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# Bats in a Cerrado landscape of Northern Brazil: species occurrence, influence of environmental heterogeneity and seasonality, and eight new records for the State of Tocantins

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**Abstract:** Patterns of bat distribution in Cerrado can be influenced by habitat heterogeneity and seasonal variation. We described the bat fauna in Cerrado landscape during an environment-monitoring program in Tocantins State, Northern Brazil. Additionally, we tested the influence of habitat heterogeneity and seasonality on the abundance and species richness of Phyllostomidae in this region by Generalized Linear Mixed Models. In 2010, we sampled 40 nights (rainy and dry seasons) in four vegetation types of Cerrado biome. Taxonomic identification was based on measurements and qualitative diagnostics. With a sampling effort of 43,965 $m^2 \cdot h$, we captured 274 bats of 30 species, 22 genera and six families. *Carollia perspicillata* was the most abundant species captured. Colinas do Tocantins municipality was richer than Goiantins (26 and 19 species respectively). The best model for abundance was the interaction between heterogeneity and seasonality and the best model for richness was a mix between these two variables. We registered eight new species for the Tocantins including three species considered threatened with extinction at national level and one at global level. Such results highlight that this region is important for new investigations on the Cerrado biome.

**Keywords:** Chiroptera; environmental licensing; faunistic inventory; new occurrences; savanna landscape.

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## Introduction

In Brazil, the order Chiroptera is widespread and represented by 184 species distributed within 69 genera and nine families (Díaz et al. 2016). Although a better knowledge on bat distribution has been achieved in recent years, including the increase in the number of recorded species in this country (Nogueira et al. 2014), the available information is still heterogeneous and fragmented, with less than 10% of the territory minimally inventoried for bats (Bernard et al. 2011).

The Cerrado is the largest neotropical savanna in the world and the second largest biome in Brazil (Scariot et al. 2005). Covering approximately 23% of the Brazilian territory, this biome encompasses a wide range of phytophysiognomies that range from open dry formations (e.g. Cerrado *strictu sensu*) to dense forest formations (e.g. Cerradão) (Scariot et al. 2005). The Cerrado of Central-western Brazil, together with Caatinga biome in the northeast and Chaco in the neighboring countries, form a dry corridor between the Amazon and the Atlantic Forest biomes (Ab'Saber 1977). Due to its high diversity, the occurrence of endemic plants and animals, huge pressure of deforestation and habitat loss (Marinho-Filho 1996, Scariot et al. 2005), the Cerrado has been globally considered as a hotspot for biodiversity conservation (Myers et al. 2000). However, in spite of such important features, only 8% of this biome is currently under protection, which poses a challenge to its conservation (ICMBIO 2014).

The heterogeneity of phytophysiognomies across the extensive area of Cerrado (2,052,533 km$^2$) favors the establishment of complex bat assemblages comprising different trophic guilds (Zortéa and Alho 2008, Gregorin et al. 2011). Historically, information on bat fauna in the Cerrado is relatively recent, with most studies starting in the 1980s (Gregorin et al. 2011). Currently, there are 107 bat species recorded for this biome (Paglia et al. 2012, Feijó et al. 2015, Louzada et al. 2015, Felix et al. 2016, Olímpio et al. 2016). However, considering that vast areas of this biome are undersampled concerning their bat fauna, this number might be underestimated. The Tocantins State, for example, comprises large areas of the Cerrado and its bat fauna is one of the least studied in comparison to other Brazilian states (Bernard et al. 2011).

Important advances in the knowledge of the chiropterofauna in Tocantins have been published in recent years, including inventory studies (Nunes et al. 2005, Bezerra and Marinho-Filho 2010, Gregorin et al. 2011, Lapenta and Bueno 2015, Felix et al. 2016) and notes on geographical distribution (Gregorin et al. 2006, Sodré et al. 2008, Novaes et al. 2012, 2014). Currently, 63 bat species have been recorded for the Tocantins (Nunes et al. 2005, Gregorin et al. 2006, Williams and Genoways 2007, Sodré et al. 2008, Tavares et al. 2008, Bezerra and Marinho-Filho 2010, Gregorin et al. 2011, Peracchi et al. 2011, Novaes et al. 2012, 2014, Lapenta and Bueno 2015, Felix et al. 2016) and it is estimated that this number could be higher if unpublished data of bat occurrence coming from environmental licensing projects come to be published (Nunes et al. 2005, Bezerra and Marinho-Filho 2010).

Herein, our main goal was to contribute to the knowledge of bats for the Tocantins State presenting the results of a rapid assessment of a bat fauna from two areas in the Northern region of this State. Specifically, we (1) provided a list of bat species from the region; (2) compared species richness and abundance of bats between these two areas; and (3) tested the influence of habitat heterogeneity and seasonality in the abundance and species richness using Phyllostomidae bats.

