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Bat (Chiroptera) assemblages in three Cerrado fragments of Mato Grosso do Sul, southwestern Brazil

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Abstract: Despite its high species richness and large area, the Brazilian Cerrado is a generally undervalued and under-protected biome. There are relatively few published studies of bat assemblages in this area. We surveyed for bats using mist-nets from April–November 2013 within and around Campo Grande, Brazil in an urban fragment, an agricultural fragment, and a larger fragment of continuous forest. We captured 508 individuals from 21 species representing four families: Phyllostomidae (10), Molossidae (6), Vespertilionidae (4), and Noctilionidae (1). Phyllostomids accounted for 91.73% of captures. The most common species were *Artibeus planirostris* (27.76%), *Artibeus lituratus* (21.06%), and *Sturnira lilium* (11.61%). There was variation between the sites: richness and diversity was highest in the continuous forest and lowest in the urban fragment. Evenness was highest in the rural fragment. The least similar sites were the urban fragment and the continuous forest; similarity was greatest between the rural site and continuous forest.

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Introduction

Brazil's Cerrado is one of the most biodiverse savannas in the world, with high levels of endemism (Mendonça *et al.* 1998; Ratter *et al.* 2003), and is considered a biodiversity hotspot (Myers *et al.* 2000). At over 2 million km^2, it is the second largest biome in the country, covering almost 24% of the national territory (IBGE 2004). Despite its ecological value, it is under-protected compared to other biomes in Brazil (Ratter *et al.* 1997; Silva and Bates 2002) with less than 3% of its area legally protected and almost 55% of its original extent deforested or degraded (Machado *et al.* 2004).

Brazil is home to 174 species of bats (Paglia *et al.* 2012), 103 of which can be found in the Cerrado (Aguiar and Zortéa 2008). However, according to Bernard *et al.* (2011), only 6% of this biome has been minimally surveyed. Further, the studies within the Cerrado are not well-distributed throughout its full area (Aguiar and Zortéa 2008). In Mato Grosso do Sul in particular, studies tend to focus on the Pantanal, leaving the Cerrado understudied. Therefore, there is far more data on bats of the Pantanal than the Cerrado in this state (Cáceres *et al.* 2008).

Mato Grosso do Sul has 65 species of bats currently recorded, 49 of which can be found in the Cerrado (Cáceres *et al.* 2008; Bordignon and Santos 2010; Bordignon *et al.* 2011; Santos and Bordignon 2011; Silveira *et al.* 2011). In Campo Grande, there are records for 24 bat species, which comprise 23% of Cerrado species and 39% of bat species found in the state of Mato Grosso do Sul (Pulchério-Leite *et al.* 1999; Ferreira *et al.* 2010).

Our objective was to evaluate the species richness, abundance, and biodiversity of bats in three Cerrado fragments: one within an urban matrix in Campo Grande, one within a rural, agricultural matrix on the edge of the municipality, and a third larger fragment of continuous forest. We also calculated the evenness and dominance of each site and compared similarity in overall biodiversity and diversity within feeding guilds between sites. These data contribute to our knowledge of the bat community in the mosaic landscape of urban, agricultural and cerrado patches of Mato Grosso do Sul and the region in general.

Materials and methods

Study sites

We conducted this study in three Cerrado fragments in and around the city of Campo Grande, Mato Grosso do Sul, southwestern Brazil (Figure1). The climate is tropical wet and dry of the Köppen classification, with a dry winter and wet summer. The annual precipitation is 1500 mm and annual average temperature is 23°C (Coleti *et al.* 2007).

Within the city of Campo Grande, we sampled in a fragment of Cerrado surrounded by an urban matrix (FUrb) with an area of approximately 0.6 km^2 on the campus of the Federal University of Mato Grosso do Sul. Sampling was conducted between the coordinates 20°30′49″ S, 54°36′54″ W and 20°30′31″ S, 54°36′49″ W. The area sits at an elevation of approximately 490 m above sea level and is generally flat with a lake and a few streams. Vegetation is characterized by Cerrado *sensu stricto*, woodland with dense scrub and scattered trees, and areas of Cerradão, denser regrowth forest with a canopy at 8–15 m (Ratter *et al.* 1997; Silva and Bates 2002).

