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Original Article

The effect of urbanization on species composition and trophic guilds of bats (Mammalia, Chiroptera) in the Brazilian Savanna

O efeito da urbanização na composição de espécies e guildas tróficas de morcegos (Mammalia, Chiroptera) no cerrado brasileiro

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Abstract

Urban environments present less environmental heterogeneity in relation to the natural ones, affecting the biodiversity of bats and the ecological processes in which they participate. In this way, we will identify how urbanization influences the structure of bat communities in the municipality of Goiânia, Goiás, Brazil. We compared species composition, guilds and bat richness in a gradient that crossed urban, semi-urban and natural areas in the municipality of Goiânia, contained in the Cerrado biome. We captured a total of 775 bats of 16 species distributed in three families. Urban areas had a higher species abundance, while semi-urban areas had a higher species richness. The three types of environments have different compositions, the urban one being more homogeneous, the fauna in these areas is composed of generalist species, which benefit from this process. The diversity present in semi-urban areas is a consequence of the intersection between urban and natural fauna, which is why urban expansion needs to occur in a planned manner to minimize the impacts of this process and ensure the maintenance of biodiversity.

Keywords: biodiversity, closed biome, ecology, urban bats.

Resumo

Ambientes urbanos apresentam uma heterogeneidade ambiental menor em relação aos naturais, afetando a biodiversidade de morcegos e os processos ecológicos dos quais participam. Desta forma, vamos identificar como a urbanização influência na estruturação das comunidades de morcegos no município de Goiânia, Goiás, Brasil. Comparamos a composição de espécies, guildas e riqueza de morcegos em um gradiente que cruzou áreas urbanas, semiurbanas e naturais no município de Goiânia, contido no bioma Cerrado. Capturamos um total de 775 morcegos de 16 espécies distribuídas em três famílias. Áreas urbanas apresentaram uma abundância maior de espécies, enquanto em áreas semiurbanas tivemos uma riqueza de espécies maior. Os três tipos de ambientes apresentam diferentes composições, sendo o urbano mais homogêneo, a fauna nessas áreas é composta por espécies generalistas, que se beneficiam com esse processo. A diversidade presente nas áreas semiurbanas é consequência do cruzamento entre a fauna urbana e a natural, por isso é necessário que a expansão urbana ocorra de forma planejada para minimizar os impactos desse processo e garantir a manutenção da biodiversidade.

Palavras-chave: biodiversidade, bioma fechado, ecologia, morcegos urbanos.

1. Introduction

Urbanization is one of the main threats to global biodiversity, as this process causes the degradation of natural ecosystems, generated in extremely altered environments (Güneralp and Seto, 2013). The effect of this process on species diversity has been the objective of numerous studies (Grimm et al., 2008; Pacheco et al., 2010; Nunes et al., 2017; Leal et al., 2019; Gili et al., 2020), where they show a negative correlation with richness of amphibians (Hamer and McDonnell, 2008), arthropods (Vergnes et al., 2014), birds (Blair, 1996) and bats (Oprea et al., 2009). This response can be influenced by the quantity and quality of resources present in the area (Kurta and Teramino, 1992; Nunes et al., 2017; Muruyama et al., 2022).

It is estimated that the conversion of natural environments to urban uses will continue to expand worldwide (Raihan and Tuspekova, 2022). Urbanization is associated with habitat fragmentation and loss, resulting in isolation, changing habitat configuration, and decreased connectivity (Alberti et al., 2003). Paving, an essential process in the design of urban centers, is harmful to biodiversity (McKinney, 2002), being one of the factors

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responsible for rising temperatures (Kleerekoper et al., 2012) and increasing human population density (Medley et al., 1995).