## Materials and methods

### Study area

This study was conducted as part of an environmental monitoring program for the construction of linear electric power lines between two areas in the north of the Tocantins State (Figure 1). We conducted samplings at the municipalities of Colinas do Tocantins (hereafter as Colinas; 8°3′19.50″S, 48°28′31.89″W) and Goiatins (7°42′54.04″S, 47°19′33.25″W). The distance between these two areas is approximately 133 km in straight line. The region is inserted in the Cerrado biome and the altitude ranges from 190 to 280 m. The vegetation found in the study areas was classified in four phytophysiognomies that occur in the Cerrado: gallery forest (GF), characterized by close corridors (gallery) of vegetation that follow the watercourses, such as streams; grassy-woody savannah (GWS; also known as clean grassland), exclusively herbaceous and shrubby, with shrubs and spaced small trees belonging to very few species; steppe savannah park (SSP; also known as shrubby grassland), predominantly herbaceous phytophysiognomy with rare shrubs and lacking trees; and Veredas (VER), characterized by dominance of the palm tree *Mauritia flexuosa* L. f. in union with groups of herbs and shrubs (Ribeiro and Walter 1998, IBGE 2012). We observed GF, GWS, SPP and VER in Colinas and only GWS and VER in Goiatins. Colinas has a larger area of human activities, such as pasture and soybean plantations, than Goiatins. In the study region, the predominant climate is semi-moist tropical with a dry winter and rainy summer (Aw according to Köppen-Geiger classification; Alvares et al. 2014), with a rainy season that occurs from September to May and a dry season that occurs from June to August (Hijmans et al. 2005). The mean annual precipitation is 1800 mm for Colinas and 1500 mm for Goiatins, with a mean temperature of 26°C for both municipalities.

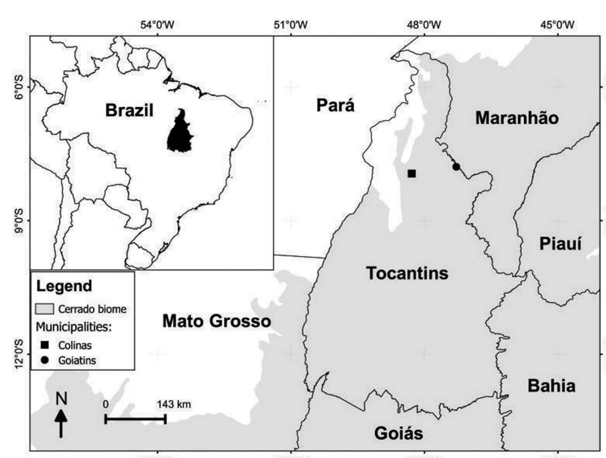


**Figure 1:** Location of Colinas do Tocantins (square filled in black) and Goiatins (circle filled in black) municipalities in the Tocantins State, Northern Brazil.
In detail, the location of this State in Brazil (black).

## Bat sampling and identification

Bats were sampled in two field trips – March 2010 (rainy season) and July 2010 (dry season). The sampling effort was 40 nights (10 nights per season in each municipality). We sampled bats with mist nets (9×2.5 m) placed along trails, clearings, corridors between fragments, riverbanks and near to potential refuges and food resources. In Colinas, we used 4–10 mist nets (mean 9±2 mist nets) that remained open during 4–6 h. In Goiatins, we used 3–10 mist nets (mean 8±2 mist nets) that remained open during 3–6 h.

Captured individuals were preliminarly identified using field guides and identification keys (e.g. Gardner 2007, Reis et al. 2007). All captured bats were individually conditioned in cotton bags and kept in these bags until the end of the capture session. Each individual received a record number; sex and reproductive status were identified, and body mass (g) and external measurements (mm) were registered. Afterwards, they were released in the same place where they had been captured. To avoid capturing the same individual in a later capturing session, all individuals received a temporary mark on the patagium (Bonaccorso and Smythe 1972) before being released.

In order to have a representative set of the bat fauna and confirm the identifications of problematic species, at least one adult individual of each species was euthanized. After death, specimens were fixed in 10% formalin and 10% calcium formaldehyde solution and conserved in 70° GL alcohol, or they were prepared in dry skin. Specimens were collected under IBAMA license n° 02001.001111/2008-14. The voucher specimens were deposited at the Museu Nacional do Rio de Janeiro (MN) (Appendix), located in the Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil.

To support the specimen identification, the following measurements of one external and eleven cranial dimensions were taken from the collected specimens (Moratelli and Dias 2015); forearm length (FA); greatest length of skull, including incisors (GLS); condyloincisive length (CIL); maxillary toothrow length ($C\text{-}M^3$); breadth across canines (C-C); postorbital breadth (POB); breadth across molars ($M^3\text{-}M^3$); braincase breadth (BB); zygomatic breadth (ZB); mastoid breadth (MB); mandibular length (ML); and mandibular toothrow length ($C\text{-}M_3$). These measurements were taken using digital calipers accurate to 0.02 mm. The taxonomic identification was confirmed by analysis of the measurements and qualitative characters reported as diagnostics in the identification keys, reviews, descriptions and other taxonomic studies.

## Data analysis

The sampling effort was calculated following Straube and Bianconi (2002). To evaluate if the capture effort was sufficient, aleatory species-accumulation curves were constructed (Gotelli and Colwell 2001) for the entire sampling region. Due to the difference of sampling effort in each area, we used rarefaction curves to compare the areas. Rarefaction curves were performed in the Past program version 3.12 (Hammer et al. 2001). The species richness for each area was estimated using the Jackknife-1 estimator through the EstimateS program version 9.0 (Colwell 2013).

