Bat-species richness in the Pantanal floodplain and its surrounding uplands

Alho, CJR.[a]*, *Fischer, E.*[b]*, *Oliveira-Pissini, LF.*[c]* and *Santos, CF.*[d]*

[a]Programa de Pós-graduação em Meio Ambiente e Desenvolvimento Regional, Universidade Anhanguera – Uniderp, CEP 79037-280, Campo Grande, MS, Brazil

[b]Departamento de Biologia, Centro de Ciências Biológicas e da Saúde – CCBS, Universidade Federal de Mato Grosso do Sul – UFMS, CEP 79070-900, Campo Grande, MS, Brazil

[c]Programa de Pós-graduação em Meio Ambiente e Desenvolvimento Regional, Universidade Anhanguera – Uniderp, CEP 79037-280, Campo Grande, MS, Brazil

[d]Programa de Pós-graduação em Ecologia e Conservação, Centro de Ciências Biológicas e da Saúde – CCBS, Universidade Federal de Mato Grosso do Sul – UFMS, CEP 79070-900, Campo Grande, MS, Brazil

*e-mail: alho@unb.br, eafischer@uol.com.br, larybio@yahoo.com.br, santoscaro@gmail.com

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(With 5 figures)

Abstract

We studied the bat fauna of the Pantanal floodplain and its surrounding plateaus in Mato Grosso do Sul, Brazil, based on the scientific collection at Universidade Anhanguera – Uniderp and on the *Projeto Morcegos do Pantanal* data bank at UFMS, comprising 9,037 captures of 56 species recorded from 1994 to 2007. The Pantanal surveys were carried out in the Nhecolândia, Aquidauana, Miranda, and Paraguai sub-regions; the uplands surveys took place in the Maracaju, Bodoquena, and Urucum formations. Bat specimens were mist-netted over 376 nights in 35 sites, predominantly near fruiting trees, bat shelters, and forest patches. In the floodplain 46 species were recorded (n = 6,292 individuals), and 44 species were found in the uplands (n = 2,745 individuals). Six families were recorded: Phyllostomidae (30 species), Molossidae (12 species), Verpertilionidae (nine species) Noctilionidae (two species), Emballorunidae (two species) and Mormoopidae (one species). The bat fauna was predominantly composed of insectivore (32) and frugivore (15) species. The frugivorous *Artibeus planirostris* (n = 3,101 individuals) was the commonest species in floodplain and uplands. Other common species were *Myotis nigricans* (n = 762), *Molossus molossus* (n = 692), *Noctilio albiventris* (n = 681), *Platyrrhinus lineatus* (n = 633), *Sturnira lilium* (n = 461), *Carollia perspicillata* (n = 451), *Glossophaga soricina* (n = 436), *Artibeus lituratus* (n = 320), and *Desmodus rotundus* (n = 281). In the floodplain there were three insectivores among the most common species, contrasting with the uplands dominated by the frugivores. The diversity for the 35 sites assembled (H' = 2.5) is comparable to that recorded for tropical forests. The bat fauna presented here represents 34% of the Brazilian bat species, and 62% of species reported for the Upper Paraguay River Basin. Additionally, five species are reported for the first time in Mato Grosso do Sul.

Keywords: bats, biodiversity, Chiroptera, habitats, Pantanal.

Riqueza de espécies de morcegos no Pantanal e no planalto em seu entorno

Resumo

Estudamos a fauna de morcegos na planície do Pantanal e nos planaltos de entorno no Mato Grosso do Sul, Brasil, com base na coleção científica da Universidade Anhanguera – Uniderp e no banco de dados do Projeto Morcegos do Pantanal, UFMS, incluindo 9.037 capturas de 56 espécies, entre 1994 e 2007. Amostragens no Pantanal foram feitas nas sub-regiões da Nhecolândia, Aquidauana, Miranda e Paraguai; no planalto as amostragens foram realizadas nas formações de Maracaju, Bodoquena e Urucum. Espécies de morcegos foram registradas ao longo de 376 noites em 35 sítios, predominantemente com o uso de redes de neblina próximas a árvores frutíferas, abrigos e florestas. Na planície, foram registradas 46 espécies (n = 6.292 indivíduos) e no planalto 44 espécies (n = 2.745 indivíduos). Seis famílias foram encontradas: Phyllostomidae (30 espécies), Molossidae (12 espécies), Verpertilionidae (nove espécies), Noctilionidae (duas espécies), Emballorunidae (duas espécies) e Mormoopidae (uma espécie). A fauna de morcegos foi predominantemente composta de espécies insetívoras (32) e frugívoras (15). O frugívoro *Artibeus planirostris* (n = 3.101) foi a espécie mais comum na planície e no planalto. Outras espécies comuns foram *Myotis nigricans* (n = 762), *Molossus molossus* (n = 692), *Noctilio albiventris* (n = 681), *Platyrrhinus lineatus* (n = 633), *Sturnira lilium* (n = 461), *Carollia perspicillata* (n = 451), *Glossophaga soricina* (n = 436), *Artibeus lituratus* (n = 320) e *Desmodus rotundus* (n = 281). Na planície, ocorreram três espécies de morcegos insetívoros dentre as espécies mais comuns, contrastando com o planalto, onde houve dominância de frugívoros. A diversidade para os 35 sítios reunidos (H' = 2,5) é comparável à encontrada em florestas tropicais. A fauna de morcegos apresentada aqui representa 34% das espécies brasileiras, e 62% das espécies já reportadas para a Bacia do Alto Paraguai. Adicionalmente, cinco espécies são reportadas pela primeira vez no Mato Grosso do Sul.