The second site was a Cerrado fragments surrounded by an agricultural matrix (FRur) with an area of approximately 3 km^2 at the periphery of Campo Grande between the coordinates 20°30′16″ S, 54°32′46″ W and 20°31′06″ S, 54°30′43″ W, with an elevation of 530–550 m above sea level. The area is divided into small rural properties that are used for recreation, cattle-ranching, and agricultural

Figure 1. Map of study areas and three sites where sampling was conducted: (1) Urban fragment (FUrb), (2) Rural fragment (FRur), (3) Fazenda Piana (FPia). Color indicates vegetation density, with darker green representing denser vegetation.

production. Most remaining vegetation is typical of the Cerradão. It also includes patches of Cerrado *sensu stricto*, and *veredas*, humid areas around small lakes (Ratter *et al*. 1997; Silva and Bates 2002). These areas of natural vegetation are small and surrounded by agricultural fields and pasture. Although the surrounding landscape is mostly agricultural, urbanization is increasing. For example, during the time of the study, the main road that turns off from the city to this rural zone was paved.

The third site is Fazenda Piana (FPia), a private reserve of approximately 6.5 km^2 connected to forested hills with an elevation of 390–490 m above sea level that extend up to 13 km from the site. The area is used for both agricultural and touristic activities; the larger landscape surrounding Fazenda Piana is primarily composed of large monoculture fields. It is located in Sidrolândia, a rural municipality about 40 km southwest of Campo Grande. 60% of FPia is covered by native Cerrado vegetation, ranging from shrubs to semideciduous forest (Ratter *et al*. 1997; Silva and Bates 2002). We sampled between the coordinates 20°48′19″ S, 54°50′36″ W and 20°47′46″ S, 54°50′42″ W. The region is part of the geological formation of the Serra de Maracaju, a chain of hills that crosses the central portion of Mato Grosso do Sul.

Data collection

Surveys were conducted twice per month from April–May and July–November 2012 at each site in the week leading up to the new moon, to reduce the interference of moonlight (Morrison 1978; Lang *et al*. 2006). Nets were opened around sunset and extended for six hours (Kunz and Kurta 1988; Bergallo *et al*. 2003). We used five mist-nets each night, totaling 1,836 m^2·h mo^{-1} of sampling effort in each site. Total sampling effort for all sites was 38,556 m^2·h (Straube and Bianconi 2002). Mist nets were placed in a variety of available habitats within the sites (*e.g.*, open areas, areas of dense shrubby vegetation, within forested areas, along forest edges, near streams or ponds), and close to possible roost sites. Each night, nets were placed in a different location within each site (Kunz and Kurta 1988; Bergallo *et al*. 2003).

Bats were removed from the mist-nets and placed in cloth holding bags. Each bat was identified by species, using external morphology, measurements, and dentition, according to Vizotto and Taddei (1973), Charles-Dominique *et al*. (2001), Gregorin and Taddei (2002), Reis *et al*. (2007) and Gardner (2008). One specimen of each species from each area was collected and deposited in the zoology collections at the Federal University of Mato Grosso do Sul as a voucher specimen following university guidelines (Appendix 1). Specimens which could not be identified in the field were also euthanized and brought to the lab for further identification. All other bats were released.

Data analysis

Calculations of the Shannon-Wiener index H′, evenness and dominance were conducted using the abundance of each species for each site in PAST (Hammer *et al.* 2001). Similarity between sites was compared using the Jaccard coefficient, calculated by hand, and the Shannon Diversity t-Test, using PAST (Hammer *et al*. 2001). We also assessed the difference in species richness and composition by feeding guild using a t-test based on species richness per guild in PAST (Hammer *et al*. 2001).

Rarefaction curves were calculated using PAST in order to estimate the completeness of our survey (Hammer *et al*. 2001). Estimates of total species richness per site and overall were calculated using the Chao 2 index classic formula with 100 randomizations in EstimateS Version 8.2.0 (Colwell 2005).

Results and Discussion

We captured a total of 508 bats: 236 in FUrb, 112 in FRur, and 160 in FPia. These represent 21 species from four families: Phyllostomidae (10), Molossidae (6), Vespertilionidae (4), and Noctilionidae (1). As is typical for studies using mist-nets, phyllostomid bats made up the largest proportion of captures (Moreno and Halffter 2001; Bergallo *et al.* 2003; Castro-Luna *et al.* 2007), accounting for 91.73%, followed by molossids (6.89%), vespertilionids (1.18%), and noctilionids (0.20%) (Table 1; Figure 2).

