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Bats in forest remnants of the Cerrado savanna of eastern Mato Grosso, Brazil

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Abstract: In the state of Mato Grosso, studies aiming to investigate the diversity and richness of bats are still scarce. In the present study, the chiropteran fauna of eastern Mato Grosso (Brazil) was investigated at four sites representing the Cerrado savanna biome with different degrees of anthropogenic impact, in the municipality of Nova Xavantina. Surveys were conducted between January and December, 2010, with a total of 48 nights of mist-netting. A total of 423 bats were captured, representing 25 species distributed in five families. A greater abundance of individuals was recorded at all sites during the rainy season, with considerable variation being observed over the course of the year in species richness and composition, and the abundance of bats. Species richness and bat abundance were higher in the better preserved habitats in comparison with the impacted areas. The timing of foraging activities appeared to vary among the specimens and there was a progressive increase in activity until 19:30 h, with a marked decline after 22:30 h. The ecological diversity (Shannon-Wiener index) of the bat community within the study area was $H' = 2.37$.

Keywords: *Chiroptera, conservation, species richness, diversity.*

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Resumo: No estado de Mato Grosso, os estudos visando investigar a diversidade e riqueza de morcegos ainda são escassos. Neste estudo, a quiropterofauna da região leste mato-grossense foi investigada por meio de capturas em quatro áreas remanescentes de Cerrado com diferentes índices de conservação, no município de Nova Xavantina. As capturas ocorreram de janeiro a dezembro de 2010, totalizando 48 noites de amostragem. Foram capturados 423 indivíduos, distribuídos em 25 espécies e cinco famílias. Os quatro ambientes apresentaram maior abundância na estação chuvosa e, ao longo dos meses e entre as estações do ano a composição, riqueza e abundância de morcegos variaram. As áreas mais preservadas apresentaram maior riqueza e maior abundância de morcegos em relação às áreas degradadas. Foi possível verificar que o horário de forrageamento variou entre os espécimes capturados, ocorrendo um pico crescente de atividade até às 19:30h e uma redução acentuada por volta das 22:30h. A diversidade calculada pelo índice de Shannon-Wiener (H') para as áreas foi de $H' = 2,37$.

Palavras-chave: *Chiroptera, conservação, riqueza, diversidade.*

Introduction

The Cerrado biome occupies almost a quarter (23%) of Brazilian territory (Ribeiro & Walter 2008), and is composed of a mosaic of forests, savannas and grasslands, the distribution of which are determined primarily by relief, soils, and climatic factors, the interaction of which creates a considerable diversity of habitats (Sano 2011). The biological diversity of the Cerrado is also substantial, due in part to the size of biome, although this wealth of natural resources is poorly studied in general (Chaveiro et al. 2011).

At the present time, 101 bat species are known to occur in the Brazilian Cerrado, which corresponds to almost 60% of the total number of species found in Brazil. These species belong to 42 genera distributed in eight families – Emballonuridae, Noctilionidae, Mormoopidae, Phyllostomidae, Furipteridae, Vespertilionidae, Molossidae, and Thyropteridae. The family Phyllostomidae is the most diverse, with a total of 55 species, followed by the Molossidae, with 20 species, and the Vespertilionidae, with 12 (Paglia et al. 2012, Reis et al. 2013).

Few detailed studies of the bat fauna of Mato Grosso are available, which hampers any attempt to define the true diversity of the state's bat fauna (Gonçalves & Gregorin 2004). Among the first surveys for the state are Pelzelin (1883) and Miranda-Ribeiro (1914), which recorded respectively 23 and 12 species. Up to now 84 bat species have been recorded in the state (Peracchi et al. 2011, Paglia et al. 2012, Reis et al. 2013), although these data are derived from widely-scattered localities, separated by extensive areas for which no data are available whatsoever.

