



Artículo

STRUCTURE OF A BAT ASSEMBLAGE FROM A FRAGMENTED LANDSCAPE IN THE STATE OF MINAS GERAIS, SOUTHEASTERN BRAZIL

Lívia O. Loureiro¹ and Renato Gregorin²

¹ Instituto de Ciências Biológicas, Departamento de Zoologia, Universidade Federal de Minas Gerais, 6627 Belo Horizonte, Minas Gerais, Brasil [correspondence: <loureirobio@yahoo.com.br>].

² Departamento de Biologia, Universidade Federal de Lavras, 3037 Lavras, Minas Gerais, Brasil.

ABSTRACT. Minas Gerais presents the richest bat fauna among the states of southeastern Brazil. Despite its high diversity, the bat fauna in large areas of the state remain poorly or completely unknown due to its wide territorial area, as well as the complexity of its relief and vegetation. This work aimed to study the bat fauna in fragments of a region in Lavras, Minas Gerais, southeastern Brazil, as well as the dynamic of their species. The study was carried out in a highly fragmented landscape area, composed by relatively small fragments of semi-deciduous forest under distinct levels of human disturbances. Forty nights of sampling were conducted with a total capture effort of 43200 m²/h. Fourteen species were recorded out of which, 10 were in the family Phyllostomidae, 3 in Vespertilionidae and 1 in Molossidae. It is important to highlight the presence of *Chiroderma doriae*, a species classified as threatened in Brazil, and *Molossops neglectus*, a rare molossid bat that needs taxonomic review.

RESUMEN. Estructura de un ensamble de murciélagos en un paisaje fragmentado del estado de Minas Gerais, sudeste de Brasil. El estado de Minas Gerais es el estado más rico del sudeste de Brasil en cuanto a número de especies de murciélagos. A pesar de esta gran diversidad, grandes áreas del estado continúan siendo poco o completamente desconocidas en lo respectivo a los quirópteros, debido a la amplitud de su área territorial, al relieve y a la complejidad de la vegetación. El presente trabajo tuvo como objetivo estudiar los murciélagos en fragmentos de la región de Lavras, Minas Gerais, sudeste de Brasil, así como la dinámica de sus especies. El estudio se llevó a cabo en una zona de paisaje altamente fragmentado, compuesta por pequeños fragmentos de bosque semidecídulo y en distintos niveles de antropización. Se realizaron muestreos durante 40 noches, con un esfuerzo de captura total de 43200 m²/h. Catorce especies fueron registradas, de las cuales 10 correspondieron a la familia Phyllostomidae, 3 a Vespertilionidae y 1 a Molossidae. Es importante destacar la presencia de *Chiroderma doriae*, una especie clasificada como amenazada en Brasil y *Molossops neglectus*, un molósido muy raro que necesita de revisión taxonómica.

Key words: Assemblage. Chiroptera. Conservation. Diversity. Fragmentation.

Palabras clave: Chiroptera. Conservación. Diversidad. Ensamble. Fragmentación.

INTRODUCTION

Minas Gerais is the largest state of southeastern Brazil, with a rich mosaic of biomes including the Cerrado, Atlantic Forest, Dry Forests, and the Caatinga (Tavares et al., 2010). The area is characterized by its environmental complexity, due to the ecotonal conditions of their landscapes and rugged relief. The longtime human colonization and their associated changes in land use, caused by the presence of small farms, have resulted in the high fragmentation of native landscapes. Presently forest fragments act as refuges maintaining part of the local biodiversity (Castro, 2004; Silva and Rossa-Feres, 2007; Collen et al., 2008; Silva, 2008). Fragmentation results in changes on the landscape structure and consequent influence on the composition and diversity of animal communities and on the local extinction of species (Saunders et al., 1991). Such extinctions are mainly caused by the combined effect of reduction of habitats and resources, increase of inter and intraspecific competition, decrease of the living area, inbreeding (Metzger, 1997), and edge effect (Faria, 2002). Changes in landscape structure result in modifications on levels of light, temperature, moisture and wind speed (Kapos, 1989), influencing directly the composition of animal and vegetal species (Murcia, 1995).