Species composition and richness varied between the sites. Nine species were captured in FUrb. The Shannon-Wiener diversity in this site (H′ = 1.68) was the lowest among the three, while FPia presented the highest diversity (H′ = 2.10) with 18 species captured. In FRur, 10 species were captured (Fig. 2). The value of the Shannon-Wiener index of FRur (H′ = 1.95) was closer to FPia than to FUrb.

The lowest similarity based on the Jaccard coefficient was between FPia and FUrb (J = 0.35), while similarity was greatest between FRur and FPia (J = 0.47) and slightly lower

Table 1. Abundance (N) and frequency (%) for each captured species and richness, Shannon's Diversity, evenness and dominance for total sampling effort and each site (Urban, Rural, and Piana). Species are listed in the left hand column, grouped by Family. The number of individuals per species (N) is followed by the percentage of captures it accounts for.

SPECIES	TOTAL		URBAN		RURAL		PIANA		FEEDING GUILD[1]
	N	%	N	%	N	%	N	%	
Phyllostomidae									
Artibeus planirostris (Spix, 1823)	141	27.76	60	25.42	26	23.21	55	34.38	F
Artibeus lituratus (Olfers, 1818)	107	21.06	85	36.02	15	13.39	7	4.38	F
Sturnira lilium (E. Geoffroy, 1810)	59	11.61	1	0.42	29	25.89	29	18.13	F
Carollia perspicillata (Linnaeus, 1758)	54	10.63	21	8.90	8	7.14	25	15.63	F
Glossophaga soricina (Pallas, 1766)	45	8.86	27	11.44	11	9.82	7	4.38	F
Platyrrhinus lineatus (E. Geoffroy 1810)	38	7.48	22	9.32	13	11.61	3	1.88	F
Platyrrhinus incarum (Thomas, 1912)	9	1.77	—	—	1	0.89	8	5.00	F
Chiroderma doriae (Thomas, 1891)	9	1.77	—	—	—	—	9	5.63	F
Chiroderma villosum (Peters, 1860)	3	0.59	—	—	—	—	3	1.88	F
Desmodus rotundus (E. Geoffroy, 1810)	1	0.20	—	—	—	—	1	0.63	S
Molossidae									
Nyctinomops laticaudatus (E. Geoffroy, 1805)	17	3.35	17	7.20	—	—	—	—	I
Molossops temminckii (Burmeister, 1854)	6	1.18	—	—	3	2.68	3	1.88	I
Cynomops planirostris (Peters, 1866)	6	1.18	—	—	4	3.57	2	1.25	I
Cynomops abrasus (Temminckii, 1827)	1	0.20	—	—	—	—	1	0.63	I
Molossus rufus (E. Geoffroy, 1805)	3	0.59	1	0.42	—	—	2	1.25	I
Molossus molossus (Pallas, 1766)	2	0.39	2	0.85	—	—	—	—	I
Vespertilionidae									
Myotis albescens (E. Geoffroy, 1806)	2	0.39	—	—	—	—	2	1.25	I
Myotis riparius (Handley, 1960)	1	0.20	—	—	—	—	1	0.63	I
Eptesicus furinalis (d'Orbigny, 1847)	2	0.39	—	—	2	1.79	—	—	I
Eptesicus brasiliensis (Desmarest, 1819)	1	0.20	—	—	—	—	1	0.63	I
Noctilionidae									
Noctilio leporinus (Linnaeus, 1758)	1	0.20	—	—	—	—	1	0.20	P
Total Individuals	508	100	236	46.46	112	22.05	160	31.5	
Shannon H′	2.13		1.68		1.95		2.10		
Evenness	0.40		0.59		0.71		0.45		
Dominance	0.16		0.23		0.17		0.19		

[1] Feeding guilds – F = Frugivore; I = insectivore; S = sanguivore; P = piscivore