In fragmented landscapes, bat communities tend to decline in abundance and species richness, and suffer considerable modifications of species composition. In particular, species with relatively restricted

geographic ranges that are relatively intolerant of habitat disturbance tend to decline and disappear under the effects of anthropogenic impacts (Granjon et al. 1996, Cosson et al. 1999). The present study analyzed the species composition and richness, and abundance of the bat species recorded in remnants of Cerrado of eastern Mato Grosso, Brazil, representing different degrees of habitat disturbance.

Material and Methods

The study area is located in the municipality of Nova Xavantina, in eastern Mato Grosso. This region corresponds to a transition zone between the Cerrado and Amazon Forest domains. Vegetation is predominantly Cerrado intercalated with extensive tracts of cerrado woodland and typical Amazon forest (Marimon-Junior & Haridasan 2005). The local climate is of Köppen's *Aw* type, with a mean annual temperature of 24 °C, and precipitation of approximately 1,500 mm (Silva et al. 2008). Nova Xavantina is considered to be a priority area for the conservation of the Cerrado, given the diversity of species found within its geographic limits (Cavalcanti 2002).

Four sites were selected for the collection of specimens in remnants of cerrado habitats characterized by different levels of anthropogenic impact (Figure 1): site 1 (14° 38' 14" S and 52° 21' 49" W) is a relatively well-preserved area of cerrado woodland; site 2 (14° 40' 23" S and 52° 19' 31" W) is an area of typical cerrado savanna with low levels of disturbance and partly surrounded by pastures; site 3 (14° 40' 12" S and 52° 21' 52" W) is typical cerrado savanna in the vicinity of the Rio das Mortes, which is suffering increasing impact from agricultural settlements, and site 4 (14° 40' 48" S and 52° 19' 31" W) is a highly degraded gallery forest surrounded by pastures and homesteads.