Among the 4 states of southeastern Brazil, Minas Gerais has proportionally the lowest number of bat studies as contrasted with its total area and its biotic and orographic complexity (Tavares et al., 2010). A recent estimate of bat diversity for the state reported 77 species belonging to 45 genera and 7 families (Tavares et al., 2010), but recent studies have increased this number up to 80 (Gregorin and Loureiro, 2011; Gregorin et al., 2011; Velazco et al., 2014). The majority of bat studies conducted in southern Minas Gerais, Brazil, are focused on the easternmost portion, as exemplified by those conducted in Serra do Brigadeiro, adjacent areas of Parque Estadual de Ibitipoca, and the municipality of Viçosa (Mumford and Knudson, 1978; Barros et al., 2006; Nobre et al., 2009). Bat data for the western and southernmost portions of Minas Gerais are incipient, and all of them are still in monographs and

dissertation formats (e.g. Chiquito, 2007; Moras and Ramos, 2008).

In southeastern Minas Gerais, there is a peculiar system of property delimitation by natural fences, resulting in a landscape composed by small fragments connected by narrow corridors of native vegetation, locally called *valos* (slopes). This array of remaining vegetation has stimulated the development of several studies on plants, insects, birds and anurans which focused on the role of slopes as effective corridors for fauna displacements, and on the role of the matrixes and fragments on biodiversity maintenance (Castro, 2004; Santos et al., 2006; Silva, 2008; Corrêa, 2008; Mesquita and Passamani, 2012). Indeed, the results of such studies highlighted the importance of these fragments and their connections for the maintenance of part of the native local biodiversity. The objectives of the current study were to describe the assemblage of bats in a system of fragments located in the region of upper Rio Grande, as well as the movement pattern of animals among the studied fragments.

MATERIAL AND METHODS

Study area

The study was carried out at Serra do Carrapato, a site located 6 km southeast of Lavras and inserted in the region of upper Rio Grande, southern Minas Gerais (21°28'99"-21°19'46"S; 44°98'63"-44°99'97"W). The climate is temperate mesothermal, with mild summer, dry winter and rains concentrated in summer (Castro, 2004). The altitude varies from 920 to 1180 m. The average annual temperature is 20.4°C, and the annual precipitation is 1460 mm (Dantas et al., 2007).

The vegetation consists of enclaves of Cerrado within the distribution area of semi-deciduous seasonal forests of southeastern Brazil. Besides the intense colonial exploration, the region of upper Rio Grande, especially in the study place, continues suffering the influence of a remarkable anthropic pressures of agro-pastoral activities. Thereby, the local landscape may be defined as a natural anthropic mosaic with small fragments of native semi-deciduous forest inserted in a matrix composed by coffee, corn and pastures (Mesquita and Passamani, 2012). The native remnants are arranged in a set of five fragments connected by a system of vegetational

corridors. Fragments have areas from 1.03 ha to 11.84 ha, with a total study area of 35.24 ha. The vegetal formation in all the fragments is characterized by semi-deciduous forest.

Fragment 1 is characterized by the scarcity of trees, which are spaced and small. It also presents a great amount of invasive weeds and plants in regeneration, besides intense luminosity, forming large clearings. The edge effect and anthropic actions are evident. Fragment 2 is located on the slope of a hill, which is a transitional area between Cerrado and semi-deciduous forest with small trees; the presence of clearings is noticeable, as well as the presence of several invasive species. Fragment 3 has several springs, abundant foliage and species in regeneration, with few invasive plants and clearings; the trees are taller, and it is apparent that there is little human intervention; this fragment is considered alluvial because of the permanently flooded soil (Veloso et al., 1991). Fragment 4 presents great impacts on the edge; it has medium to large-sized trees with thick foliage and species in regeneration; the presence of lianas is remarkable. Fragment 5 also presents several streams and springs and, as well as fragment 3, it is considered alluvial because of the permanently flooded soil; the edge effect is outstanding; the fragment is limited by fence and the vegetation is dense and more preserved in these portions, with great amount of organic matter.

Sampling

Forty nights of sampling were conducted from September 2009 to August 2010, and they were equally distributed among the fragments, allowing a direct comparison by effort. At each night, 5 mist nets (12 x 3 m) were used during six hours after nightfall. They were installed on both edges and the interior of each fragment. In order to analyze the effect of seasonality over the bat community, samples were equally distributed among seasons. The sampling effort was given in m²/h (Straube and Bianconi, 2002).