In order to evaluate habitat heterogeneity influence on bats, we categorized Colinas as more heterogeneous than Goiatins because Colinas presented four phytophysiognomies (SGL, VER, GF and SEP) whereas Goiantins had only two (SGL and GF). Thus, to test whether habitat heterogeneity and seasonality influenced abundance and species richness, generalized linear mixed models (GLMM) with a Poisson distribution were used. The seasons (dry and rainy) and the areas (more and less heterogeneous) were considered as fixed effects, while the sampling nights were considered as random effect (see Zuur et al. 2009). Akaike information criteria (AIC) was applied to select the model that best explains the relationship between variables. AIC selects the best adjusted model that represents the information lost when the complexity increased, calculating the weight of each model. The most adequate model has the smallest AIC value and the largest weight (Wagenmakers and Farrell 2004, Symonds and Moussalli 2011). Due to the greatest efficiency of mist nets in capturing phylostomid bats (Kalko et al. 1996), only these bats were considered in GLMM that were run using the R environment (R Core Team 2014) with the *lme4* package (Bates et al. 2015).

# Results

## Bats captured in the sampling region

With a total sampling effort of 43,965 $m^2 \cdot h$, 274 bats of 30 species, 22 genera and six families were captured (Table 1). Phyllostomidae was the most representative family with 257 individuals of 23 species. *Carollia perspicillata* was the most abundant species in both areas, with approximately 57% of all captures. *Dermanura cinerea*, *Lophostoma silvicola*, *Artibeus lituratus*, and *Pteronotus parnellii* were considered the most abundant species, ranging from 10 to 14 captures. *Rhinophylla pumilio*,

**Table 1:** Bats captured in Colinas do Tocantins and Goiatins municipalities, state of Tocantins, Brazil, and relative abundance according to the seasons, habitat phytophysiognomies and global/national conservation status (MMA 2014, IUCN 2016).

| Bat species | Municipalities | | | | Total captures (%) | Phytophysiognomies | | | | Status (IUCN/MMA) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Colinas | | Goiatins | | | | | | | |
| | Dry | Rainy | Dry | Rainy | | GF | GWS | SSP | VER | |
| *Carollia perspicillata* (Linnaeus 1758) | 16 | 38 | 12 | 93 | 159 (58.03%) | 32 | 109 | 4 | 14 | LC/NC |
| *Dermanura cinerea* Gervais 1856 | 3 | 1 | 3 | 7 | 14 (5.11%) | 0 | 12 | 0 | 2 | LC/DD |
| *Lophostoma silvicola* d'Orbigny 1836 | 6 | 5 | 0 | 0 | 11 (4.01%) | 0 | 6 | 1 | 4 | LC/NC |
| *Artibeus lituratus* (Olfers 1818) | 4 | 3 | 2 | 1 | 10 (3.65%) | 0 | 5 | 2 | 3 | LC/NC |
| *Pteronotus parnellii* (Gray 1843) | 1 | 0 | 8 | 1 | 10 (3.65%) | 2 | 7 | 0 | 1 | LC/NC |
| *Rhinophylla pumilio* Peters 1865 | 1 | 4 | 1 | 2 | 8 (2.95%) | 0 | 4 | 0 | 4 | LC/NC |
| *Artibeus planirostris* (Spix 1823) | 1 | 2 | 1 | 2 | 6 (2.19%) | 0 | 5 | 1 | 0 | LC/NC |
| *Lophostoma brasiliense* Peters 1866 | 3 | 2 | 0 | 1 | 6 (2.19%) | 1 | 3 | 0 | 2 | LC/NC |
| *Glossophaga soricina* (Pallas 1766) | 0 | 3 | 0 | 2 | 5 (1.82%) | 0 | 4 | 0 | 1 | LC/NC |
| *Sturnira tildae* de la Torre 1959 | 0 | 3 | 0 | 2 | 5 (1.82%) | 0 | 4 | 1 | 0 | LC/NC |
| *Uroderma bilobatum* Peters 1866[a] | 1 | 1 | 0 | 3 | 5 (1.82%) | 0 | 4 | 0 | 1 | LC/NC |
| *Artibeus obscurus* (Schinz 1821) | 1 | 2 | 0 | 1 | 4 (1.46%) | 1 | 1 | 1 | 1 | LC/NC |
| *Platyrrhinus incarum* (Thomas 1912)[a] | 0 | 3 | 1 | 0 | 4 (1.46%) | 0 | 1 | 2 | 1 | NC/NC |
| *Hsunycteris thomasi* (Allen 1904) | 2 | 1 | 0 | 0 | 3 (1.09%) | 0 | 2 | 0 | 1 | LC/NC |
| *Dermanura gnoma* (Handley 1987)[a] | 2 | 1 | 0 | 0 | 3 (1.09%) | 0 | 2 | 0 | 1 | LC/DD |
| *Platyrrhinus lineatus* (É. Geoffroy St.-Hilaire 1810) | 0 | 1 | 1 | 1 | 3 (1.09%) | 0 | 3 | 0 | 0 | LC/NC |
| *Artibeus concolor* W. Peters 1865 | 1 | 0 | 0 | 1 | 2 (0.73%) | 0 | 2 | 0 | 0 | LC/NC |
| *Chiroderma salvini* Dobson 1878[a] | 0 | 0 | 1 | 1 | 2 (0.73%) | 1 | 1 | 0 | 0 | LC/NC |
| *Dermanura anderseni* (Osgood 1916) | 0 | 1 | 0 | 1 | 2 (0.73%) | 0 | 1 | 0 | 1 | LC/DD |
| *Molossops temminckii* (Burmeister 1854) | 0 | 2 | 0 | 0 | 2 (0.73%) | 0 | 1 | 0 | 1 | LC/NC |
| *Saccopteryx leptura* (Schreber 1774)[a] | 1 | 0 | 0 | 0 | 1 (0.36%) | 0 | 0 | 0 | 1 | LC/NC |
| *Eptesicus furinalis* (d'Orbigny and Gervais 1847) | 1 | 0 | 0 | 0 | 1 (0.36%) | 1 | 0 | 0 | 0 | LC/NC |
| *Lasiurus ega* (Gervais 1856) | 0 | 1 | 0 | 0 | 1 (0.36%) | 0 | 0 | 0 | 1 | LC/NC |
| *Micronycteris minuta* (Gervais 1856) | 0 | 0 | 1 | 0 | 1 (0.36%) | 0 | 1 | 0 | 0 | LC/NC |
| *Gardnerycteris crenulatum* (É. Geoffroy 1803) | 1 | 0 | 0 | 0 | 1 (0.36%) | 1 | 0 | 0 | 0 | LC/NC |
| *Pteronotus personatus* (Wagner 1843)[a] | 1 | 0 | 0 | 0 | 1 (0.36%) | 1 | 0 | 0 | 0 | LC/NC |
| *Rhogeessa hussoni* Genoways and Baker 1996[a] | 1 | 0 | 0 | 0 | 1 (0.36%) | 0 | 0 | 1 | 0 | DD/NC |
| *Tonatia saurophila* Koopman and Williams 1951[a] | 0 | 0 | 0 | 1 | 1 (0.36%) | 0 | 1 | 0 | 0 | LC/NC |
| *Trachops cirrhosus* (Spix 1823) | 1 | 0 | 0 | 0 | 1 (0.36%) | 0 | 1 | 0 | 0 | LC/NC |
| *Trinycteris nicefori* (Sanborn 1949) | 0 | 0 | 0 | 1 | 1 (0.36%) | 1 | 0 | 0 | 0 | LC/NC |
| Abundance | 48 | 74 | 31 | 121 | 274 | 41 | 180 | 13 | 40 | – |
| Species richness | 19 | 18 | 10 | 17 | 30 | 9 | 23 | 8 | 17 | – |
| Sampling effort ($m^2 \cdot h$) | 9382.5 | 13,500 | 7582.5 | 13,500 | 43,965 | 4275 | 30,960 | 2250 | 6480 | – |

