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The response of bats (Mammalia: Chiroptera) to an incidental fire on a gallery forest at a Neotropical savanna

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Abstract: Fire is a common and natural event in Cerrado that can influence the composition of trees and mammals and change the entire conditions of the environment. This study was developed in a gallery forest of Distrito Federal - Brazil. Bat samplings were conducted for a total of six nights after a fire that happened on the gallery forest. Three samplings were conducted: one day, three months and seven months after fire. A total of nine mist nets (12 m x 3 m) were opened from 7pm to 1am. Captured bats were measured and identified to species. Shannon index measured the species diversity of bats in the gallery forest over time. A rarefaction curve was made to assess the estimated bat richness in each of the samplings and a chi-square test was used to check whether there have been changes on bat abundances over time. A total of 46 bats from 8 different species and one family were captured. The most abundant species was *Sturnira lilium.* Species diversity and abundance increased over time and there was a gradual accumulation of species and specimens indicating that the succession and recovery of the forest occurs due to a temporal addition of specimens and species in the assemblage and not as punctual occurrences. Probably, this recovery pattern reflects a gradual increase in the availability of resources and recovery of the forest canopy, progressively offering more shelter and food for the bat assemblage.
Keywords: *Chiroptera, Cerrado, fire, impact, recovery.*

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Resumo: O fogo é um evento comum e natural no Cerrado que pode influenciar a composição de árvores e mamíferos e mudar totalmente as condições do ambiente. Esse estudo foi desenvolvido na mata de galeria do Distrito Federal – Brazil. As amostragens dos morcegos foram conduzidas por um total de seis noites depois da ocorrência do fogo na mata de galeria. Três amostragens foram conduzidas: um dia, três meses e sete meses depois que o fogo ocorreu. Um total de nove redes de neblina (12 m x 3 m) foram abertas das 7pm a 1am. Os morcegos capturados foram medidos e identificados ao nível de espécie. O índice de Shannon mediu a diversidade de espécies de morcegos na mata de galeria ao longo do tempo. Uma curva de rarefação foi feita para acessar a riqueza estimada de morcegos em cada amostragem e um teste qui-quadrado foi usado para verificar se houve mudanças na abundância de morcegos ao longo do tempo. Um total de 46 morcegos de 8 espécies diferentes e uma família foram capturados. A espécie mais abundante foi *Sturnira lilium*. A diversidade de espécies e abundância aumentaram com o tempo e houve um acúmulo gradual de espécies e espécimes indicando que a sucessão e recuperação da mata ocorreu com uma adição temporal de espécimes e espécies na assembleia e não de forma pontual. Provavelmente, o padrão de recuperação reflete o aumento gradual na disponibilidade de recursos alimentares e recuperação do dossel da mata, que progressivamente passaram a ofertar mais abrigo e alimento para a assembleia de morcegos.
Palavras-chave: *Chiroptera, Cerrado, fogo, impacto e recuperação.*

Introduction

Bats are the only mammals capable of true flight. This ability enabled them to explore an enormous variety of niches that had never been used by any other mammal species (Norberg 1994). In the Neotropical region, frugivory is a common characteristic of bat species from the Phyllostomidae family (Altringham 1997). There are different explanations concerning the occurrence of frugivorous bats in the Neotropics. In most cases, bat occurrence is associated with food distribution and availability (Morrison 1978; Heithaus & Fleming 1978; Fleming 1988; Lima & Reis 2004). In total, the neotropical savannah of Cerrado comprises

about 106 bat species (Aguiar & Machado 2010) making it the richest group of mammals in this domain (Marinho-Filho & Guimarães 2001). Although gallery forests comprise only 5% of the total area of Cerrado, this formation hosts more than 80% of its mammal species and most of them are bats (Marinho-filho & Gastal 2000).

Fire is a common and natural event in Cerrado regions (Miranda, Bustamente & Miranda 2002) and form an important structuring factor of their vegetal communities and phytophysiognomies (Hoffman & Moreira 2000). Fires can cause high mortality rates of wooded plants and mammals, influencing the composition of tree species and the mammalian fauna (Hoffman & Moreira 2000; Henriques et al. 2000; Briani et al. 2004) as they tend to favor the establishment of gramineae and pioneer species (Hoffman & Moreira 2000). Although gallery forests are more difficult to burn due to their low amount of gramineae and high humidity (Hoffman et al. 2003), fires are an important component of their dynamics, especially in their borders (Hoffman 1999). Fires can induce changes in forest structure, composition and promote the development of plant species that are more light tolerant (Miguel et al. 2011) and shifts in the composition of trees (Santiago et al. 2005), but borders are usually less affected as they have plants that are more adapted and resistant to it (Meave et al. 1991).