Urbanization is responsible for eliminating animal shelters, such as caves, used by bat colonies (Presley et al., 2008), despite this, some species are able to adapt to new environmental settings, using buildings and houses as shelters (Rodríguez-Aguilar et al., 2017). In addition, natural habitats inserted in the urban matrix, such as parks, are alternatives to help maintain biodiversity (Tena et al., 2020). Although the response of bats to the urbanization process is still very variable, a decrease in species richness is noticeable (Carballo-Morales et al., 2021). The order Chiroptera has a worldwide diversity of 1470 species, the second largest in the class Mammalia (Simmons and Cirranello, 2023), of which 184 occur in Brazil (Garbino et al., 2022). They have different trophic guilds such as frugivores, insectivores, nectarivores, omnivores, piscivores and hematophages, presenting a great foraging potential (Silva et al., 2020).

Environmental heterogeneity is important for the survival of frugivorous species, this diversity is mostly found in semi-urban and natural environments (Verde et al., 2018). Urban environments can offer and concentrate a greater abundance of insects, which are often attracted by lights, being beneficial to some insectivorous bats by contributing to the food supply (Avila-Flores and Brock Fenton, 2005). However, artificial light has a negative impact on fruit bats, decreasing their foraging capacity, influencing seed dispersal (Lewanzik and Voigt, 2014). Bats provide different ecological services, insectivores regulate insect populations (Aguiar et al., 2021), frugivores disperse seeds to different ecosystems (Estrada and Coates-Estrada, 2002) and nectarivores play the role of pollinators, acting in the maintenance of diversity genetics (Kasso and Balakrishnan, 2013), making it essential to reduce the impacts and losses of species in the urbanization process.

Given the above, the objective is to identify how urbanization affects the structure of the bat community, for this, we will compare the diversity and composition of the fauna between urban, semi-urban areas and a natural area in the municipality of Goiânia, state of Goiás, Brazil. Our hypotheses are (i) bat diversity will be negatively correlated with urbanization and (ii) the composition of the feeding guild will be more homogeneous in urban areas than in semi-urban and natural areas.

2. Materials and Methods

The collection and euthanasia processes followed the protocols approved by the Ministry of the Environment and the Chico Mendes Institute for Biodiversity Conservation (SISBIO license 57294 2).

2.1. Study área

The study was carried out in the municipality of Goiânia, state of Goiás, central region of Brazil. Covers 73,280 hectares and has a population of approximately 1.3 million people. The region's climate is seasonal, with two well-defined seasons, one dry and one rainy (Peel et al., 2007). Goiânia has 30 municipal conservation units, we chose seven sampling sites (See Figure 1), three in fully urbanized areas, three in semi-urban areas and one in a natural area. All locations are influenced by streams.

2.2. Urban area

The selected urban parks have streams and natural vegetation (Cirreira and Mata Seca/Cerradão as the main formation) containing food and shelter for bats. The landscape surrounding the parks is anthropic, characterized by many buildings and paved areas, since they are inserted in the central region of the city (See Figure 1). We sampled three urban parks in ten nights. Five nights in the dry season and five in the wet season.

2.3. Semi-urban area

We selected three remnants that had areas of vegetation and low urbanization, namely, the agronomy school and the veterinary school of the federal university of Goiás and the caraíbas farm (See Figure 1). The vegetation of all remnants is a typical Cerrado, Mata Seca/Cerradão formation. The landscape that surrounds these remnants is composed of pastures, with the presence of livestock. We carried out 10 collections in the semi-urban area, arbitrarily dividing the collections between the three