Palavras-chave: morcegos, biodiversidade, quirópteros, hábitats, Pantanal.

1. Introduction

Bats are often the most species-rich mammalian taxonomic group in the tropics (Patterson et al., 2001) and represent nearly one-third of Brazilian land fauna (Marinho-Filho and Sazima, 1998). Different studies have shown latitudinal gradients contributing to the understanding of geographic distribution of bat diversity, by analysis of species richness patterns on a large scale, across wide spatial areas or with regional focus (Rohde, 1992; Willig, 2000; Stevens and Willig, 2002). Another approach is to examine changes in species richness along environmental gradients, when an assemblage of interacting bat species utilizes the same resource, for example seasonal productivity, which is carried out on smaller spatial scales (Alho, 2008; Drobner et al., 1998; Wilsey and Potvin, 2000). Some environmental factors limit the occurrence and abundance of some species, including habitat heterogeneity, seasonality and conservation status (Alho, 2005; Keddy et al., 2009).

Bat communities exhibit a variety of functional groups (guilds) such as insectivores, frugivores, nectarivores, sanguivores and piscivores (Stevens and Willig, 2002). Some studies have shown these bat assemblages in different areas: trophic relations in the Phyllostomidae from Panga Reserve, southeastern Brazil (Pedro and Taddei, 1997); bat community structure in a south-east Brazilian reserve in a transition zone between Cerrado and Atlantic Forest (Falcão et al., 2003); diversity of a Cerrado habitat in central Brazil (Zortéa and Alho, 2008). Recent literature has synthesised the number of species and distribution in Brazil (Reis et al., 2007), as well as a bat community in a savanna habitat in Bolivia, near the Pantanal (Willig et al., 2000; Aguirre, 2002). Available data on bats of the Pantanal floodplain and its neighbouring uplands, particularly from Mato Grosso do Sul state, are reported in Leite et al. (1998, 2000), Taddei et al. (2000, 2001, 2003), Camargo and Fischer (2005), Gonçalves et al. (2007), Longo et al. (2007), Camargo et al. (2009), Cunha et al. (2009), and Teixeira et al. (2009).

Large and environmentally heterogeneous wetlands like the Pantanal (147,574 km² - latitude 15° 30'-22° 30' S and longitude 54° 45'-58° 30' W), exhibiting annual changes in evenness along environmental gradients, play an important role in biological diversity, because of the heterogeneity of natural habitats, offering opportunities for feeding and reproductive niches (Alho, 2008; Keddy et al., 2009). Differences in bat species abundance may respond to local environmental annual changes or to degree of habitat degradation. Because the Pantanal and its surrounding habitats harbour a large number of bat species, some common (high abundance) and some relatively rare, intensive survey efforts are needed to estimate confidently the species abundance distributions.

The aim of this study is to show the magnitude of the bat species richness and the structure of the community, evaluating relative abundance and trophic distribution within the Pantanal floodplain and throughout its surrounding Cerrado plateaus, as well as to discuss the present status of natural habitat conservation and their bat-associated species.

2. Methods

2.1. Study sites

2.1.1. Pantanal flood plain and surrounding uplands

The maze of fluctuating water levels, nutrients, and biota in the Pantanal forms a dynamic ecosystem (Alho, 2008). The degree of inundation creates a range of major habitats. Flooding occupies about 80% of the whole Pantanal. In contrast, during the dry season, most of the flooded areas stay dry, when the water returns to the river beds or evaporates. Major habitats include patches (~ 0.5-5 ha) of semi-deciduous forests (*capões*) surrounded by grasslands, belts of *cerradão* or semi-deciduous forests surrounding lagoons (*cordilheiras*), riparian semi-deciduous forests, and mono-specific forests of woody species such as *Tabebuia aurea* (*paratudal*) and *Vochysia divergens* (*cambarazal*) (Silva et al., 2000; Araújo and Sazima, 2003). The upper ground (where there are *capões* and *cordilheiras*) is at most only a couple of metres above average water level. Rivers and depressions locally known as *corixos* are lined by riparian forests. In these forest habitats, different species of *Ficus* and other trees serve as food supply and shelter for frugivores (Teixeira et al., 2009). The uplands surrounding the Pantanal are covered by senso strictu *cerrado*, *cerradão* and semi-deciduous forests, which are severely threatened by agriculture and cattle ranching (Alho, 2008; Scariot et al., 2005). Bats were sampled in 35 sites in the Pantanal floodplain and its bordering plateaus, as described below.