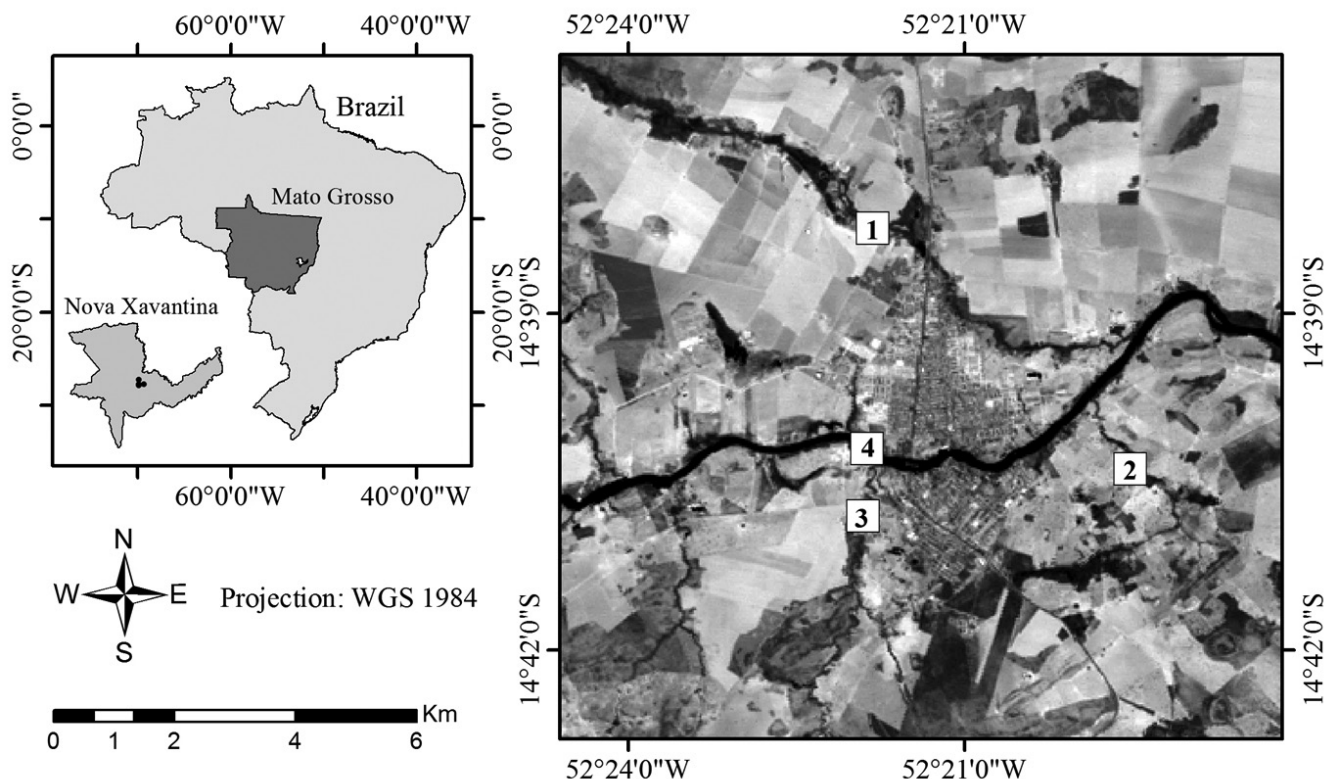


Figure 1. Map of the municipality of Nova Xavantina, state of Mato Grosso, showing the location of the four sites sampled. 1: Site 1 (14° 38' 14" S and 52° 21' 49" W), 2: Site 2 (14° 40' 23" S and 52° 19' 31" W), 3: Site 3 (14° 40' 12" S and 52° 21' 52" W) and 4: Site 4 (14° 40' 48" S and 52° 19' 31" W).

Twelve nights of sampling each site were performed between January and December, 2010, with a total of 48 nights of field work. Five mist-nets (four of 9 m × 3 m and one 12 m × 3 m, with a 20 mm mesh) were used and they were set between 18:00 h and 24:00 h, and they were monitored at 30-minute intervals for the removal of captured bats, which were placed in cotton bags. The ambient temperature was measured during each visit with an analogical thermometer.

The bats captured in the mist-nets were identified based on the specialized literature, in particular Vizotto & Taddei (1973), Eisenberg & Redford (1999), Gregorin & Taddei (2002) and Gardner (2007). The specimens that could not be identified were taken to the Nova Xavantina campus of the Mato Grosso State University (license number 18276-1 – IBAMA/SISBIO/MT) for examination in the Genetics Laboratory, and were deposited in this laboratory's chiropteran collection (collection numbers: RM 63-75; 80-86; 92-97; 102-108; 122-124; 131-137; 160-164; 181-183; 185-195; 205). In some cases, specialists were consulted in order to confirm the taxonomic identification of the specimens. Nomenclature was based on Paglia et al. (2012).

Species richness and abundance was computed for each site and season. The reliability of the estimates of species richness was evaluated using the Jackknife I richness estimator, run in the Estimates program (Colwell 2008). The Chi-square test (χ^2) was used to evaluate differences in the number of individuals captured in the rainy and dry seasons. The sampling effort was based on the proposal of Straube & Bianconi (2002). Ecological diversity was estimated using the log-based Shannon-Wiener index, or H' (Krebs 1999). All analyses were run in Microsoft Office Excel 2007.

Results

During the study, a total of 423 bats were captured, representing 25 species belonging to five families (Table 1). The Phyllostomidae was the most diverse family, with a total of 18 species (72% of the total captured), followed by the Molossidae, with three species (12%), Vespertilionidae, with two species (8%), and Emballonuridae and Mormoopidae with one species each (4%).