Some individuals were collected as voucher specimens with authorization of ICMBio (License 18528-2) and deposited in the Collection of Mammals of the Universidade Federal de Lavras (CMUFLA). Before being released, the individuals were identified and the time of capture, sex, age, weight and external morphometry were recorded. Data related to moonlight intensity were obtained through the software Moontool (John, 1987). The individuals were marked with necklaces of nickel balls (Handley et al., 1991), provided with plastic rings of different colors representing different numbers (Esbérard and Daemon, 1999), and released in the same area of capture.

Data analyses

Bat species were classified in trophic guilds, which are defined as the set of species that have similar strategies of foraging, habitats and diet, following Kalko et al. (1996).

As assemblage parameters, the relative abundance of each species and diversity were estimated through the Shannon and Pielou Equitability indexes (Magurran, 1988) using software Past (Hammer and Harper, 1999).

The observed and estimated richness values were also calculated (Gotelli and Colwell, 2001) and the sufficiency of capture effort was obtained by Mao Tau's curve of species accumulation, considering the total number of sampled sites during the studied period. The richness and accumulation curves were calculated by first order Jackknife estimator (Jackknife 1) using the software ESTIMATES S 8.2 (Colwell, 2004). Data were estimated using 1000 random draws without reposition of sampling sequences (Gotelli and Colwell, 2001).

Comparisons among the fragmented areas and also the relation with moonlight intensity were made through a linear correlation test. To estimate the similarity in terms of captures between the edge and the interior of the fragments, a *t* Test was performed. The normality of samples was tested using Kolmogorov-Smirnov and Lilliefors' test in the software Statistica 7 (StatSoft). The area of each fragment and the distance among them were calculated by the software Google Earth 2011[®]. The relation between abundance and structure of each fragment was statistically tested by the application of an Anosim test (Oksanen and Minchin) in the software Primer 5[®] (Amper Fern).

RESULTS

With a total sampling effort of 43 200 m²/h and capture success of 0.0032 ind./m²/h, 139 individuals of 14 species belonging to 3 families (Phyllostomidae, Molossidae and Vespertilionidae) were captured (**Table 1**). 121 individuals were ringed, with 8 recaptures of 3 species: *Carollia perspicillata*, with 4 individuals (21.05%), *Sturnira lilium* with 3 individuals (6.25%) and *Artibeus lituratus* with 1 individual (3.03%), resulting in an overall recapture rate of 6.61%. The longest temporal recapture interval was observed for one female of *S. lilium*: 10 months after its first capture. The longest observed displacement (4.82 km)

Table 1

Relative frequencies, number, and feeding habits of bat species currently recorded in five fragments in the state of Minas Gerais, southeastern Brazil.

Family Subfamily	Species	Feeding habit	N ¹	RF ² %
PHYLLOSTOMIDAE				
Stenodermatinae	<i>Artibeus fimbriatus</i> (Gray, 1838)	Frugivores	10	7
	<i>Artibeus lituratus</i> (Olfers, 1818)	Frugivores	33	24
	<i>Chiroderma doriae</i> (Thomas, 1891)	Frugivores	1	1
	<i>Platyrrhinus lineatus</i> (E. Geoffroy, 1810)	Frugivores	2	1
	<i>Vampyressa pusilla</i> (Wagner, 1843)	Frugivores	1	1
	<i>Sturnira lilium</i> (E. Geoffroy, 1810)	Frugivores	48	34
Carollinae	<i>Carollia perspicillata</i> (Linnaeus, 1758)	Frugivores	19	14
Glossophaginae	<i>Anoura caudifer</i> (E. Geoffroy, 1818)	Nectarivores	8	6
	<i>Glossophaga soricina</i> (Pallas, 1766)	Nectarivores	8	6
Desmodontinae	<i>Desmodus rotundus</i> (E. Geoffroy, 1810)	Hematophages	2	1
VESPERTILIONIDAE				
Vespertilioninae	<i>Eptesicus chiroquinus</i> (Thomas, 1920)	Insectivores	1	1
	<i>Eptesicus furinalis</i> (d'Orbigny, 1847)	Insectivores	2	1
	<i>Myotis riparius</i> (Handley, 1960)	Insectivores	1	1
MOLOSSIDAE				
Molossinae	<i>Molossops neglectus</i> (Williams and Genoways, 1980)	Insectivores	3	2
Total			139	100