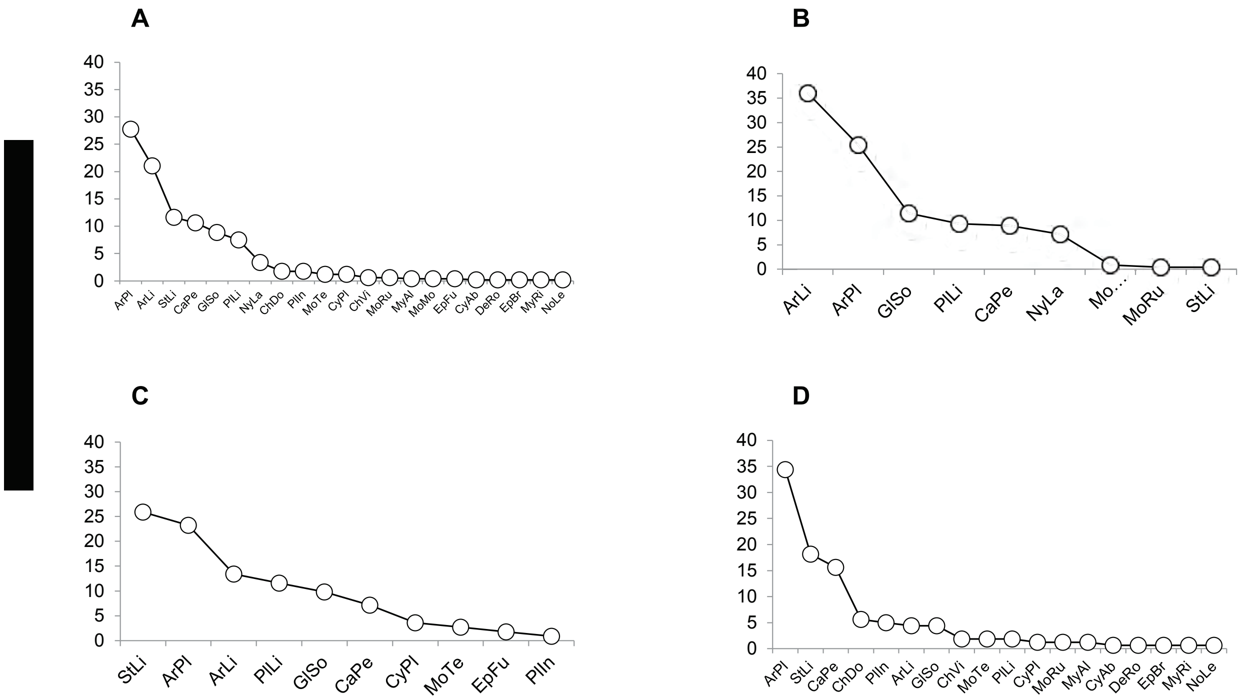

Figure 2. Relative abundance of each species calculated as the percentage of captures for (A) total sampling effort, (B) Urban fragment (FUrb), (C) Rural fragment (FRur), (D) Fazenda Piana (FPia). Abbreviations represent species names: ArLi (*A. lituratus*), ArPl (*A. planirostris*), GlSo (*G. soricina*), CaPe (*C. perspicillata*), ChDo (*C. doriae*), ChVi (*C. villosum*), CyAb (*C. abrasus*), CyPl (*C. planirostris*), DeRo (*D. rotundus*), EpBr (*E. brasiliensis*), EpFu (*E. furinalis*), MoMo (*M. molossus*), MoRu (*M.* rufus), MoTe (*M. temminckii*), MyAl (*M. albescens*), MyRi (*M. riparius*), NoLe (*N. leporinus*), NyLa (*N. laticaudatus*), PlIn (*P. incarum*), PlLi (*P. lineatus*), StLi (*S. lilium*).

between FRur and FUrb (J = 0.46). The Shannon Diversity T-test showed a significant difference in diversity between FPia and FUrb (t = 3.75, p = 0.0002) and between FUrb and FRur (t = -3.00, p = 0.003). There was no significant difference between FPia and FRur (t = 1.16, p = 0.25).

FRur had the greatest evenness (0.71) and lowest dominance (0.17) compared to FUrb (evenness = 0.59, dominance = 0.23) and FPia (evenness = 0.45, dominance = 0.19) (Table 1). This result is unusual, as previous studies have found evenness to be greatest in larger, continuous forests rather than smaller fragments (Aguirre 2002; Aguirre *et al.* 2003; Gorresen and Willig 2004; Loayza and Loiselle 2009). We can attribute this result partially to the low number of rare species (< 3 individuals) at FRur (two out of ten species captured). In contrast, FPia was home to 8 rare species, making up 44.44% of the total species richness. Further, the most common species in FRur, *Sturnira lilium* (E. Geoffrey, 1810) (25.89%) made up a smaller percentage of captures than the dominant species in either FUrb (*Artibeus lituratus* Olfers, 1818; 36.01%) or FPia (*Artibeus planirostris* Spix, 1823; 34.37%).