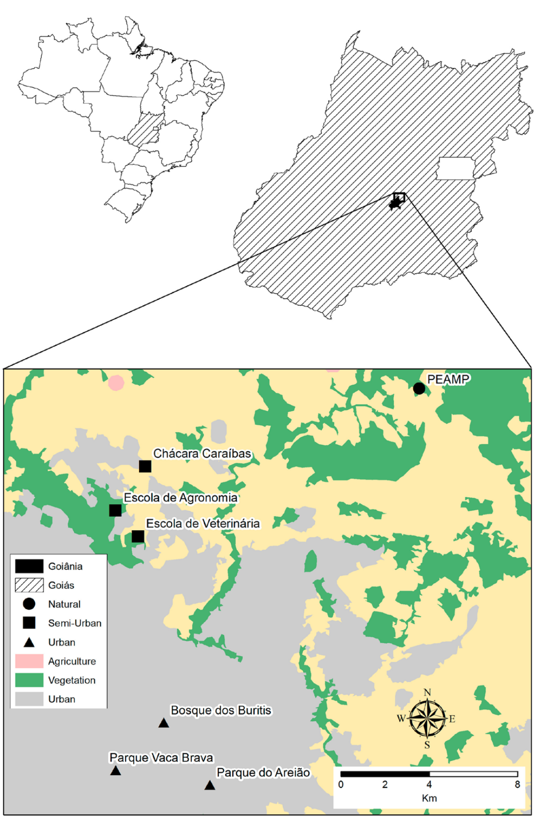

Figure 1. Location of the seven localities sampled between March 2015 and June 2016 in the municipality of Goiânia, Goiás, Brazil. PEAMP - Altamiro de Moura Pacheco State Park.

locations mentioned above. Five were carried out in the dry season and five in the rainy season.

2.4. Natural area

Finally, we selected a state park to represent the area with natural vegetation. The Altamiro de Moura Pacheco State Park (PEAMP) represents the largest remnant of Mata Seca in the central region of the state of Goiás (Consolaro et al., 2019) (See Figure 1). The predominant type of vegetation is Cerrado Sensu Strito and Cerradão and with the presence of gallery forests (Riparian vegetation) (Consolaro et al., 2019). The surrounding landscape is characterized by the presence of a mining area, pasturelands, degraded lands and areas with agricultural use. We carried out 10 collections in the natural area, five in the dry season, and five in the rainy season.

2.5. Sampling

We performed 30 sampling nights between March 2015 and June 2016 with a one-month interval between collections, so that the 30 were equally divided between the three types of area. We captured bats preferentially in phases of waning or new moon, as the capture of bats is lower in other phases of the moon due to the high luminosity (Esbérard, 2007). We used 10 mist nets (mist-nets), each 9.5 m long x 3.0 m high, which remained open for six hours after sunset, and at intervals of 15 to 30 minutes we inspected them. We set up the nets on trails inside each sampling site, when this was not possible, the nets were set up at the edge of the vegetation.

After the bats were captured, we identified the individual at the species level according to (Gardner, 2008), determined sex, age, and reproductive status. In females, we observed the presence or absence of pregnancy through abdominal palpation and secretion in the breasts, through slight compression in the nipples. In males, we checked whether the testicle was evident (sexually active) or abdominal (sexually inactive) (Willig, 1985). For each individual, we also noted the following data: place and time of capture, body mass and length of the forearm. After collecting data, we marked the individuals captured using plastic rings or collars (Esbérard et al., 1999), and released them close to the capture site. We collected an individual of each species, they were euthanized by cervical dislocation. We fixed the specimens in 10% formalin and conserved in 70% ethanol, afterwards the individuals were registered in the Zoological Collection of the Federal University of Goiás under the code RE 01 to RE 21.

2.6. Data analysis

We calculated the sampling effort following the method proposed by (Straube and Bianconi, 2002). Species richness was estimated by the Jackknife procedure (Heltshe and Forrester, 1983), in the program EstimateS version 8.0 (Colwell, 2005) with 1000 randomizations. Estimated and observed species richness was compared using the 95% confidence intervals. Species richness in the three class (urban, semi-urban and natural) was compared using the intersection among confidence intervals of estimated species richness.