[a]First occurrence documented for the Tocantins state. Habitat phytophysiognomies: GF, gallery forest; GWS, grassy-woody savannah; SSP, steppe savannah park; VER, Vereda. Global/national conservation status: VU, vulnerable; NT, near threatened; LC, least concern; DD, data deficient; NC, not listed.

*Artibeus planirostris*, and *Lophostoma brasiliense* had intermediate abundance, with six to eight captures. The other species were less abundant with less than five individuals. Species richness was similar in the dry and rainy seasons (n = 23 species), while abundance was lower in the dry season (n = 79) than in the rainy season (n = 195). *Carollia perspicillata* was the most abundant species in both seasons, representing 67% of all captures in the rainy season. The second most abundant species was *P. parnellii* in the dry season and *D. cinerea* in the rainy season. In the phytophysiognomies, both species richness and abundance were higher in GWS and lower in SSP (Table 1).

The species accumulation curve did not stabilize (Figure 2) and the species richness estimator Jackknife-1 predicted 40 (±4) species for the study region. Eight species were recorded for the first time for the Tocantins State: *Saccopteryx leptura*, *Tonatia saurophila*, *Chiroderma salvini*, *Dermanura gnoma*, *Platyrrhinus incarum*, *Uroderma bilobatum*, *Pteronotus personatus* and *Rhogeessa hussoni* (Tables 1 and 2).

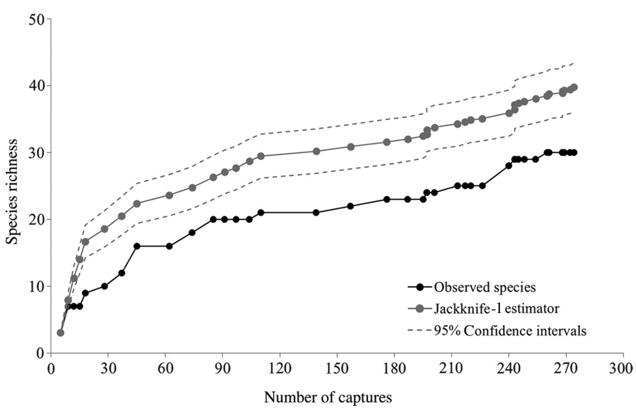


**Figure 2:** Bat species accumulation curves: observed and expected (Jacknife-1) for the Cerrado region in northern Tocantins State, Northern Brazil.

## Comparing the bat fauna of Colinas and Goiatins

The sampling effort and species richness were higher in Colinas (22,882.5 $m^2 \cdot h$ and 26 species) than in Goiatins (21,082.5 $m^2 \cdot h$ and 19 species) (Table 1). The rarefaction curves indicated that Colinas presents a higher species richness than Goiatins, based on the first 120 captures (Figure 3). However, the bat abundance was higher in Goiatins (n = 152 captures) than in Colinas (n = 122 captures) (Table 1). According to the Jackknife-1 estimator, Colinas was expected to harbor 37 (±4) species and Goiatins 28 (±3) species.