The few studies reporting the effects of fire on the mammal fauna are for small non-flying mammals (Viera & Marinho-Filho 1998; Vieira 1999; Henriques et al. 2000; Briani et al. 2004). Most studies reporting the effects of fire on bats have been carried out on North American forests with special attention to insectivorous species (Boyles & Aubrey 2006; Dickinson et al. 2008; Loeb & Waldrop 2008; Lacki et al. 2009; Layne 2009; Fisher & Wilkinson 2005; Johnson et al. 2010; Dickinson et al. 2010; Perry 2011; Silvis 2011; Armitage & Ober 2012). According to Fisher & Wilkinson (2005), bat activity after fire may vary according to the density of the remaining trees. In some cases, insectivorous bats may be unresponsive to fire (Loeb & Waldrop 2008), fire may increase shelter availability in dead trees (Boyles & Aubrey 2006) or decrease bat activity (Silvis 2011). However, there is no study on the effect of fire in frugivorous and nectarivorous bats or the response of the chiropterofauna to fire in Cerrado.

The objective of this study is to report the response of frugivorous and nectarivorous bat species to a fire that burned a gallery forest in the Neotropical savanna of Cerrado.

Methods

This study was developed in a gallery forest of a small farm (Chácara Solar da Águia – 15°55.640' S; 47°49.890' W) located in the Distrito Federal - Brazil. The forest was characterized by its reduced width (100 meters in the portion sampled), presence of clearings and exotic plants, like bamboos, and pastures in its surrounding area. The fire burned the whole forest, from small shrubs to tall trees, along its whole width and at least 4 km of its extension. Fire promoted an increase in the number and size of gaps, a reduction of its width and the establishment of pioneer plants inside it. Bat sampling was conducted for two consecutive nights each time in a total of six nights. The first sampling started one day after the fire (19th and 20th of September of 2007), the second after three months and the last sampling after seven months. A total of nine mist nets (eight 2m x 12m and one 2m x 6m) were opened from 7pm to 1am on each night. Captured bats were tagged with plastic rings, had their forearm lengths measured with a caliper and were identified to species level (Vizotto & Taddei 1973).

Shannon index was used to measure the diversity of species in each sampling with Biodiversity Pro software (McAleece 1997). A rarefaction curve was made to assess the estimated bat richness in each samplings and the chi-square test was used to check whether there have been changes in the abundance of bats over time. Both calculations were made with the software R (Ihaka & Gentleman 1996).

Results and discussion

A total of 46 bats from 8 species and one family were captured (Table 1). The highest richness of species, abundance and diversity were registered in the last sampling. The most

Table 1. Bat assemblages captured after one day, three and seven months of a fire that happened in a forest gallery of Distrito Federal - Brazil.

	Abundance			
Guild/Species	**After 1 day**	**After 3 months**	**After 7 months**	**Total**
Frugivorous				
Sturnira lilium	04	04	08	16
Carollia perspicillata	00	04	04*	07
Artibeus cinereus	00	01	10	11
Artibeus fimbriatus (Gray, 1838)	00	00	03	03
Artibeus planirostris (Spix, 1823)	00	00	01	01
Artibeus lituratus (Olfers, 1818)	00	00	05	05
Platyrrhinus lineatus (E. Geoffroyi, 1810)	00	00	01	01
Nectarivorous				
Glossophaga soricina (Pallas, 1766)	00	01	02	03
Total	04	10	33	46
Richness	01	04	08	08
Diversity (Shannon)	0,00	1,19	1,82	1,83
Equitability	1,00	0,82	0,84	0,78

*Recaptured specimen

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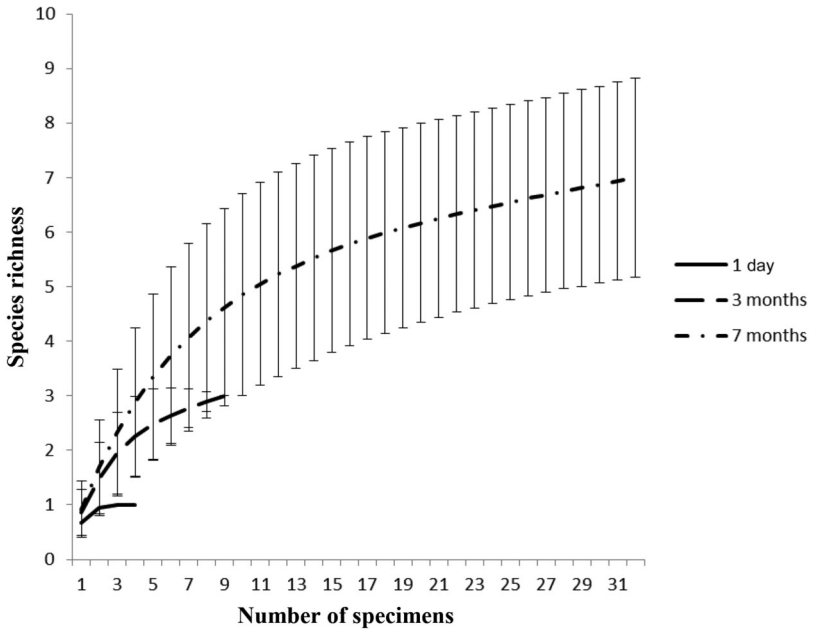