To verify how the composition of species and guilds are structured along the urbanization gradient, we performed a permutational analysis of variance using distance matrices, using the collection nights as the replicates and the points as the categorical variable (PERMANOVA). Associated with the multivariate homogeneity of groups dispersions (PERMIDISP) (Anderson, 2006; Anderson et al., 2006). For both tests, we used a Bray-Curtis similarity matrix, built from the species abundance matrix or from the food guilds, which were defined according to Kalko et al. (1996). With PERMANOVA, we tested the similarity between the three areas, that is, if the means of variation referring to the composition of species or food guilds were similar. With PERMIDISP, we also tested the similarity between the areas, however it was measured from the average variance within the groups. Finally, to illustrate how the sampling sites are distributed in a multi-dimensional space and which species and guilds are associated with each type of environment, we standardized the abundance data using the Hellinger method and made a composition PCA (Legendre and Legendre, 1998). All tests were performed in R environment (R Core Team, 2022). Function adonis was used for PERMANOVA, function betadisper for PERMDISP, function rda for PCA and function vegdist for all distance matrices, all functions are implemented in the Vegan package (Oksanen et al., 2016).

3. Results

With a sampling effort of 51,300 h.m2, we captured a total of 775 bats of 16 species, from the families Phyllostomidae, Molossidae and Vespertilionidae (as shown in Table 1), and we had 19 recaptures. The most abundant species were *Artibeus planirostris* (Spix, 1823) (236 captures), *Carollia perspicillata* (Linnaeus, 1758) (222 captures) and *Artibeus lituratus* (Olfers, 1818) (119 captures). The urban area concentrated 55% of captures (424 captures), the semi-urban area 26% of captures (203 captures) and the natural 19% of captures (148 captures). 86% of catches are frugivorous (670 catches) followed by nectarivores, omnivores, insectivores and hematophagous with 6% (44 catches), 5% (37 catches), 2% (17 catches) and 1% (seven catches) of catches, respectively.

For the three areas analyzed together, we obtained an estimated richness close to 20 species (See Figure 2). We do not show all estimated species for the study region (See Figure 2). It is likely that four species are present at the study site that were not sampled by us. For the areas analyzed separately (See Figure 3), the estimated richness of the urban (See Figure 3a), semi-urban (See Figure 3b) and natural areas (See Figure 3c) approach 13, 21 and 8 species, respectively. All Jackknife estimator curves tend to stabilize. We recorded the highest richness in the semi-urban area with 16 species, followed by the natural area with nine species and the urban area with seven species (See Figure 3d).

Both species composition (PERMANOVA – $F_{(2,29)} = 4.658$; $p < 0.001$) and trophic guild composition (PERMANOVA - $F_{(2,29)} = 3.722$; $p = 0.004$) differ along the gradient (Figure 4 and Figure 5). The same result was observed for

Table 1. Bat composition sampled in Goiânia (Goiás) between March 2015 and June 2016 with the abundance, land use/cover and trophic guild.

Captured Species	Captures	Land use/cover	Trophic Guild
Family Phyllostomidae			
Subfamily Carollinae			
Carollia perspicillata (Linnaeus, 1758)	222	N, S, U	Frugivore
Subfamily Desmodontinae			
Desmodus rotundus (É. Geoffroy, 1810)	7	N, S	Hematophagous
Subfamily Glossophaginae			
Anoura caudifer (É. Geoffroy Saint-Hilaire, 1818)	2	S	Nectarivore
Glossophaga soricina (Pallas, 1766)	42	N, S, U	Nectarivore
Subfamily Phyllostominae			
Lophostoma brasiliense (Peters, 1866)	1	S	Omnivorous
Phyllostomus discolor (Wagner, 1843)	30	N, S, U	Omnivorous
Phyllostomus hastatus (Pallas, 1767)	6	N, S	Omnivorous
Subfamily Stenodermatinae			
Artibeus lituratus (Olfers, 1818)	119	N, S, U	Frugivore
Artibeus planirostris (Spix, 1823)	236	N, S, U	Frugivore
Platyrrhinus lineatus (É. Geoffroy, 1810)	76	N, S, U	Frugivore
Sturnira lilium (É. Geoffroy, 1810)	17	N, S	Frugivore
Family Molossidae			
Molossops temminckii (Burmeister, 1854)	1	S	Insectivorous
Family Vespertilionidae			
Eptesicus brasiliensis (Desmarest, 1819)	3	S	Insectivorous
Eptesicus furinalis (D'Orbigny & Gervais, 1847)	1	S	Insectivorous
Histiotus velatus (I. Geoffroy, 1824)	1	S	Insectivorous
Myotis nigricans (Schinz, 1821)	11	S, U	Insectivorous