It is also possible that the low evenness at FPia could be partially attributed to the matrix around it. Although the chain of forested hills extends for up to 13 km around FPia, it is surrounded by a matrix of large monocultures. Large extents of homogenous monoculture can negatively affect bat species richness and diversity, even in habitat patches within these matrices (Gehrt and Chelsvig 2003; Numa *et al.* 2005).

Divided by trophic guilds, we found 10 species of insectivores, eight species of frugivores, one species of nectivore, one species of sanguivore, and one species of piscivore (Figure 3). Despite high species richness, the number of individual insectivores captured was low, while frugivores had relatively high species richness as well as a large number of individuals. There was no significant difference in species richness per guild between any of the sites (FPia and FUrb: t = 2.449, p = 0.07048; FPia and FRur: t = 2.359, p = 0.07774; FUrb and FRur: t = 1, p = 0.3739).

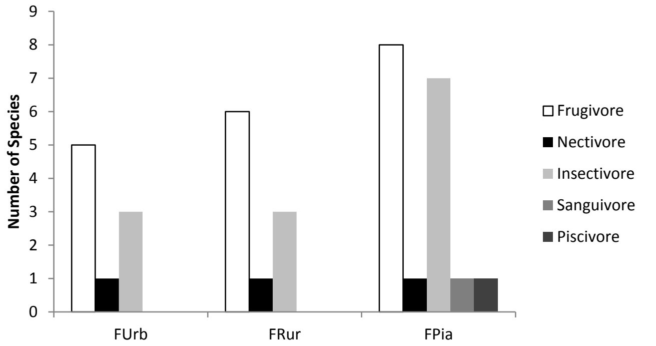

Figure 3. Species richness classified by feeding guild (frugivore, insectivore, nectivore, sanguivore, and piscivore) sampled in each site: Urban fragment (FUrb), Rural fragment (FRur), and Fazenda Piana (FPia).

The most common species in FUrb, *A. lituratus*, *A. planirostris*, and *Glossophaga soricina* (Pallas, 1766), are generalists that are common throughout Brazilian cities (*e.g.,* Bredt and Uieda 1996; Reis *et al.* 2006; Lima 2008; Oprea *et al*. 2009; Ferreira *et al*. 2010; Reis *et al*. 2012). Their high abundance may indicate the availability of resources for generalists such as roost sites and food sources from both native and exotic plant species (Sazima and Fisher 1994; Bredt and Uieda 1996; Reis *et al*. 2006; Aguiar and Marinho-Filho 2007; Lima 2008; Novaes and Nobre 2009).

Our captures of phyllostomid bats were limited to three subfamilies: Glossophaginae, Carollinae, and Stenodermatinae. The absence of individuals from the subfamily Phyllostominae, which are considered bioindicators (Fenton *et al.* 1992), may point to disturbed,