2.1.2. Pantanal sampling sites

Field work was carried out in 19 sites (Figure 1) in different Pantanal sub-regions and municipalities (see Silva and Abdon, 1998). In the Pantanal sub-region of *Pantanal da Nhecolândia* eight sites were sampled: Fazenda Nhumirim (18° 59' 6.93" S and 56° 37' 24.37" W), Fazenda Arara Azul (19° 23' 41.37" S and 57° 1' 43.11" W), Fazenda Guanabara (18° 14' 6.5" S and 55° 45' 0.9" W), Fazenda Campo Neta (18° 45' 38.8" S and 56° 17' 48.3" W), Fazenda Santa Terezinha (19° 22' 38.5" S and 56° 3' 20.5" W), Fazenda Baía das Pedras (19° 18' 9.78" S and 55° 47' 0.44" W), Fazenda Mangabal (19° 2' 27.91" S and 55° 49' 43.97" W), and Fazenda Barra Mansa (19° 36' 0.94" S and 56° 4' 36.31" W). In the sub-region of *Pantanal de Aquidauana* seven sites were sampled: Fazenda Conquista (19° 18' 15.54" S and 55° 14' 40.38" W), Fazenda Santa Maria (19° 19' 47.48" S and 55° 22' 50.62" W), Fazenda Olhos D'água (19° 26' 0.52" S and 55° 12' 8.71" W), Fazenda Santa Emília (19° 30' 23.24" S and 55° 36' 46.10" W), Estância Caiman (19° 57' 56'' S and 56° 18' 37'' W), Fazenda Guaicurus (20° 4' 49.96" S and 56° 28' 55.05" W), and Fazenda Santana (19° 37' 51'' S and 55° 40' 36'' W). In the sub-region of *Pantanal do Miranda* three sites were sampled: Fazenda São Bento (19° 33'

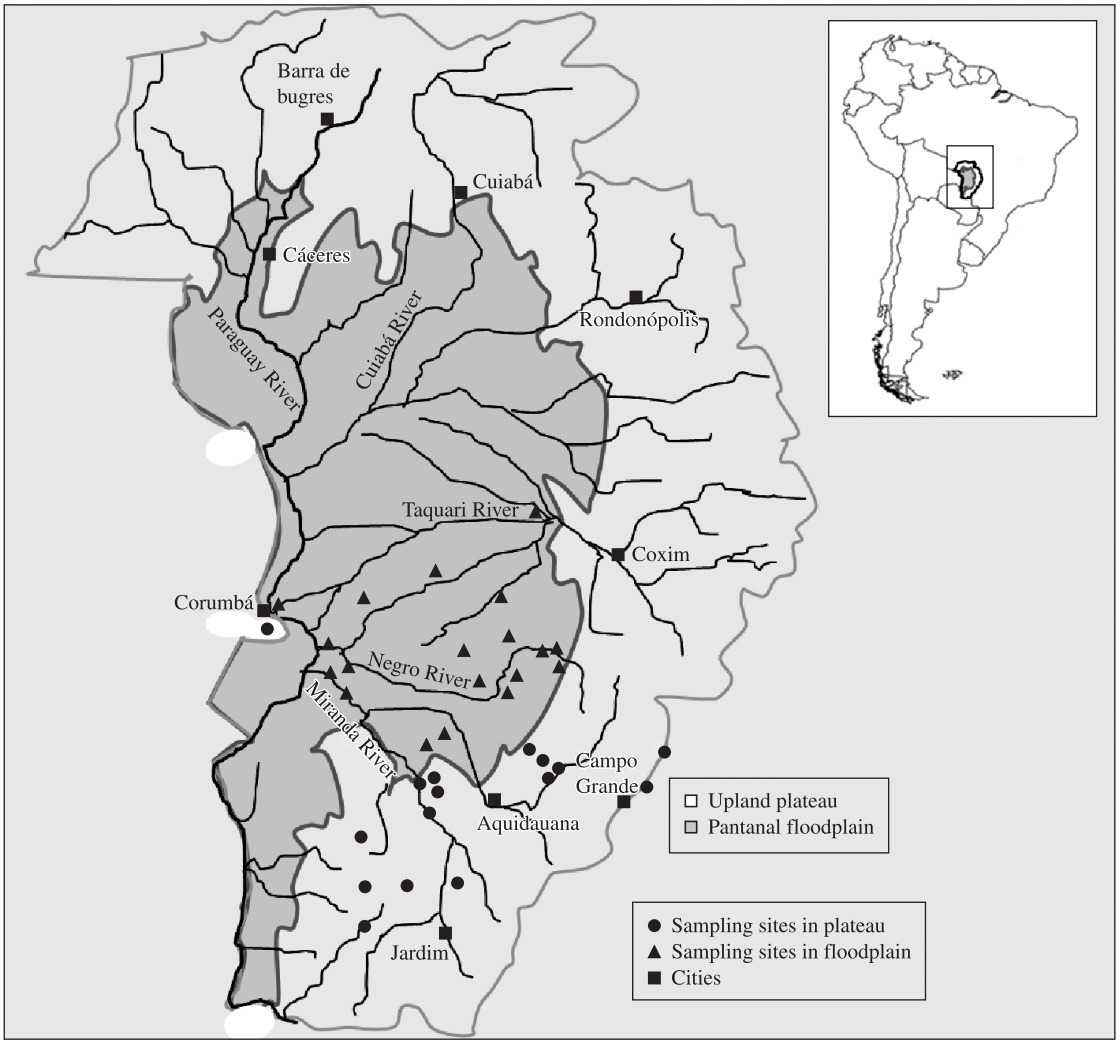

Figure 1. Sampling sites in the Pantanal floodplain (triangles) and in the neighbouring Cerrado upland plateaus (black circles), and cities (grey circles) in Mato Grosso do Sul, Brazil.

40.35" S and 57° 1' 29.44" W), Fazenda Santa Clara (19° 27' 44.10" S and 57° 4' 30.39" W), and Fazenda Sagrado (19° 25' 56.30" S and 57° 1' 40.81" W). In the sub-region of *Pantanal do Paraguai* there was one site: Fazenda Corumbá (19° 0' 35.36" S and 57° 39' 17.08" W).