¹ N=abundance

² RF=relative frequency

corresponded to 1 male of *C. perspicillata*. The average range of movement was 2.34 km. Individuals belonging to family Phyllostomidae were the most abundant, comprising 82.01% of the assemblage with 114 individuals. The dominant species were *S. lilium* with 34.5% of the captures, *A. lituratus* with 23.7% and *C. perspicillata* with 13.7%. Shannon index for edges and interior of fragments were 1.9 and 1.8, respectively, and equitability values were 0.7 and 0.8, respectively. It indicates that diversity on the edge and on the fragment was almost the same ($p < 0.05$), and that the distribution of individuals among species was uniform, showing that the local bat assemblage may be in balance. Richness and abundance of species were distinct among fragments due the single-

ton elements present in different fragments and restriction to one or two fragments (**Table 2**).

In the analysis of the interior and the edge independently, more individuals were recorded on the edge ($n=73$) than within the fragment (66), but different species with different feeding strategies contributed to this number (**Fig. 1**). The aerial insectivore bats *Molossops neglectus* and *Eptesicus furinalis* were only recorded on the edge of the fragments, and *Desmodus rotundus* were exclusively found within the fragments. Twelve species were recorded for the edges, being *Sturnira lilium* (36.99%) and *Artibeus lituratus* (26.02%) the most abundant. Nine species were recorded within the fragment, being *S. lilium* (31.82%) and *Carollia perspicillata* (22.73%) the dominant ones.

Table 2

Number of individuals of each bat species recorded from five fragments located in Minas Gerais, southeastern Brazil.

Species	Fragments				
	1 (7.2 ha)	2 (11.8 ha)	3 (1.1 ha)	4 (7.8 ha)	5 (7.8 ha)
<i>A. caudifer</i>				5	3
<i>A. fimbriatus</i>	3		1	4	2
<i>A. lituratus</i>	1	5	9	10	8
<i>D. rotundus</i>				1	1
<i>M. neglectus</i>				3	
<i>P. lineatus</i>	1				1
<i>S. lilium</i>	14	12	8	9	5
<i>V. pusilla</i>					1
<i>G. soricina</i>	2	1		2	3
<i>C. perspicillata</i>	4	1	5	6	3
<i>C. doriae</i>				1	
<i>E. furinalis</i>				2	
<i>E. chiriquinus</i>				1	
<i>M. riparius</i>				1	
Total	25	19	23	45	27

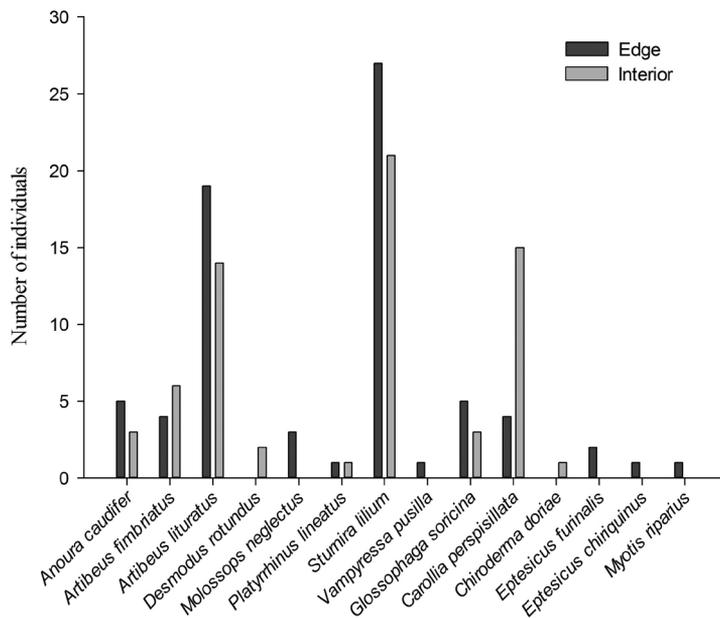
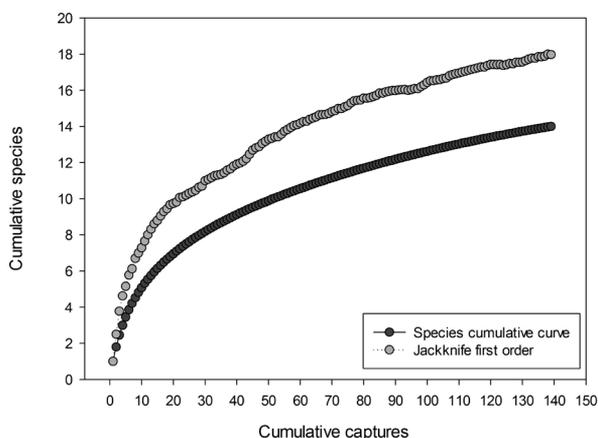


Fig. 1. Frequency histogram of bat species captured on the edge and inside 5 fragments in the state of Minas Gerais, southeastern Brazil.