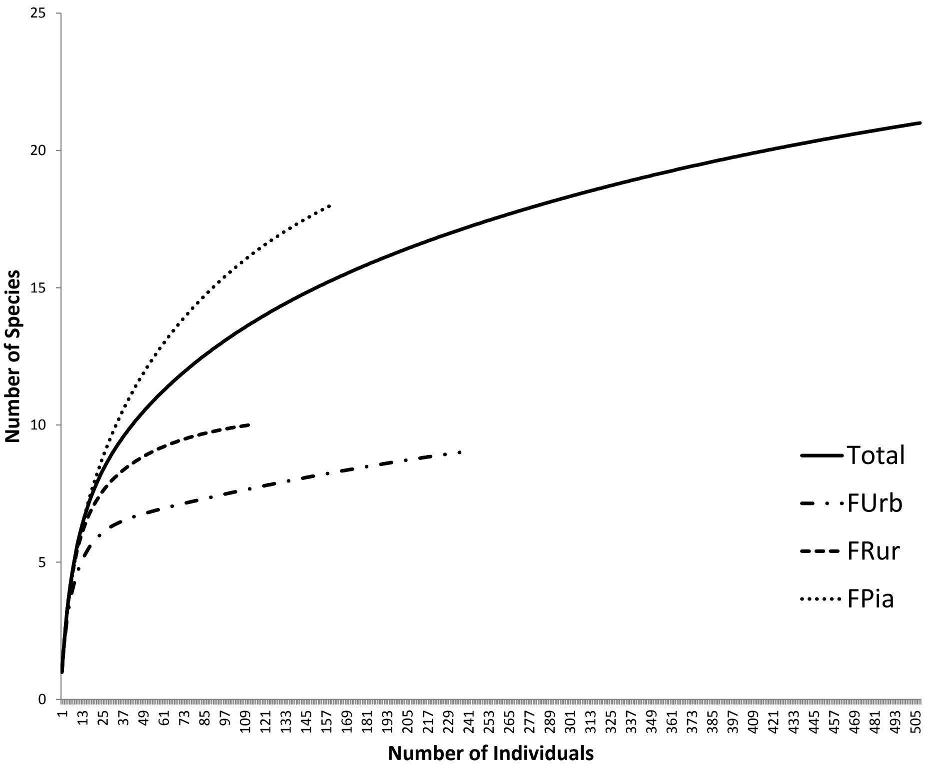

Figure 4. Rarefaction curves based on the number of individuals captured for total sampling effort (Total), Urban fragment (FUrb), Rural fragment (FRur), and Fazenda Piana (FPia).

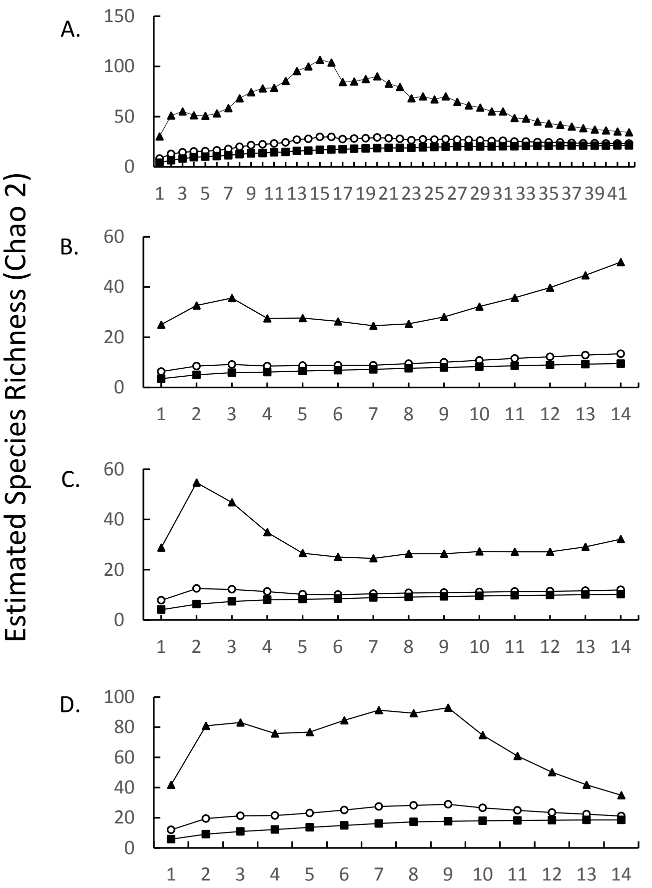

Figure 5. Variation in mean species richness (open circles) estimated by the Chao-2 index (100 randomizations) and upper (triangles) and lower (rectangles) limits with 95% confidence based on the accumulated number of capture nights for (A) total sampling effort, (B) Urban fragment (FUrb), (C) Rural fragment (FRur), (D) Fazenda Piana (FPia).

lower quality habitat, even at FPia (Fenton *et al*. 1992; Medellín *et al*. 2000). However this could also indicate the need for further sampling at this site, as the rarefaction curves have not yet reached an asymptote (Figure 4) (Moreno and Halffter 2000).

Two molossid species, *Nyctinomops laticaudatus* (E. Geoffrey, 1805) and *Molossus molossus* (Pallas, 1766), were found only in the urban site. Molossid bats are known to adapt well to urban environments due to the availability of insect prey attracted by city lights (Bredt and Uieda 1996; Avila-Flores and Fenton 2005; Reis *et al.* 2006; Lima 2008) and their ability to use artificial roosting sites such as crevices in buildings (Romano *et al.* 1999; Perini *et al*. 2003; Mendes *et al*. 2011). However, due to the difficulty of capturing insectivorous species with mist-nets (Pedro and Taddei 1997; Bergallo *et al*. 2003; Cunto and Bernard 2012), we cannot be certain of the absence of either *N. laticaudatus* or *M. molossus* at FRur or FPia.