2.1.3. Upland plateau sampling sites

Samplings comprised 16 sites in the plateau (Figure 1). In the Maracaju uplands there were six sites: Fazenda Furnas D'água (20° 9' 29.38" S and 55° 24' 16.02" W), Distrito de Camisão (20° 17' 11.28" S and 55° 23' 2.07" W), Distrito de Piraputanga (20° 16' 38.03" S and 55° 18' 18.54" W), Fazenda Vista Alegre (20° 5' 55.13" S and 54° 27' 26.67" W), Município de Campo Grande (20° 27' 4.58" S and 54° 36' 57.38" W), Fazenda Taboco (20° 3' 36" S and 55° 36' 20" W). In the Bodoquena uplands there were nine sites: Fazenda Campina Grande (20° 21' 22.32" S and 56° 22' 25.90" W), Fazenda Dona Benedita (20° 20' 44.78" S and 56° 26' 13.12" W), Fazenda São Cristóvão (20° 20' 16.93" S and 56° 22' 55.48" W), Fazenda São Vicente (20° 31' 25.37" S and 56° 24' 56.63" W), Fazenda Santa Tereza (21° 5' 14.27" S and 56° 3' 10.63" W), Fazenda Campo Verde (21º 24' 48.23'' S and 56º 46' 32.12'' W), Fazenda Harmonia (21° 7' 39.31" S and 56° 45' 42.04" W), Fazenda Rancho Branco (20° 41' 17.62" S and 56° 46' 42.40" W), Bonito (21° 7' 38.46" S and 56° 29' 13.68" W). In the Maciço do Urucum uplands there was one site (19° 18' 52.42" S and 57° 36' 12.19" W).

2.2. Samplings and analyses

This study relies on the bat scientific collection organised by Dr. Valdir Antônio Taddei at Universidade Anhanguera – Uniderp, Campo Grande, MS, between 1994 and 2006, with 4,239 bat specimens collected through

different procedures, predominantly straightforward mist-net surveys, and on the *Projeto Morcegos do Pantanal* databank at UFMS, Campo Grande, MS, with 4,798 bat entries through mist-net captures between 1998 and 2007. Surveys covered different hydrological seasons of the Pantanal and its surroundings in different habitats, near fruiting trees, bat shelters, or forest canopies. Total capture effort was about 290,000 h.m^2 (time in which nets were kept open multiplied by the area of the nets), distributed throughout 376 nights, with four to 12 nets of variable sizes open per night. Biometrical data were obtained and voucher specimens were prepared for identification, which followed the criteria established by Vizotto and Taddei (1973), Taddei (1983), Anderson (1997), Lopez-González et al. (2001), Gregorin and Taddei (2002), Vicente et al. (2005), and Reis et al. (2006, 2007).

3. Results and Discussion

3.1. Bat fauna in south Pantanal and surrounding uplands

In all 35 sites 9,037 individuals belonging to 56 species, 36 genera and six families were recorded (Table 1). This number of species represents 34% of the whole richness of bats in Brazil, including the Amazon, annotated by Reis et al. (2006, 2007); it reaches 62% of the total richness reported for the entire Upper Paraguay River Basin (n = 90 bat species), including the northern area in Mato Grosso, Brazil, and the Bolivian and Paraguayan areas (Tomas et al., 2009). In the floodplain sites, 6,292 individuals of 46 species were captured, a number which reaches 64% of the bat species already registered in the whole Pantanal floodplain (Tomas et al., 2009; Alho et al., 2003); in the upland sites surrounding the Pantanal 2,745 individuals of 44 species were recorded, representing 65% of the bat species already reported to occur along the entire Pantanal borders (Tomas et al., 2009). The large number of captures and the cumulative curve of species captured (Figure 2), throughout a relatively long period of time dedicated to survey (1994-2007), indicate that overall species richness was well sampled and that this is a reliable representation of bat diversity in the focal region. In addition, five species found here – *Diphylla ecaudata*, *Mimon bennettii*, *Trachops cirrhosus*, *Uroderma magnirostrum*, and *Molossus pretiosus* – were still not reported for Mato Grosso do Sul (Cáceres et al., 2008), increasing to 66 the number of bat species registered in this state.

The richest and most abundant families in our 35 study sites were Phyllostomidae (30 species and 6,228 individuals) and Molossidae (12 species and 1,071 individuals) (Table 1), corresponding to 34% and 46% of the Brazilian species in these two families respectively (Gregorin and Taddei, 2002; Reis et al., 2006, 2007). Richness of molossid bats (all insectivorous) in the floodplain (n = 11) was almost twice that in the upland plateaus (n = 6), largely contributing to the high number of insectivorous species exclusively found in the floodplain rather than in plateaus (Figure 3). Otherwise, the number of phyllostomid species in plateaus (n = 27) was slightly higher than in the floodplain (n = 23), contributing to the increased number of exclusively frugivorous species in the plateaus (Figure 3). Although phyllostomids were richer in plateaus, the subfamily Phyllostominae presented more species in the floodplain; and it included all the insectivorous bats among phyllostomid species. Therefore, insectivory appears to be a trait which favours the occurrence of bat species in the floodplain. Indeed, even the frugivorous phyllostomids feed on insects proportionally more in the Pantanal floodplain than in its bordering plateaus or elsewhere (Munin, 2008; Teixeira et al., 2009). Diets toward insectivory might be partially explained because insects are available throughout the year, and massively during several months, whereas bat fruit sources are markedly seasonal and poor in the Pantanal floodplain (Munin, 2008; Teixeira et al., 2009).