## Influence of the heterogeneity and seasonality on the phyllostomid bat assemblage

Five models were constructed to test the influence of habitat heterogeneity and seasonality on the abundance and species richness for the phyllostomid bats in the study region. The best model that explained bat

**Table 2:** Selected measurements (in millimeters) of voucher specimens of eight bat species recorded for the first time in Tocantins State, Northern Brazil.

| Measures | *Saccopteryx leptura* | *Tonatia saurophila* | *Chiroderma salvini* | *Dermanura gnoma* | | *Platyrrhinus incarum* | *Uroderma bilobatum* | *Rhogeessa hussoni* | *Pteronotus personatus* |
|---|---|---|---|---|---|---|---|---|---|
| Sex (N) | M (1) | F (1) | M (1) | M (2) | F (1) | M (2) | F (1) | F (1) | M (1) |
| FA | 39.34 | 57.76 | 46.98 | 37.78–38.14 | 39.82 | 37.22–37.56 | 44.12 | 30.74 | 44.84 |
| GLS | 14.40 | 28.24 | 24.74 | 18.86–19.20 | 19.12 | 21.00–21.28 | 22.62 | 12.98 | 15.84 |
| CIL | 13.00 | 24.66 | 22.50 | 16.60–17.08 | 17.14 | 18.84–19.14 | 20.58 | 12.7 | 14.82 |
| $C\text{-}M^3$ | 5.56 | 9.92 | 9.00 | 5.86–6.14 | 6.08 | 7.24–7.4 | 8.18 | 4.80 | 6.38 |
| C-C | 3.28 | 5.56 | 5.74 | 5.30–5.34 | 5.28 | 4.92–5.14 | 5.64 | 3.82 | 4.58 |
| $M^3\text{-}M^3$ | 6.08 | 8.64 | 10.70 | 7.90–7.96 | 7.90 | 8.50–8.70 | 9.06 | 5.52 | 5.84 |
| POB | 2.46 | 5.44 | 6.04 | 5.28–5.34 | 4.96 | 5.36–5.44 | 5.38 | 3.36 | 3.48 |
| BB | 7.14 | 10.30 | 10.64 | 8.64–8.82 | 8.44 | 9.36–9.50 | 9.68 | 6.06 | 7.64 |
| ZB | 9.16 | 14.00 | 15.46 | 11.10–11.20 | 11.04 | 12.00–12.00 | 12.84 | 8.20 | 9.00 |
| MB | 7.58 | 12.70 | 11.96 | 9.62–10.20 | 9.70 | 10.50–10.60 | 10.78 | 7.00 | 8.58 |
| ML | 9.40 | 17.90 | 16.48 | 11.60–11.76 | 11.82 | 13.60–14.12 | 14.86 | 9.26 | 10.84 |
| $C\text{-}M_3$ | 5.52 | 10.70 | 9.78 | 6.22–6.60 | 6.46 | 7.80–8.06 | 8.68 | 5.30 | 6.74 |

Sex: M, male; F, female. Measurements abbreviations are listed in the Materials and methods section.

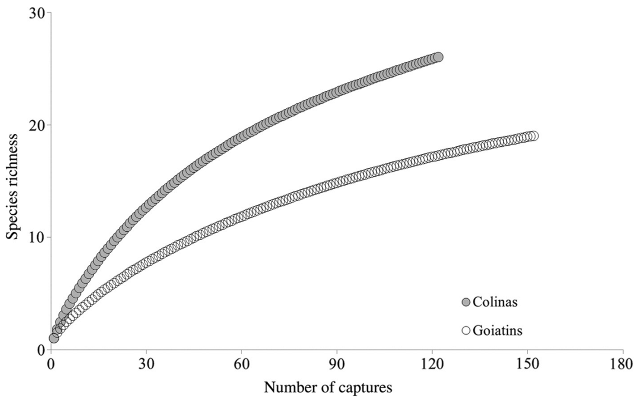


**Figure 3:** Comparison by rarefaction method between bat assemblages of Colinas do Tocantins and Goiatins municipalities, Tocantins State, Northern Brazil.

abundance of phyllostomid considered the interaction between habitat heterogeneity and seasonality (Table 3). For this family of bats, the complexity of habitats seems to be structurally associated with seasonality (abiotic conditions), which can forecast the abundance of bats. Habitats with more complexity (more phytophysiognomies could have more niches) in the rainy season could favor a high abundance of phyllostomids, probably because food resources are in higher densities in the rainy season too.

For species richness the model that considered the sum of habitat heterogeneity and seasonality was slightly better than the model that considered the interaction between these two variables (Table 3). This result showed that differences in the habitat (more niches) could favor the prevalence of more species of bats. Beyond this model, two other models (interaction between phytophysiognomies and seasonality and, only seasonality) showed $\Delta AIC < 2$. For bats richness, seasonality is present in all models.