Species richness and bat abundance were higher in the better preserved habitats (sites 1 and 2) in comparison with the impacted areas (sites 3 and 4). The largest number of individuals (158) was captured at site 1, although the number of species (18) recorded at this site was only the second highest of the four sites. A total of 55 individuals was captured during the dry season, and 103 in the rainy season ($\chi^2 = 14.58$, d.f. = 1, $P < 0.001$), with a predominance of females ($n = 89$). The most abundant species were *Carollia perspicillata* (Linnaeus, 1758), with 36.7% of the specimens captured, *Artibeus lituratus* (Olfers, 1918), with 20.2%, *Platyrrhinus lineatus* (E. Geoffroy, 1810), with 10.1%, and *Artibeus planirostris* (Spix, 1823), with 7.6%. *Phyllostomus elongatus* (E. Geoffroy, 1810) (one male and one female) and *Vampyrus spectrum* (Linnaeus 1758) (a male) were captured only at this site in the dry season.

The highest species richness (20 species) was recorded at site 2, and the second highest number of individuals (96), of which, 34 were captured during the dry season, and 62 during the rainy season ($\chi^2 = 8.16$, d.f. = 1, $P < 0.005$), once again with a predominance of females ($n = 58$). The most abundant species were *A. lituratus*, with 20.8% of the individuals captured, *A. planirostris*, with 16.7%, *C. perspicillata*, with 16.7%, and *Molossops temminckii* (Burmeister, 1854), with 9.4%. Six species were recorded only at this site – *Chiroderma villosus* Peters, 1860, *Cynomops abrasus* (Temminck, 1872), *Lophostoma brasiliense* Peters, 1866, *Molossus molossus* (Pallas, 1766), *Uroderma bilobatum* Peters, 1866, and *Eptesicus diminutus* Osgood, 1915. In all cases, one female was captured in the rainy season, except for *U. bilobatum*, with a male

and female captured in the rainy season, and *E. diminutus*, with a female captured in the dry season.

Site 3 was characterized by the lowest species richness (10 species recorded), with 33 individuals captured during the dry season and 57 in the rainy season ($\chi^2 = 6.41$, d.f. = 1, $P < 0.01$). In all, 56 females and 34 males were captured. The most abundant species were *A. lituratus*, with 36.7% of the individuals captured, *Glossophaga soricina* (Pallas, 1766), with 12.2%, and *C. perspicillata* and *P. lineatus*, both with 11%. One species – *Rhynchonycteris naso* (Wied-Neuwied, 1820) – was recorded only at this site, with three females and a male being captured during the dry season.

Site 4 was characterized by the second lowest species richness and the lowest abundance. Eleven species were recorded, with 27 individuals being captured in the dry season, and 52 in the rainy season ($\chi^2 = 7.91$, d.f. = 1, $P < 0.005$), and once again, the majority of specimens were female ($n = 52$). The most abundant species were *P. lineatus*, with 27.8% of the individuals captured, *C. perspicillata* and *A. lituratus* with 20.2% each, and *A. planirostris*, with 12.7%. None of the species were unique to this site.

Overall, *A. lituratus* ($n = 101$) was the most abundant species, corresponding to 23.9% of the total number of individuals captured, followed closely by *C. perspicillata* ($n = 100$ or 23.6%), *P. lineatus* with 12.5% of the total ($n = 53$), *A. planirostris* with 11.1% ($n = 47$), and *G. soricina*, with 7.3% ($n = 31$) (Table 1). Together, these species represent 78.5% ($n = 332$) of the total number of individuals captured. Of the other species, which accounted for 21.5% of the records ($n = 91$), did not exceed 17 individuals (Table 1).

Total sampling effort for the four sites was 41,472 m².h. The number of species recorded during the first six months of the study period accumulated rapidly to 17, that is, with half of the total sampling effort (20,736 m².h). A further eight species were added to the inventory during the second half of the study, including three (*C. villosus*, *M. molossus*, and *U. bilobatum*) in the last three months, when more than 83% of the total sampling effort had been completed. Estimated species richness by Jackknife I was 32.3 species, which indicates that only around 77.3% of the species that occur within the study area may have been captured during the study. The cumulative species curve did reach the asymptote (Figure 2).