Artibeus planirostris (n = 3,101 individuals) was by far the most dominant bat species throughout the entire focal region (Figure 4), showing one order of magnitude more captures than the next nine highly common species – *Myotis nigricans* (n = 762), *Molossus molossus* (n = 692), *Noctilio albiventris* (n = 681), *Platyrrhinus lineatus* (n = 633), *Sturnira lilium* (n = 461), *Carollia perspicillata* (n = 451), *Glossophaga soricina* (n = 436), *Artibeus lituratus* (n = 320), and *Desmodus rotundus* (n = 281). Such strong dominance of *A. planirostris* has been also reported in other local surveys in the Pantanal floodplain and in its neighbouring upland regions (Camargo, 2003; Camargo et al., 2009; Cunha et al., 2009; Teixeira et al., 2009). Although the dominance by *A. planirostris* occurred in both regions, in the Pantanal floodplain there were three insectivorous non-phyllostomid species (*Myotis nigricans*, *Noctilio albiventris*, and *Molossus molossus*) among the most common bats, contrasting with the upland plateaus where the commonest species were all frugivorous phyllostomids (Figure 4). The frugivorous *C. perspicillata* was the second most abundant species in the uplands, but it was not one of the top ten species in the floodplain (Figure 4). Thus, the relative abundance of insectivorous bats appears to be higher in the floodplain than in the uplands, probably for the same reasons which explain the exceptionally high richness of insectivores as discussed above. Calculated values for the Shannon index of diversity were similar between the Pantanal floodplain (H' = 2.3) and its neighbouring uplands (H' = 2.5). Assembling all the 35 sampling sites, diversity was found to be H' = 2.5. These values are higher than those (H' = 1.5 to 1.8) found in short-term surveys in the Bodoquena region (Camargo et al., 2009; Cunha et al., 2009), and closer to values (H' = 1.8 to 2.3) found for different areas in the Atlantic forest in southeastern Brazil (Pedro and Taddei, 1997; Esbérard, 2003).

In pockets of *cerrado* habitats the most abundant species are *Artibeus planirostris* (n = 431), *Noctilio albiventris* (n = 381) and *Molossus molossus* (n = 362). In fragments of semi-deciduous and deciduous forest on plateaus on the outskirts of the Pantanal the common species are: *Myotis nigricans* (n = 489), *Noctilio albiventris* (n = 168)

Table 1. Number of surveyed individuals from 1995 to 2007 and feeding niche of 56 bat species in the Pantanal floodplain and its surrounding upland plateaus, Mato Grosso do Sul, Brazil.

Family / Species	Number of individuals			Feeding niche
	Flood plain	Plateau	∑	
Phyllostomidae	3856	2372	6228	
Artibeus planirostris (Spix, 1823)	2335	766	3101	Frugivore
Platyrrhinus lineatus (E. Geoffroy, 1810)	382	251	633	Frugivore
Sturnira lilium (E.Geoffroy, 1810)	199	262	461	Frugivore
Carollia perspicillata (Linnaeus, 1758)	87	364	451	Frugivore
Glossophaga soricina (Pallas, 1766)	225	211	436	Nectarivore
Artibeus lituratus (Olfers, 1818)	177	143	320	Frugivore
Desmodus rotundus (E. Geoffroy, 1810)	190	91	281	Sanguivore
Anoura geoffroyi Gray, 1838	0	124	124	Nectarivore
Lophostoma silvicolum d'Orbigny, 1836	84	13	97	Insectivore
Phyllostomus hastatus (Pallas, 1767)	59	30	89	Frugivore
Anoura caudifer (E. Geoffroy, 1818)	1	57	58	Nectarivore
Phyllostomus discolor Wagner, 1843	39	7	46	Frugivore
Chrotopterus auritus (Peters, 1856)	21	12	33	Carnivore
Platyrrhinus helleri (Peters, 1866)	8	10	18	Frugivore
Diaemus youngi (Jentink, 1893)	16	0	16	Sanguivore
Lophostoma brasiliense Peters, 1866	9	2	11	Insectivore
Mimon bennettii (Gray, 1838)	7	4	11	Insectivore
Vampyressa pusilla (Wagner, 1843)	2	5	7	Frugivore
Chiroderma villosum Peters, 1860	5	1	6	Frugivore
Chiroderma doriae Thomas, 1891	2	3	5	Frugivore
Mimon crenulatum (E. Geoffroy, 1810)	5	0	5	Insectivore
Tonatia bidens (Spix, 1823)	1	4	5	Insectivore
Micronycteris minuta (Gervais, 1856)	1	3	4	Insectivore
Phylloderma stenops Peters, 1865	0	3	3	Frugivore
Uroderma magnirostrum Davis, 1868	0	2	2	Frugivore
Diphylla ecaudata Spix, 1823	0	1	1	Sanguivore
Macrophyllum macrophyllum Schinz, 1821	0	1	1	Insectivore
Pygoderma bilabiatum (Wagner, 1843)	0	1	1	Frugivore
Trachops cirrhosus (Spix, 1823)	0	1	1	Carnivore
Vampyrodes caraccioli (Thomas, 1889)	1	0	1	Frugivore
Molossidae	833	238	1071	
Molossus molossus (Pallas, 1766)	602	90	692	Insectivore
Molossus rufus E.Geoffroy Saint-Hilaire, 1805	4	84	88	Insectivore
Molossops temminckii (Burmeister, 1854)	50	21	71	Insectivore
Cynomops abrasus (Temminck, 1827)	42	0	42	Insectivore
Eumops auripendulus (Shaw, 1800)	34	6	40	Insectivore
Molossus pretiosus Miller, 1902	39	0	39	Insectivore
Nyctinomops macrotis (Gray, 1840)	0	28	28	Insectivore
Promops centralis Thomas, 1915	26	0	26	Insectivore
Cynomops planirostris (Peters, 1865)	21	0	21	Insectivore
Eumops glaucinus (Wagner, 1843)	11	0	11	Insectivore
Nyctinomops laticaudatus (E.Geoffroy Saint-Hilaire, 1805	1	9	10	Insectivore
Promops nasutus (Spix, 1823)	3	0	3	Insectivore