# Discussion

## Bats sampled in the Northern Tocantins State

The total bat species in the present study represents 28% of the known species that occur in the Cerrado biome (107 species; Paglia et al. 2012, Feijó et al. 2015, Louzada et al. 2015, Felix et al. 2016, Olímpio et al. 2016) and 42% of the species that were listed for the state of Tocantins (71 species; Nunes et al. 2005, Gregorin et al. 2006, Williams and Genoways 2007, Sodré et al. 2008, Tavares et al. 2008, Bezerra and Marinho-Filho 2010, Gregorin et al. 2011, Peracchi et al. 2011, Novaes et al. 2012, 2014, Lapenta and Bueno 2015, Felix et al. 2016, present study). Although about 50% of the species of this state have been captured in the present study, more species are expected for the region according to Jackknife-1 estimator. Therefore, our results indicate that the study region has potential to harbor high bat species richness and should be considered as a focus for recent studies related to distributions and new species records of bats. Phyllostomidae was the most abundant bat family in the present study. The highest number of phyllostomids was possibly due to the bias of the method used (mist nets set at ground level). This method is widely used to capture bats, and in the Neotropics, it tends to favor the captures of phyllostomids that forage mainly in the understory (Brosset and Charles-Dominique 1990, Voss and Emmons 1996, Simmons and Voss 1998). It is possible that other complementary sampling methods, such as searching for roosts and acoustic surveys, for example, may provide complementary efforts for sampling other families whose bats avoid the mist nets set in the understory (Bernard et al. 2011).

*Carollia perspicillata* was the most abundant species in this study. This is a frugivorous species that feeds preferencially on fruits from genus *Piper* (Andrade et al. 2013),

**Table 3:** Influence of the habitat heterogeneity and seasonality in the abundance and species richness of Phyllostomidae bats in a Cerrado region, Northern state of Tocantins, Brazil, tested by generalized linear mixed models with Poisson distribution followed by Akaike information criteria (AIC).

| Model | Abundance | | | Species richness | | |
|---|---|---|---|---|---|---|
| | AIC | ΔAIC | ω | AIC | ΔAIC | ω |
| Season * habitat heterogeneity | 235.76[a] | 0.00[a] | 0.99720[a] | 162.94 | 0.09 | 0.34800 |
| Season + habitat heterogeneity | 249.35 | 13.59 | 0.00112 | 162.85[a] | 0.00[a] | 0.36445[a] |
| Season | 248.53 | 12.77 | 0.00168 | 163.7 | 0.85 | 0.23779 |
| Habitat heterogeneity | 310.81 | 75.05 | <0.00001 | 166.83 | 3.98 | 0.04976 |
| Null model | 310.00 | 74.24 | <0.00001 | 167.7 | 4.85 | 0.03119 |

ΔAIC, Difference between values of AIC; ω, model weight. [a]Best model.

a pioneer plant commonly found in forest clearings, trail edges and areas of forest regeneration (personal observation). In the study areas, mist nets were set in those places that may explain the higher abundance of *C. perspicillata*. Moreover, this species has a wide distribution in Brazil (Reis et al. 2013) and inventories performed in the Cerrado indicate that it is usually the first or second most dominant species (Cunha et al. 2011, Gregorin et al. 2011, Muylaert et al. 2014, Lima et al. 2017). According to Cunha et al. (2011), the relative abundance of *C. perspicillata* tends to increase towards the central and northern areas of the Cerrado, as observed herein, and is less abundant in the southern portion of this biome.

The presence and abundance of some species were related to the quality and heterogeneity of habitat. For example, many gleaning insectivorous bats usually forage in preserved areas (Faria 2006). In the present study, some samplings were performed in the interior and along the edge of preserved remnants, resulting in captures of gleaning insectivorous bats such as *Micronycteris minuta*, *Gardnerycteris crenulatum*, *Tonatia saurophila*, *Trachops cirrhosus*, and *Trinycteris nicefori*. However, some bat species are opportunistic in relation to habitat changes (anthropogenic pressure), exploring frequently the disturbed areas to search for resources, as pioneer plant species that are used as food (Ortêncio-Filho et al. 2014). *Carollia perspicillata* is an example of this kind of bat, once it was highly abundant in the disturbed areas, such as clearings and forest edges.

Considering conservation of bat species, *Rhogeessa hussoni* is considered as Data Deficient at international level (IUCN 2016) and *Dermanura anderseni*, *Dermanura cinerea* and *Dermanura gnoma* as Data Deficient at national level (MMA 2014). *Rhogeessa hussoni* is distributed in Suriname and Brazil and is considered Data Deficient due to the lack of current information related to its occurrence, ecological requirements, threats and conservation status (Sampaio et al. 2016). *D. anderseni* and *D. gnoma* occur in the north, northeast and central-west regions, and *D. cinerea* is widely distributed in Brazil (Peracchi et al. 2011). We captured *Chiroderma salvini*, a species that was reported only recently for Brazil in the Northern and central-western regions (Rocha et al. 2016). As the most recent update of the the Brazilian endangered species list was published in 2014 (MMA 2014), the conservation status of this species has not been evaluated yet.

## Bat assemblages' comparison and influence of habitat heterogeneity and seasonality

Based on the first 120 captures of the rarefaction curves, Colinas municipality was richer in species number than Goiatins. This difference may reflect the types of phytophysiognomies (habitats) that were sampled. In Colinas, four phytophysiognomies were identified (GF, GWS, SSP and VER) and, in Goiatins, only two (GWS and GF). According to Muylaert et al. (2014), it is important to sample different habitats in order to have high species richness in Cerrado. Additionally, our results indicate that, besides sampling in different habitats, it is also important to take into account samplings in both dry and rainy seasons. It is known that seasonality influences the capture success of bats due to variable food availability (Zortéa and Alho 2008, Gomes et al. 2015, Rocha et al. 2015). Lima et al. (2017) observed that both seasonality and habitat heterogeneity influenced the bat abundance in the Cerrado. We found the same result as these authors, however, we also showed that the interaction between these variables influenced the richness of phyllostomid bats. Therefore, besides sampling in different phytophysiognomies, we suggest that bat studies in the Cerrado should be conducted throughout the rainy and dry seasons to obtain a suitable representation of the local bat fauna.