During the dry season (April to September), a total of 149 individuals representing 16 species were captured, increasing to 274 individuals and 20 species during the rainy season (October-

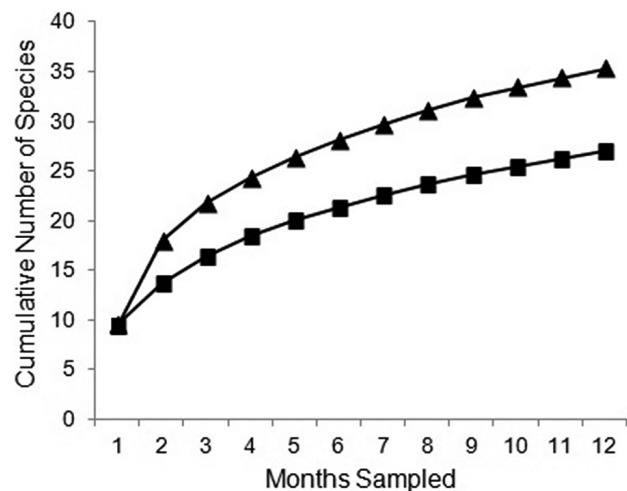


Figure 2. Accumulation curve of bats species (■) calculated using sampling effort employed during the period of capture and estimated richness (▲) by nonparametric Jackknife I estimator, between January and December 2010, at four sites representing the Cerrado savanna de Nova Xavantina, Mato Grosso.

March). Twelve species were recorded in both seasons, whereas eight were captured only during the rainy season, and five during the dry season (Table 1). The number of specimens captured increased progressively to peak at 19:30 h, and then oscillated before declining after 22:30 h (Figure 3).

Shannon-Wiener's diversity index (H') for the study area as a whole was $H' = 2.37$. Site 1 presented the highest diversity ($H' = 2.40$), while the other sites were considerably less diverse, and also more similar to one another (site 2: $H' = 2.10$; site 3: $H' = 2.03$; site 4: $H' = 2.08$).

Discussion

Inventories of bats in a number of different areas of the Cerrado have recorded between 11 and 25 species (Willig 1983, Gonçalves & Gregorin 2004, Bordignon 2006, Anacleto et al. 2008, Camargo et al. 2009, Bezerra & Marinho-Filho 2010, Ferreira et al. 2010, Zortéa et al. 2010, Silva & Anacleto 2011). The number of species recorded in the present study represents 26.2% of the total

known to occur in the Cerrado biome, and 29.8% of those recorded in Mato Grosso (Peracchi et al. 2011).

A relatively high abundance of *A. lituratus*, *C. perspicillata*, *P. lineatus*, and *G. soricina* was also recorded at a Cerrado site in Mato Grosso by Gonçalves & Gregorin (2004). Similar results were obtained in Cerrado in Minas Gerais by Knecht et al. (2005) and in Mato Grosso do Sul by Ferreira et al. (2010). In the present study, there was a tendency for diversity to be lower at the more disturbed sites, although diversity at site 2 was similar to that of the disturbed sites, due to the marked abundance of *C. perspicillata* and *A. lituratus*, which together accounted for 56% of the individuals captured.

Eight species (*A. lituratus*, *A. planirostris*, *C. perspicillata*, *M. temminckii*, *G. soricina*, *L. silvicolium*, *P. hastatus* and *P. lineatus*) occurred at all four sites, indicating their generalist habits, which enable them to adapt to the different conditions found within the study area. Of these species, only *L. silvicolium* is thought to have a preference for well-preserved habitats (Nogueira et al. 2007b), while the other species are known to inhabit forest formations,

Table 1. Bat species and number of captured individuals in the four sites sampled in remnants of the Cerrado savanna, in the municipality of Nova Xavantina, state of Mato Grosso, in the rainy season (R) and dry season (D).

