclusive use of mist-nets for the collection of specimens, given that this technique favors the capture of phyllostomids, to the detriment of species of other families (Kunz & Parsons 2009), even though specimens of both vespertilionids and molossids were collected in the present study, despite the fact that they tend to fly at very high levels and are not usually collected in mist-nets (Muylaert et al. 2014).

The bat fauna of the Brazilian state of Maranhão is still poorly-known, and the species *D. gnoma*, *L. ega*, *L. blossevillii*, *M. schmidtorum*, *M. temminckii*, *P. stenops*, *Platyrrhinus cf. recifinus*, *P. fusciventris*, *T. cirrhosus*, *A. fimbriatus* and *P. fusciventris* were all recorded in the state for the first time. The records of *A. fimbriatus* and *P. fusciventris* also represent new occurrences for the Cerrado biome. Range extensions were also recorded for a number of species. In addition to the intrinsic value of these findings, the data represent a valuable resource for the planning of conservation measures, and emphasize the need for additional surveys in the Cerrado of Maranhão, given that the biological diversity of this system is still virtually unknown.

Acknowledgments

We are grateful to the Maranhão State Scientific Research and Development Foundation (FAPEMA) for financing this study and the members of the GENBIMOL family (Genetics and Molecular Biology Laboratory, Caxias, Maranhão, Brazil) for technical support.

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Received: 20/07/2015

Revised: 02/06/2016

Accepted: 17/08/2016