Table 1. Continued...

Family / Species	Number of individuals			Feeding niche
	Flood plain	Plateau	Σ	
Vespertilionidae	895	92	987	
Myotis nigricans (Schinz, 1821)	712	50	762	Insectivore
Myotis albescens (E. Geoffroy, 1906)	109	7	116	Insectivore
Eptesicus furinalis (d'Orbigny and Gervais, 1847)	15	21	36	Insectivore
Lasiurus ega (Gervais, 1856)	22	1	23	Insectivore
Myotis riparius Handley, 1960	15	4	19	Insectivore
Myotis simus (Thomas, 1901)	18	0	18	Insectivore
Lasiurus blossevillii (Lesson and Garnot, 1826)	0	7	7	Insectivore
Eptesicus brasiliensis (Desmarest, 1819)	3	1	4	Insectivore
Lasiurus cinereus (Beauvois, 1796)	1	1	2	Insectivore
Noctilionidae	690	41	731	
Noctilio albiventris Desmarest, 1818	641	40	681	Insectivore
Noctilio leporinus (Linnaeus, 1758)	49	1	50	Piscivore
Emballonuridae	18	0	18	
Rynchonycteris naso (Wied-Neuwied, 1820)	13	0	13	Insectivore
Peropteryx macrotis (Wagner, 1843)	5	0	5	Insectivore
Mormoopidae	0	2	2	
Pteronotus parnellii (Gray, 1843)	0	2	2	Insectivore
Σ	6292	2745	9037	

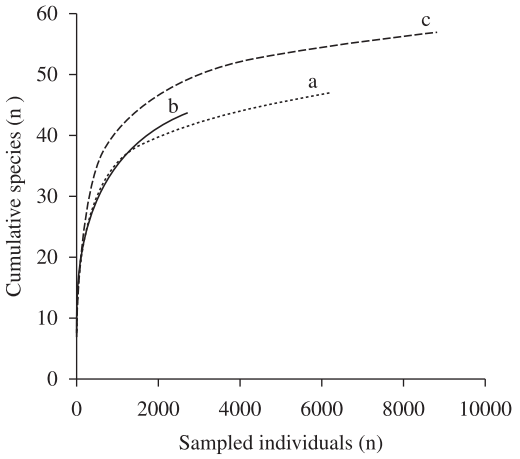

Figure 2. Rarefaction curves for bats sampled in 19 sites in the Pantanal floodplain (a), and in 16 sites in the surrounding upland plateaus (b), in Mato Grosso do Sul, Brazil. The upper curve refers to all these 35 sites assembled (c).

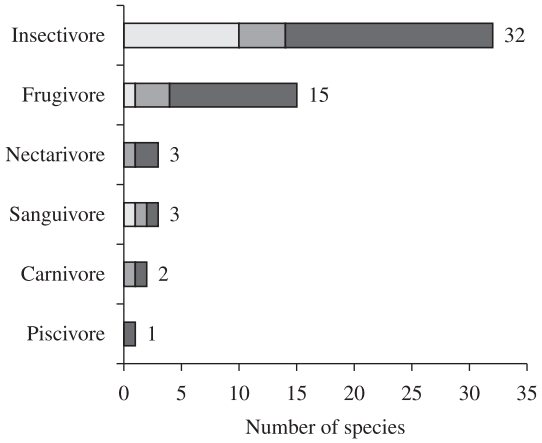

Figure 3. Richness of bats according to feeding niche, based on 9,037 individuals examined belonging to 56 species, in the Pantanal floodplain and in its neighbouring upland plateaus, Mato Grosso do Sul, Brazil. Light grey bars indicate species exclusive to the floodplain, grey bars species only found in plateau, and dark grey bars those occurring in both floodplain and plateau.

and *Molossus molossus* (n = 155). In disturbed areas, near the houses of cattle ranchers, the common species are: *Carollia perspicillata* (n = 129), *Molossus molossus* (n = 125) and *Artibeus planirostris* (n = 97). Figure 5 shows the distribution of the species within three major kinds of habitats: *Cerrado*, disturbed habitats and semi-deciduous forest of plateaus. On the other hand, 24 rare species were detected, such as *Chiroderma doriae, Chrotopterus auritus*, and *Artibeus lituratus* (Table 1). *Chiroderma doriae* is a species which requires habitat integrity and so