## New records of bat species for the state of Tocantins

Eight species, *Saccopterys leptura*, *Tonatia saurophila*, *Chiroderma salvini*, *Dermanura gnoma*, *Platyrrhinus incarum*, *Uroderma bilobatum*, *Pteronotus personatus* and *Rhogeessa hussoni* were recorded for the first time for the Tocantins state. *Saccopterys leptura* was collected in VER phytophysiognomy, *T. saurophila* in GWS and *P. personatus* in GF. Individuals of *U. bilobatum* and *D. gnoma* were collected in GWS and VER phytophysiognomies. Measurements of our specimens (Table 2) fall within the known range for these species and the qualitative characteristics that support their identifications (see Davis 1968, Handley 1987, Jones and Hood 1993, Williams et al. 1995, Hood and Gardner 2007, Williams and Genoways 2007, Lim et al. 2008, de la Torre and Medellín 2010).

We emphasize herein the second record of *Chiroderma salvini* for Brazil and for the Cerrado biome. We captured two individuals of *C. salvini* in GWS and GF phytophysiognomies. The voucher specimen has conspicuous stripes on the face, a narrow and moderately conspicuous dorsal stripe, elongated and thick central upper incisors obliquely placed and in contact at the tips, first lower premolar with a flat crown and measurements (Table 2) within the range for the species (Taddei and Lim 2010). *Chiroderma salvini* is morphologically similar to *Chiroderma villosum* (Peters 1860), but *C. villosum* have the facial and dorsal stripes less evident or even absent, and thin and parallelly placed central upper incisors, which are completely separated (Taddei and Lim 2010). *Chiroderma salvini* was recently recorded in Brazil, based on a specimen from Porto Velho, Rondônia State, in the Amazon biome and another individual from Aricá, Mato Grosso State, in the Cerrado (Rocha et al. 2016). Our record is more than 1800 km from Porto Velho and about 1200 km from Aricá and it is possible that *C. salvini* also occurs in northeastern Brazil, because of the shortest distance between the sampled site in Tocantins and the border with state of Maranhão (<2 km).

We captured four specimens of small *Platyrrhinus* Saussure, 1860 in GWS, GF and VER phytophysiognomies. The vouchers were identified as *P. incarum* based on measurements (Table 2) and characteristics that distinguished this species from *Platyrrhinus angustirostris* and *Platyrrhinus fusciventris* (Velazco et al. 2010), which are the other small *Platyrrhinus* species that occur in Brazil (Nogueira et al. 2014). However, unambiguous identification is difficult due to the overlapping of measurements and the difficulty in evaluating the presence or absence of small dental cusps which are regarded as useful characteristics for distinguishing species (Velazco et al. 2010). *Platyrrhinus incarum* is currently recorded in Brazil in different biomes (Paglia et al. 2012, Garcia et al. 2014) and in eleven Brazilian states (Reis et al. 2013), with taxonomic status of the most records pending reassessment.

We also highlight the record of *Rhogeessa hussoni*, a species considered rare and scarcely represented in zoological collections. The distinction from *Rhogeessa io* Thomas, 1903, a congener that also occurs in Brazil (Nogueira et al. 2014), is usually based on size, with *R. hussoni* being larger in all measurements, except the mandibular toothrow length (Genoways and Baker 1996, Bickham and Ruedas 2007). Our specimen was collected in SSP phytophysiognomy and has all the measurements (Table 2) within the range of *R. hussoni* (Genoways and Baker 1996, Aires et al. 2011). Additionally, it has reddish brown dorsal pelage with a yellowish base of the hairs, yellowish ventral pelage and inflated pads above the muzzle, useful characteristics for the identification of *R. hussoni* – *R. io* has light brownish dorsal pelage, light yellow ventral pelage and small pads above the muzzle (Aires et al. 2011). In Brazil, *R. hussoni* is known to occur in the Bahia, Maranhão, Minas Gerais, Mato Grosso, Pará, Paraíba, Pernambuco, Paraná and Sergipe States (Bickham and Ruedas 2007, Percequillo et al. 2007, Tavares et al. 2010, Aires et al. 2011, Mikalauskas et al. 2011). Previous records for the Cerrado are represented by two specimens, one collected near to buriti trees (*Mauritia* sp.) and the other in riparian vegetation, in ecotone Amazon Forest-Cerrado, Mato Grosso State (Aires et al. 2011).