Figure 1. Rarefaction curve of bat species captured after one day, three months and seven months of a fire that happened in a forest gallery of Distrito Federal - Brazil.

abundant species was *Sturnira lilium* with 16 captured specimens, representing 43.5% of the total catches. One *Carollia perspicillata* was recaptured in the seventh month, suggesting that after three months, some specimens were already using the area more continuously after the fire. The diversity of species increased over time, as can be seen by the increasing values of H', indicating recovery of the area. The χ^2 test showed a significant difference ($\chi^2 = 29{,}92$ DF $= 2$, $9 < 0{,}001$) in the total of bats captured in each period, indicating an increase in the abundance of bats over time. Rarefaction curves (Figure 1) didn't evidence differences in species richness between areas, but a gradual accumulation of species and specimens was observed and all of the species captured in the first or second month of sampling were also captured on a later moment and always with a higher abundance than was previously recorded.

These results indicate that the succession of the gallery forest for bats is given by the temporal addition of specimens and species in the assemblage and not by their punctual occurrences. Although it's difficult to estimate the recovery of the forest itself after a fire as the conditions probably don't return to the initial phase as there is a change in the composition of tree species (Santiago et al. 2005), the present recovery pattern for bats seems to be more related to a gradual increase in the availability of food resources and shelter in the area.

In contrast to the fauna of small non-flying mammals, which normally reach their abundance peak shortly after fire due to an increase in the gramineae of the area (Yarnell et al., 2007), the low abundance and richness of bats during the first sampling may have been influenced by the high mortality of wooded plants that can happen after a fire (Santiago et al. 2005), which resulted on an initial decrease of food supply and shelter deficit under foliage.

The gradual increase in richness and abundance over the following months may also have occurred as a result of the establishment of pioneer plants such as some Solanaceae that were found in the area and the recovery of the foliage in the canopy. Boyles & Audrey (2006) reported a rise in light penetration and a reduction of tree density together with an increased availability of shelters for bats in a semi deciduous forest in United States of America after fire. Nardoto (2000) observed that at heights above 160 cm, foliage may be exposed to hot air flows with possible and intense fall of leaves only a few days after fire. This effect could have reduced the availability of shelter for species that roost under leaves, like species of the genus *Artibeus*, justifying its record only later in the assemblage. The late record of *Artibeus* species was not expected as they are common species in gallery forests and could easily cross substantially modified areas as they are highly vagile (Bernard & Fenton 2003; Costa et al. 2006; Jr et al. 2008). This fact helps to reinforce the big impact of the fire on the bat assemblage.

Although natural regenerating gallery forests are stable regarding their vegetation composition and structure (Oliveira & Felfili 2005) and to keep their diversity of plant species (Felfili 1997), fire can cause intense death of trees in gallery forests and change their floristic composition (Santiago et al. 2005), promote secondary succession and formations of clearings that play similar roles as the gaps of continuous forests (Kellman and Meave 2007). There is usually an increase in the abundance of some species of bats in open and degraded environments, like *S. lilium* and other frugivore species (Castro-Luna et al. 2007; Willig et al. 2007). The colonization of forest clearings by pioneer plants in this study, especially from the family Solanaceae, may have occurred together with the recording of the first bat species after fire and the initial recovery of the forest. Silva *et al.* (2005) observed the formation of clearings and the presence of a great number of species of the genus *Cecropia*, *Piper* and *Solanum* in a semideciduous broadleaved forest after the fire. These plant genera constitute some of the main plant items in the diet of species such as: *C. perspicillata*, *Sturnira lilium* and *Artibeus* spp. (Bizerril & Raw 1998; Garcia et al. 2000; Aguiar & Marinho-Filho 2007; Mikich 2002). These bat species are also, in many cases,

dispersers of pioneer plants (Bizerril & Raw 1998; Garcia et al. 2000; Aguiar & Marinho-Filho 2007; Mikich 2002), indicating that they could also be helping in the regeneration process of the forest.

Although fire may have momentarily diminished the supply of food and shelter for bats, as time went by, conditions have changed and there was an increase of food supply, especially those that are more adapted to relatively altered environments and forest gaps. Therefore, it is possible that bat assemblages in gallery forests may have a considerable capacity for recovery when affected by fires and succession in these areas may occur on basis of temporal sum of specimens and species and not by eventual colonization as frugivorous species are most likely attracted by the reestablishment of original features of the forest and colonization by pioneer plants used in their diets.

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