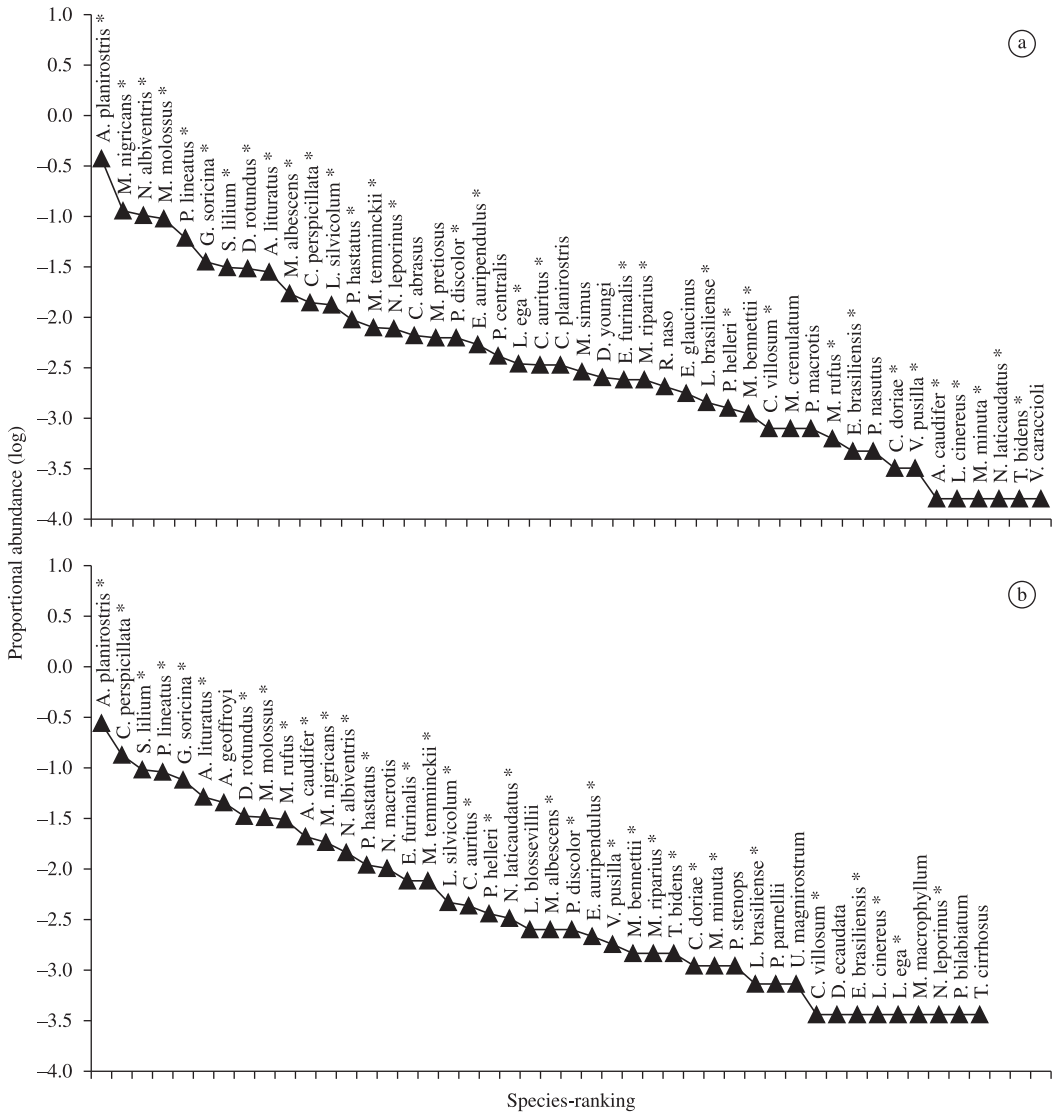

Figure 4. Rank abundance distribution of 56 species of bats in a) the Pantanal floodplain and b) its surrounding upland plateaus in Mato Grosso do Sul, Brazil. Asterisks indicate species which were recorded in both the floodplain and uplands.

is sensitive to disturbance. Some authors (Bergallo et al., 2000) consider this species as threatened by extinction, but it is not listed in the "Livro Vermelho da Fauna Brasileira Ameaçada de Extinção [The Red Book of Brazilian Fauna under Threat of Extinction]", published by the Ministry for the Environment (Ministério do Meio Ambiente) in 2008. No species found in our survey for the Pantanal is officially listed as threatened. *Chrotopterus auritus* is a large carnivore/insectivore, preying on small mammals, birds and insects, which is very sensitive to environmental disturbance, requiring good forest habitats and shelter in caves. *Artibeus lituratus* was recorded at only 1.5% in our study, but it is a good coloniser of disturbed habitat, besides living in low densities. The survey conducted in the region of Aporé-Sucuriú, northern Mato Grosso do Sul, revealed that the most caught family was Phyllostomidae, represented by *Glossophaga soricina* and *Artibeus lituratus;* and some rare species such as *Lophostoma brasiliense*, *Lonchophylla mordax* and *Lionycteris spurrelli* (Bordignon, 2006).