Family/ Subfamily/ Species	Sites								Total	Frequency
	1		2		3		4			%
	R	D	R	D	R	D	R	D		
Emballorunidae										
<i>Rhynchonycteris naso</i> (Wied-Neuwied, 1820)	-	-	-	-	-	4	-	-	4	0.9
Molossidae										
<i>Cynomops abrasus</i> (Temminck, 1826)	-	-	1	-	-	-	-	-	1	0.2
<i>Molossops temminckii</i> (Burmeister, 1854)	2	1	8	1	4	-	1	-	17	4.0
<i>Molossus molossus</i> (Pallas, 1766)	-	-	1	-	-	-	-	-	1	0.2
Mormoopidae										
<i>Pteronotus parnellii</i> (Gray, 1843)	-	1	-	1	-	-	-	-	2	0.5
Phyllostomidae										
Desmodontinae										
<i>Desmodus rotundus</i> (E. Geoffroy, 1810)	5	4	-	1	-	-	-	1	11	2.6
Glossophaginae										
<i>Anoura caudifer</i> (E. Geoffroy, 1818)	1	-	1	-	2	-	-	-	4	0.9
<i>Glossophaga soricina</i> (Pallas, 1766)	2	5	3	4	4	7	1	5	31	7.3
<i>Lonchophylla</i> sp. Thomas, 1903	1	-	-	-	-	-	1	-	2	0.5
Phyllostominae										
<i>Lophostoma brasiliense</i> Peters, 1866	-	-	1	-	-	-	-	-	1	0.2
<i>Lophostoma silvicolium</i> d'Orbigny, 1836	1	1	1	-	4	-	-	2	9	2.1
<i>Phyllostomus discolor</i> Wagner, 1843	-	1	-	-	-	-	-	-	1	0.2
<i>Phyllostomus elongatus</i> (E. Geoffroy, 1810)	2	-	-	-	-	-	-	-	2	0.5
<i>Phyllostomus hastatus</i> (Pallas, 1767)	3	2	1	-	2	1	3	-	12	2.8
<i>Vampyrum spectrum</i> (Linnaeus, 1758)	-	1	-	-	-	-	-	-	1	0.2
Carollinae										
<i>Carollia perspicillata</i> (Linnaeus, 1758)	34	24	8	8	7	3	12	4	100	23.6
Sternodermatinae										
<i>Artibeus lituratus</i> (Olfers, 1818)	21	11	14	6	22	11	11	5	101	23.8
<i>Artibeus planirostris</i> (Spix, 1823)	12	-	14	2	8	1	9	1	47	11.1
<i>Chiroderma villosus</i> Peters, 1860	-	-	1	-	-	-	-	-	1	0.2
<i>Platyrrhinus incarum</i> (Thomas, 1912)	3	1	2	2	-	-	-	-	8	1.9
<i>Platyrrhinus lineatus</i> (E. Geoffroy, 1810)	14	2	3	2	4	6	14	8	53	12.5
<i>Sturnira lilium</i> (E. Geoffroy, 1810)	-	1	1	5	-	-	-	-	7	1.7
<i>Uroderma bilobatum</i> Peters, 1866	-	-	2	-	-	-	-	-	2	0.5
Vespertilionidae										
<i>Eptesicus diminutus</i> Osgood, 1915	-	-	-	1	-	-	-	-	1	0.2
<i>Myotis nigricans</i> (Schinz, 1821)	2	-	-	1	-	-	-	1	4	0.9
	103	55	62	34	57	33	52	27	423	100