N = natural area; S = semi-urban area; U = urban area.

the variation of the bat species composition (PERMIDISP – $F_{(2,29)} = 3.751$; $p = 0.036$) and trophic guild composition (PERMIDISP – $F_{(2,29)} = 3.395$; $p = 0.048$) (Figure 4 and Figure 5). The composition of species and food guilds in the semi-urban and natural areas are more similar and have the largest variances and the urban area has a composition of species and food guilds with less variance (Figure 4 and Figure 5).

In the PCA of composition, made with bat species, we observed that the first two axes explain 63.06% of the total variance (Figure 5a). As a standard, we observed that the composition of the semi-urban area consists of species from both the urban and natural areas. *Carollia perpicillata* is more associated with the natural area; *Desmodus rotundus* to the semi-urban; *Platyrrhinus lineatus*, *Artibeus planirostris* and *Artibeus lituratus* to the urban area (Figure 5a). In the guild composition PCA, we found that the first two axes explain 70.06% of the total variation (Figure 5b). The urban area has

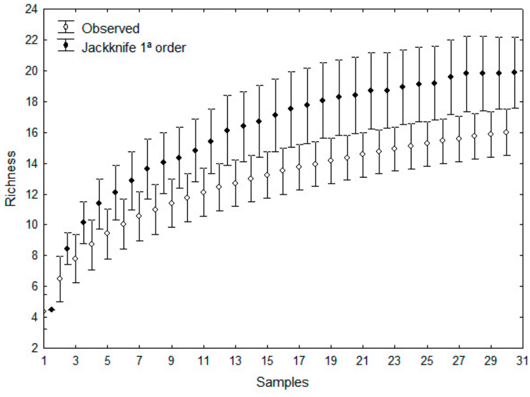

Figure 2. Observed and estimated bat species richness of the municipality of of Goiânia, Goiás, Brazil. The bars represent the 95% confidence interval.

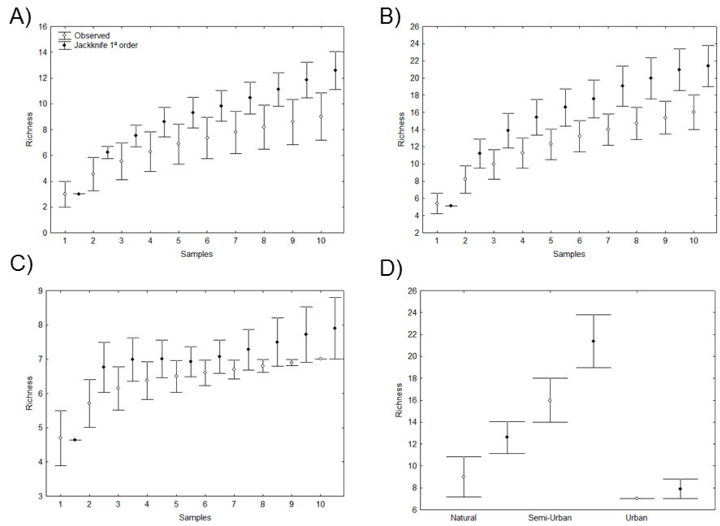

Figure 3. Observed and estimated bat species richness of the natural (A), semi-urban (B), urban area (C) and comparison of estimated and observed richness between the three class of areas (D). The bars represent the 95% confidence interval.