To analyse possible grouping of species or assemblages in the three major habitats, we performed a non-metric multi-dimensional scaling analysis taking the frequencies of species distribution, and found that the grouping composed of *Myotis albescens, Molossops temminckii, Sturnira lilium, Phyllostomus hastatus, Desmodus rotundus, Glossophaga soricina, Carollia perspicillata, Platyrrhinus lineatus, Molossus molossus, Artibeus planirostris* and *Noctilio albiventris* occurs in the three major habitats: *cerrado*, semi-deciduous forest and disturbed habitats (with 82% of similarity).

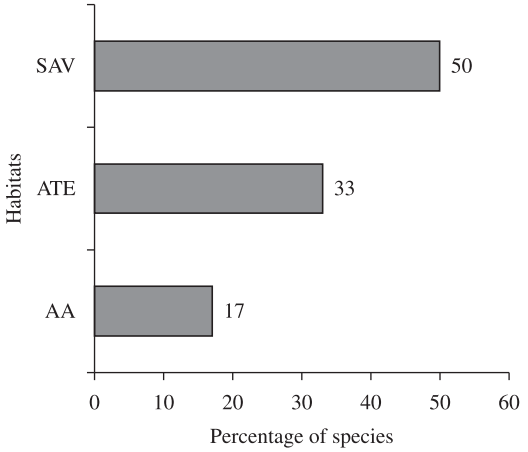

Figure 5. Distribution of the bat species in three major habitats in Mato Grosso do Sul, Brazil. SAV: savanna or Cerrado; AA: disturbed areas near ranches and other human occupation; and ATE: the ecotone zone between the floodplain and the upland "planalto", covered by semi-deciduous forest.

3.2. Bat species as bio-indicator

The Pantanal is undoubtedly an important domain and therefore deserves comprehensive ecosystem studies. Our present information on bat species richness and assemblages, considering such abundant sampling data, contributes to making a more general interpretation of species magnitude for conservation purposes. Bat species, for example, can serve as indicators for habitat quality. Natural habitats of the Pantanal have been disrupted by non-sustainable practices of socio-economic development, mainly by conversion of natural vegetation to pastures for cattle ranching and agriculture (Alho, 2008). Farms have been established in the floodplain and in its surrounding uplands, where much of the natural vegetation has been converted to soybean plantations or to other human activities. Studies concluded that 17% of the Pantanal has been deforested through the use of fire (mainly *cerrado* patches or "*capões de cerrado*"), with an annual rate of deforestation of 2.3%; and 63% of the natural vegetation cover of the surrounding plateaus in the Planalto (savanna woodland and semi-deciduous forests) has been destroyed (Harris et al., 2005). Deforestation between1976 and 2008 in the Pantanal floodplain increased 26.5 times (12.14%), compared to 40.97% of deforestation within the Upper Paraguay basin (Silva et al., 2010).

In pastures continuously used for cattle ranching, the dominance of *A. planirostris* in the bat assemblages is higher than in areas used intermittently by cattle (C. Santos, unpublished data), indicating that cattle ranching may cause a reduction in bat diversity. In addition, fire events seem to promote changes in bat species composition. *Artibeus planirostris* has been found to be the most abundant bat in both burned and unburned sites in the floodplain; however, after fire, the insectivorous phyllostomine bats increase in abundance, whereas the abundance of frugivorous stenodermatines and nectarivorous glossophagines decreases (C. Santos, unpublished data).

Our data show a high number of Phyllostomidae, which may represent a good indicator for low levels of habitat disturbance (Pedro at al., 1995; Pedro, 1998; Medellín et al., 2000). This family is well diversified in number of species and in feeding habits. The high number of frugivore species in the family implies that the habitats support a high number of fruit-bearing trees (see Pott and Pott, 1994). In addition, the high primary production favours an increased abundance of arthropods, which supports the guild of insectivore bats. The abundance of frugivore species reflects the importance of this guild for the Pantanal bat assemblages. In addition, bats play an important role in regulating the Pantanal ecosystem as seed dispersers, pollinators and regulators of insect populations (Gonçalves et al., 2007; Munin, 2008; Teixeira et al., 2009). Given that some bat species or bat assemblages require pristine habitat conditions while others are opportunistic, taking advantage of some disturbance, the group should be more studied as an indicator of levels of change in the natural environment. Drastic human alteration in natural habitats may result in simplifying bat diversity and assemblage, since those species which require more specific items in feeding strategy tend to disappear, while those with a wide spectrum of feeding habits, such as insectivore-omnivore and frugivore-omnivore, are generally less affected by environmental changes.

Effects of forest fragmentation on frugivore and nectarivore species have been pointed out in French Guiana (Cossons, 1999). The role of frugivorous bats has been emphasised in tropical forest succession (Muscarella and Flemming, 2007). Overall, Phyllostomid bats have been identified as indicators of habitat disruption in the Neotropics (Fenton et al., 1992). Work conducted in forest habitats of Paraguay has shown that abundance was highest for *Artibeus lituratus* in deforested landscapes and for *Chrotopterus auritus* in forested habitats; in contrast, *Artibeus fimbriatus*, *Carollia perspicillata*, *Glossophaga soricina*, *Platyrrhinus lineatus*, *Pygoderma bilabiatum*, and *Sturnira lilium* attained highest abundance in moderately fragmented forest landscapes. Forest cover, patch size, and patch density frequently were associated with abundance of species (Gorresen and Willig, 2004).

Therefore, our data indicate that bat species richness and assemblages in the Pantanal and its surrounding habitats are still well preserved, and it is hoped that these findings may be useful for constructive lines of biodiversity conservation and management in this important wetland ecosystem.

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