There was neither a significant positive nor negative relation between richness and abundance in relation to luminosity ($t=1.13$, $p=0.23$ and $t=6.61$, $p=0.54$, respectively) or to the area of fragments ($t=0.19$, $p=0.86$ and $t=0.13$, $p=0.91$, respectively), what indicates that the same species in the same proportion was captured in different luminosity conditions and on fragments with different sizes. Despite these results, some species, such as *Eptesicus chiroquinus*, *E. furinalis*, *M. neglectus*, *Myotis riparius* and *Chiroderma doriae* were captured exclusively on full moon. Regarding the trophic guilds, it was observed that frugivores were the richest and most abundant guild, with seven species and 83.45% of captured individuals. This guild was significantly more abundant than others ($p < 0.01$, $F = 46.33$). Nectarivore bats were represented by two species and showed a relative abundance of 10.07%. Four species of insectivore bats were recorded, with relative abundance of 5.04%. Hematophage bats were represented by one species (1.44%). Anosim showed that there is a significant separation of bat abundance between the fragments 1 and 4 ($p=0.05$, $R=18.6$), and between fragments 2 and 4 ($p=0.30$, $R=25.4$). In the comparison of assemblage structure, significant differences were found between fragments 2 and 4 ($p=0.02$, $R=25.8$) and 2 and 5 ($p=0.48$, $R=19.8$). The obtained curve of species accumulation did not reached asymptote; thus, more sampling effort is necessary in order to capture all the expected species (Fig. 2)



DISCUSSION

The total number of species reported by the current study corresponds to only 18.18% of all the species previously reported for Minas Gerais (Tavares et al., 2010). The reported richness is consistent when compared with some studies in larger fragments of semi-deciduous forests in southern and southeastern Brazil (Pedro et al., 2001; Sekiama et al., 2001). A low richness was expected and explained by the intense local fragmentation, besides the high altitude (over 900 m) with mild average temperature, which are also variables related to the low diversity and abundance of plants (Mantovani, 2001) and bats (Mello, 2009).

The assemblage structure with dominance of the family Phyllostomidae is in accordance with what is verified in several Neotropical sites considering the applied methodology in Amazonia (Bernard and Fenton, 2007), Caatinga (Gregorin et al., 2008), Atlantic Forest (Dias and Peracchi, 2008) and Cerrado (Zortea and Alho, 2008). Some species show a higher adaptive potential in response to habitat disturbance and supply their demand for shelter and food, for example, with success (Pianka, 1982). It can provide great efficiency on adaptation in processes of fragmentation and habitat modification as occurs with high frequency of *S. lilium*, *A. lituratus* and *C. perspicillata* in the fragments. Such flexibility may be related with their ability to use various strata of vegetation, benefiting from the various opportunities present in environments modified by man (Estrada and Coates-Estrada, 2002). The dominance of such species has already been related in other studies of bat communities in Brazil (Marinho-Filho, 1991; Pedro and Taddei, 1997; Reis et al., 2000).

Fig. 2. Bat species accumulation curve by Mao Tau method and Jackknife in 5 fragments in the state of Minas Gerais, southeastern Brazil. The X axis represents the number of cumulative capture and the Y axis represents the number of cumulative species.

Another fact that has been noticed is the relative homogeneity in diversity between the edge and internal areas of the fragments. This fact does not support the expected higher diversity sheltered by internal areas (Zimmerman and Bierregaard, 1986; Stevens and Husband, 1998). Thus, the studied system of highly fragmented forest remnants certainly does not present adequate conditions for some species found in more preserved areas (Zanon and Reis, 2007). However, even though the studied fragments did not present the ideal size, they must be kept in consonance with restrictions to anthropic actions in the region, in order to restrain degradation and preserve the inhabiting populations.

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