## Bat studies in the context of environmental licensing

The present study is an example of the importance of rapid inventories to report new species occurrences and extensions of their geographic distributions. Rapid inventories are part of the studies of environmental impacts and monitoring programs, required by Brazilian environmental government agencies for large-scale infrastructure projects (e.g. hydroelectrics, roads, energy line transmissions). These studies provide opportunities and logistic conditions to conduct inventories in areas never sampled before, contributing to filling the gaps concerning the knowledge on the Brazilian fauna (Bernard et al. 2011). Through these rapid assessments, new records of bats (Sodré et al. 2008, Maas et al. 2013) and other mammals (Hack and Krüger 2013), as well as amphibians, reptiles (Vaz-Silva et al. 2015) and birds (Sanaiotti et al. 2015) are expected. However, most licensing information are still minimally publicized and sometimes is not available in scientific literature due to the absence of voucher material in scientific collections, restrictions on data release and the non-standardized use of methodologies by companies that preclude comparisons among their data (Nunes et al. 2005, Bezerra and Marinho-Filho 2010). Thus, our records could be seen as a case study on how important such studies are in bringing new data about species distribution, including the species classified as threatened and Data Deficient, which are interesting considering the future reassessments of their conservation status. Thus, it is very important not only to create but also to incentivize the peer reviewed publication of data from environmental licensing projects.

The present study was conducted in the dry and rainy seasons during the monitoring phase of an energy power line, where part of the vegetation was suppressed to construct access ways (roads). Despite this environmental change, it was possible to sample different phytophysiognomies in order to provide information for mitigating measures planning. The methodology used in the present study followed the present Brazilian licensing policy, which requires studies in both dry and rainy seasons within a year and in different habitats during all phases of the construction process (licensing, installation and operation) (Fearnside 2016). Our results confirm that this procedure is important since habitat and seasonality were variables that influenced the community. These requirements allow assessing the local fauna refuting the main criticism that the long time required for environmental diagnosis following the current process of Brazilian environmental licensing program causes delays in the final process (Hofmann 2015).

Futhermore, constitutional amendments, such as project law 654/2015 and the PEC-65, have been introduced in the Brazilian National Congress to simplify the licensing process in general (Senado Federal 2015, 2016). At the same time, the Brazilian congress is preparing a substitute of the Law Project number 3.729/04 (Camara dos Deputados 2017) that proposes (1) a general law for the licensing steps, (2) exoneration lot of types of infrastructure projects to do the licensing steps and (3) insufficient deadlines to evaluate the results. According to Fearnside (2016), these initiatives of shortening and simplification process of environmental licensing are worrisome because the knowledge on fauna in impacted areas could be lost and the mitigation actions could be less effective for conserving Brazilian biodiversity.

It is important to point out that specimen collection, although common and recommended in faunistic inventories, has been largely neglected during the environmental licensing process in Brazil, causing a loss of species information. Our study is an example of the importance of this collected material to be studied with more precision, and taxonomic reavaluation requires sometimes a longer time than the Brazilian licensing process.

## Conclusion

Our new records of eight species, upgrades the bat list of Tocantins State to 71 species belonging to 46 genera and eight families. Nevertheless, this number is far from real, considering that the knowledge of this bat fauna is still scarce, requiring more inventories in the northern, northeastern and southern regions of this state to present a complete picture of bat species that occur in this State. All future inventories need to be done in different phytophysiognomies, encompassing a minimum sampling in both rainy and dry seasons. Efforts at using a more diverse methodology are also recommended.

The study region comprises a mosaic of phytophysiognomies and has suffered rapid environmental changes caused by many types of linear impacts and by uncontrolled soybean plantations and pastures. As we sampled high value of bat species richness including endangered species at the national level, we suggest that Cerrado landscape deserves more attention towards bat conservation.

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## Appendix

List of the voucher specimens from Colinas do Tocantins and Goiatins municipalities, state of Tocantins, Brazil, deposited at the Mammal Collection of the Museu Nacional (MN), Universidade Federal do Rio de Janeiro, Brazil.

*Saccopteryx leptura* (1): male – MN 75004.
*Micronycteris minuta* (1): female – MN 75007.
*Lophostoma brasiliense* (2): male – MN 73536; female – MN 75003.
*Lophostoma silvicola* (5): males – MN 73537, 75002; females – MN 74993, 74997, 74998.
*Gardnerycteris crenulatum* (1): male – MN 75000.
*Tonatia saurophila* (1): female – MN 73543.
*Trachops cirrhosus* (1): male – MN 74988.
*Glossophaga soricina* (1): female – MN 73530.
*Hsunycteris thomasi* (3): males – MN 73535, 74990; female – MN 74989.
*Carollia perspicillata* (1): male – MN 73522.
*Trinycteris nicefori* (1): male – MN 73540.
*Rhinophylla pumilio* (1): female – MN 73529.
*Artibeus concolor* (2): male – MN 73544; female – MN 74992.
*Artibeus lituratus* (1): female – MN 73527.
*Artibeus obscurus* (2): male – MN 73524; female – MN 75005.
*Artibeus planirostris* (1): female – MN 73521.
*Chiroderma salvini* (1): male – MN 73439.
*Dermanura anderseni* (2): male – MN 73541; female – MN 73528.
*Dermanura cinerea* (3): males – MN 73532, 73545, 74995.
*Dermanura gnoma* (3): males – MN 74991, 74994; female – MN 73534.
*Platyrrhinus incarum* (2): males – MN 73526, 75009.
*Sturnira tildae* (2): females – MN 73523, 73525.
*Uroderma bilobatum* (1): female – MN 73533.

*Pteronotus parnellii* (3): females – MN 73542, 74996, 75008.
*Pteronotus personatus* (1): male – MN 75001.
*Molossops temminckii* (1): female – MN 73531.
*Eptesicus furinalis* (1): female – MN 74999.
*Lasiurus ega* (1): male – MN 73538.
*Rhogeessa hussoni* (1): female – MN 75006.

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