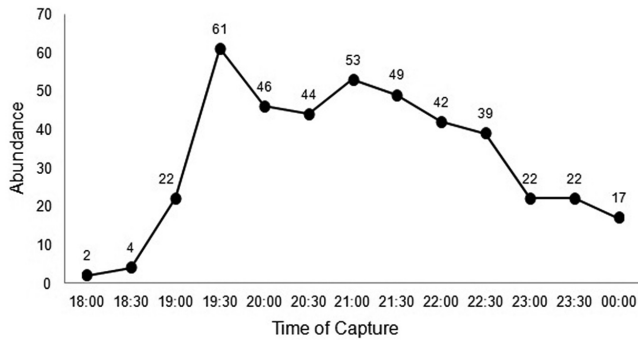


Figure 3. Number of bats captured at 30-minute intervals, during the six hours of exposure of the mist-nets in each of the 48 nights of field work, from January to December 2010, in remnants of the Cerrado savanna, in the municipality of Nova Xavantina, Mato Grosso.

tree holes, caves, and even urban areas (Ortêncio Filho et al. 2007, Nogueira et al. 2007a, b, Zortéa 2007).

Nine of the species recorded in the present study (*C. villosum*, *C. abrasus*, *P. discolor*, *P. elongatus*, *L. brasiliense*, *Platyrrhinus incarum* (Thomas, 1912), *Pteronotus parnellii* (Gray, 1843), *Sturnira lilium* (E. Geoffroy, 1810) and *V. spectrum*) were only captured in well-preserved habitats, that is, sites 1 and 2. *P. discolor* and *S. lilium* have been recorded in anthropogenic habitats (Evelyn & Styles 2003, Nogueira et al. 2007b). The other seven species are all found in primary or secondary forest (Reis & Peracchi 1987), where they may roost in tree holes and crowns, palm leaves, and cracks in rocks (Fabián & Gregorin 2007, Nogueira et al. 2007a, b, Zortéa 2007). The only species found exclusively in anthropogenic habitats was *R. naso*, although this does not appear to reflect a preference for disturbed environments, but may simply be related to the tendency for the species to be found near bodies of water (Peracchi & Nogueira 2007), given that site 3, where the species was captured, is close to the Rio das Mortes.

In the Cerrado, resources such as fruit and insects tend to increase in abundance with the onset of the rainy season (Marinho-Filho & Sazima 1998). The seasonal pattern in bat diversity and abundance recorded in the present study is typical of areas with well-defined seasons (Pedro & Taddei 1997). Bats were especially abundant between October and December, when feeding resources (fruit, nectar, and insects) tend to be more available in the Cerrado (Ribeiro & Walter 2008). Sipinski & Reis (1995), Kneigt et al. (2005), Zanon & Reis (2007), and Tomaz & Zortéa (2008) all recorded an increased abundance of bats in the rainy season.

The peak of activity observed during the first hours of the nocturnal period (and the subsequent decline in captures) in the present study is typical of the pattern recorded in most other studies, such as those of Reis (1981), Marques (1985), Reis & Peracchi (1987), Sipinski & Reis (1995) and Zanon & Reis (2007). The activity pattern of bats is related primarily to their foraging behavior, although other factors may also be important, such as the reproductive or social status of the individual, as well as intra- and inter-specific competition for feeding resources (Fleming et al. 1972). Esbérard (2003) concluded that $H' = 2.0$ was a typical value for the Shannon-Wiener index for bat communities in the Neotropical region. The value recorded in Nova Xavantina ($H' = 2.37$) is, as expected for the region, higher than the results of surveys of southern portions of the biome (Bordignon 2006, Zortéa & Alho 2008, Camargo et al. 2009, Ferreira et al. 2010, Zortéa et al. 2010). Gregorin et al. (2011) recorded $H' = 2.86$ in preserved areas of the northern Cerrado.

The data obtained in this study, which had focused on forest remnants of Cerrado, characterized by different degrees of habitat disturbance, demonstrates the importance of preserved environments in maintaining the bat fauna of the region and contribute to the knowledge of the bats in the eastern portion of the state of Mato Grosso. However, knowledge about the bat fauna of Mato Grosso is still incipient and future studies in different areas and biomes of the state may significantly increase the species richness for the Mato Grosso.

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