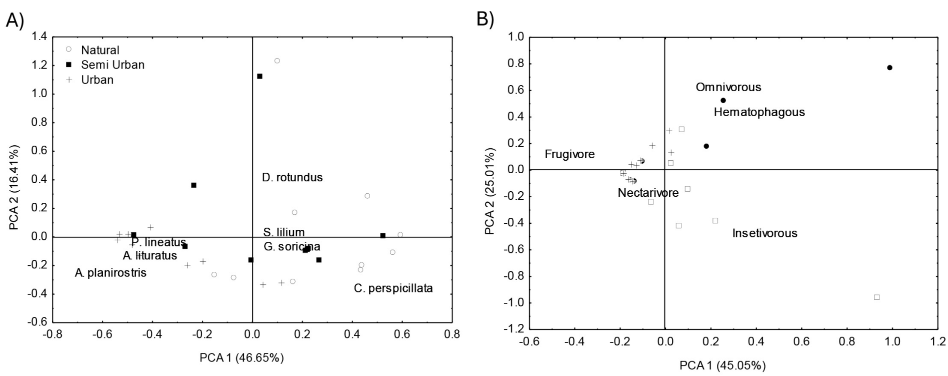

Figure 4. Multivariate homogeneity of groups dispersions - PERMDISP of the bat species (A) and trophic guilds (B) sampled between March 2015 and June 2016 in the municipality of Goiânia, Goiás, Brazil. Ordination was performed by species abundance and the matrix was transformed by Hellinger procedure.

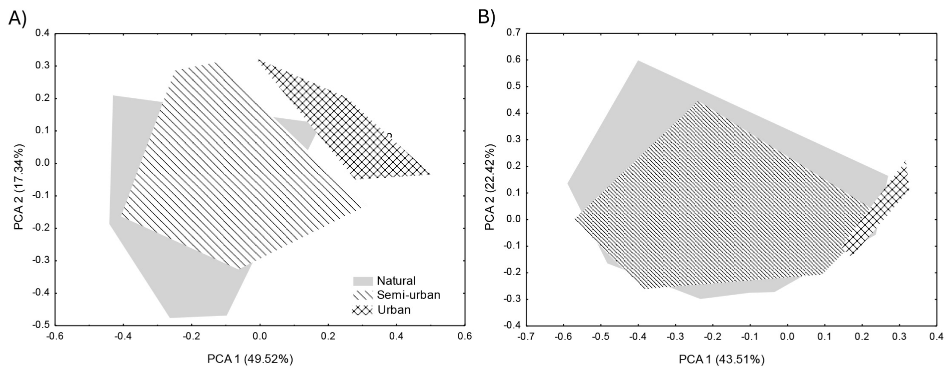

Figure 5. Principal Component Analyses of the bat species (A) and trophic guilds (B) sampled between March 2015 and June 2016 in the municipality of Goiânia, Goiás, Brazil. Ordination was performed by species abundance and the matrix was transformed by Hellinger procedure.

the most homogeneous composition, being represented mainly by fruit bats. Hematophagous and omnivorous bats are more associated with the natural area, and insectivorous bats are more associated with the semi-urban area.

4. Discussion

We recorded a lower species richness in urban areas with similar results obtained by other authors (Russo and Ancillotto, 2015; Threlfall et al., 2011). Urban environments suffer from biotic homogenization, with native plants being replaced by exotic ones, often for landscaping reasons (McKinney, 2006). The loss of vegetation simplifies the environments, therefore, the more specialist bats are not able to persist in urban areas, since these environments have a smaller amount of food resources and shelter for the species (van der Ree and McCarthy, 2005). We also recorded a greater richness in semi-urban areas, one of the factors that influence this is the environmental heterogeneity that these environments present, containing elements from both the urban area and the natural area. Intermediate disturbance theory (Connell, 1978) predicts that semi-urban areas can be marked by adequate disturbance intensity (Russo and Ancillotto, 2015). A study carried out in the Federal District of Brazil also found a great diversity of bats in rural areas, attributing this to the heterogeneity of the environment (Bredt and Uieda, 1996).