Eight species were captured only at FPia, including two dietary specialists—*Desmodus rotundus* (E. Geoffrey, 1810) (sanguivore) and *Noctilio leporinus* (Linnaeus, 1758) (piscivore). The abundance and availability of food sources, *e.g.,* livestock for *D. rotundus* (Delpietro *et al.* 1992; Numa *et al.* 2005) and artificial lakes stocked with fish for *N. leporinus* (Zortéa and Aguiar 2001) at FPia probably contribute to the presence of these two species at this site. The large proportion of species found only at FPia (38.09%), as well as the high level of diversity (H′= 2.10), point to the importance of maintaining patches of natural habitat for the conservation of bats in the Cerrado.

The rarefaction curves for FUrb and FRur were reaching their asymptote, while the rarefaction curve was still rising steeply at FPia (Figure 4). Using nights of capture as the unit of sampling effort, the species richness estimated by the Chao 2 index was 24 (± 1.36) across all three sites, indicating the capture of approximately 87.5% of estimated species richness. The estimated species richness for FUrb (12 ± 1.69, 75%) and FRur (12 ± 1.25, 83.33%) were similar while the value for FPia was higher (21 ± 1.55, 85.71%) (Figure 5). Continued research, especially the use of acoustic monitoring and active roost searches, in addition to mist-netting, could increase the number of species recorded in all three sites (Cunto and Bernard 2012) and further contribute to our knowledge of the bat communities of the Cerrado, which is generally lacking (Bernard *et al*. 2010).

Although a lack of replicates for each habitat type prevents us from drawing general conclusions on the effect of land-use change on the bat community of the Cerrado, our results indicate that conversion of savanna habitat to urban or agricultural areas may have negative effects on bat species richness and diversity. Bats provide valuable ecosystem services: controlling insect populations, including agricultural pests, dispersing seeds, and pollinating plants, a number of which are of economic value to humans (Kalka *et al*. 2008; Williams-Guillén *et al.* 2008; Boyles *et al*. 2011; Kunz *et al*. 2011). In the Cerrado in particular, bats have been shown to be important pollinators, carrying pollen long distances between isolated tree stands (Moraes and Sebbenn, 2010). Further, by dispersing seeds, especially those of important pioneer species, phyllostomid frugivores play a role in the secondary succession and the regeneration of degraded forests (Gorresen and Willig 2004; Kelm *et al*. 2008; Kunz *et al*. 2011). Given these ecological functions and their importance for human activity, declines in bat populations and species richness are cause for concern. Further research on the effects of landscape changes on bats in the Cerrado is needed.

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Appendix 1. Bats deposited in the collection of UFMS.

Artibeus lituratus: ZUFMSMA-1565.
Artibeus planirostris: ZUFMSMA-1558, ZUFMSMA-1559, ZUFMSMA-1560, ZUFMSMA-1561.
Carollia perspicillata: ZUFMSMA-1568, ZUFMSMA-1379, ZUFMSMA-1567.
Chiroderma doriae: ZUFMSMA-1562, ZUFMSMA-1564, ZUFMSMA-1553.
Chiroderma villosum: ZUFMSMA-1552.
Desmodus rotundus: ZUFMSMA-1571.
Glossophaga soricina: ZUFMSMA-1452, ZUFMSMA-1566.
Platyrrhinus incarum: ZUFMSMA-1551.
Platyrrhinus lineatus: ZUFMSMA-1572, ZUFMSMA-1451.
Sturnira lilium: ZUFMSMA-1377, ZUFMSMA-1569, ZUFMSMA-1563, ZUFMSMA-1454 ZUFMSMA-1455.
Cynomops abrasus: ZUFMSMA-1550.
Cynomops planirostris: ZUFMSMA -1557.
Molossops temminckii: ZUFMSMA-1378.
Myotis albescens: ZUFMSMA-1453.
Myotis riparius: ZUFMSMA-1554.
Noctilio leporinus: ZUFMSMA-1570.