Semi-urban and natural environments had a similar species composition, although species richness between semi-urban and natural areas was different, abundance was similar between these areas. Such a pattern called evenness consists of more uniformly distributed abundances among different species. The equity of a community refers to how similar the species are distributed in a community, the more similar the representativeness of the species, the greater the equity and, consequently, the diversity (Nogueira et al., 2008). The semi-urban area was composed of all species captured during this work. The species *Eptesicus brasiliensis*, *Eptesicus furinalis*, *Molossops temminckii*, *Lophostoma brasiliense*, *Histiotus Velatus* and *Anoura caudifer* were captured exclusively in the semi-urban environment.

The urban area has a composition of feeding guilds with lower variance, this pattern reflects a homogeneous community with few species representing each guild. Omnivorous, frugivorous, insectivorous and nectarivorous bats represent the guilds captured in the urban area of this study and are commonly recorded in this type of environment (Stone et al., 2015). Bats that feed on plant parts find different sources of food and shelter in cities, factors that favor their permanence in this type of environment (Bredt and Uieda, 1996). In the urban area of Goiânia there are plant species, such as *Cecropia sp.*, *Terminalia sp.*, *Ficus sp.*, *Andira sp.* and *Mangifera sp.* (Santos et al., 2006), which are important items in the diet of fruit and nectar bats. The practice of using exotic fruit trees in urban fragments may be a factor that favors the greater establishment of fruit bats in this type of area (Galetti and Morellato, 1994). Although it is common to capture insectivorous bats in urban areas (Avila-Flores and Brock Fenton, 2005), mainly species of the Molossidae family, only one individual of the species *Myotis nigricans* (Vespertilionidae) was captured. In general, Vespertilionidae bats are more associated with less degraded areas (Avila-Flores and Brock Fenton, 2005), but the species *M. nigricans* has already been widely sampled in urban environments in other cities (Perini et al., 2003; Barros et al., 2006; Oprea et al., 2009). Its presence in urban environments may be related to its ability to use artificial shelters, such as roofs of homes (Esbérard et al., 1999) and benefit from the offer of insects attracted by artificial lighting (Stone et al., 2015). High levels of urbanization result in negative consequences for most insectivorous bats (Cravens and Boyles, 2019; Damásio et al., 2021; Weier et al., 2021), therefore, few insectivorous species may have managed to establish themselves in the parks of Goiânia, reflecting the high level of urbanization around the sampled parks. In addition, new samplings with greater sampling effort and with the use of additional methods, such as ultrasound recorders, can register new species for the city of Goiânia. The low capture of insectivorous bats may have been influenced by the capture method used in this work, which is inefficient in capturing insectivores, as they easily detect nets (Mancini et al., 2022) and fly above the treetops (Muller and Reis, 1992). Hematophagous animals were recorded only in semiurban and natural areas, possibly due to the presence of cattle close to these places, a scenario that is not observed in the urban area.

The bat fauna found in the urban area of Goiânia is small, when compared with records made in other cities of the Cerrado biome, such as Uberlândia (41 species), Brasília (21 species) and Campo Grande (14 species) (Stone et al., 2015; Stutz et al., 2004; Ferreira et al., 2010), but this result may have been influenced by the lower sample effort in the present study. The bat fauna in Goiânia is composed of generalist frugivorous species, such as *Artibeus lituratus*, *Artibeus planirostris*, *Platyrrhinus lineatus* and *Carollia perspicillata* that end up benefiting from urbanization. Among several taxa, there is a substantial reduction in species richness at high levels of urbanization (Blair, 1996; Sadler et al., 2006; Hamer and McDonnell, 2008; Vergnes et al., 2014). The results obtained in this work follow this general pattern.

5. Conclusions

It is necessary for urban expansion to occur in a planned manner, to minimize the impacts of this process and ensure the maintenance of biodiversity. In this work, we provide the first list of bat species for the municipality of Goiânia, although it did not present any new occurrence for urban areas, we can strengthen the results already found for other cities in Brazil. The data provided are important to support decisions regarding the management of the bat community in the municipality of Goiânia.

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