



USE OF FOREST FRAGMENTS AND AGRICULTURAL MATRICES BY SMALL MAMMALS IN SOUTHEASTERN BRAZIL

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ABSTRACT. The use of matrix by species that naturally inhabit forest fragments can be an important instrument to restore connectivity in fragmented landscapes. The type and structure of the matrix are determinant for this connectivity, however, few studies have explored this theme. In this study, we evaluated the community of small mammals within forest remnants and within two types of matrices (coffee plantation and pasture). In all, 11 species of small mammals were captured, being *Akodon montensis*, *Oligoryzomys nigripes* and *Calomys cerqueirai* the most abundant in fragments, coffee plantation and pasture, respectively. The results show that the composition and structure of the community in the two matrix types are distinct from those found in fragments, and the coffee plantation matrix has greater abundance and greater richness of small mammals than the pasture matrix.

RESUMO. Uso de fragmentos florestais e matrizes agrícolas por pequenos mamíferos no sudeste do Brasil. O uso da matriz por espécies que naturalmente habitam manchas florestais pode ser um instrumento importante para restaurar a conectividade em paisagens fragmentadas. O tipo e a estrutura da matriz são determinantes para esta conectividade, porém, poucos estudos exploram este tema. Neste estudo, nós avaliamos a comunidade de pequenos mamíferos dentro de fragmentos florestais e também dentro de dois tipos de matrizes (plantação de café e pasto). No total foram capturadas 11 espécies de pequenos mamíferos, sendo *Akodon montensis*, *Oligoryzomys nigripes* e *Calomys cerqueirai* as mais abundantes nos fragmentos, plantação de café e pasto, respectivamente. Os resultados mostram que a composição e a estrutura da comunidade nos dois tipos de matrizes foram diferentes daquelas encontradas nos fragmentos, e que a matriz de café possui maior abundância e riqueza de espécies que a matriz de pasto.

Key words: agriculture, fragmentation, Marsupialia, matrix, Rodentia

Palavras-chaves: agricultura, fragmentação, Marsupialia, matriz, Rodentia

INTRODUCTION

In a human altered landscape, the land covers of an anthropogenic origins can act as filters for structuring communities of wild species, such as small mammals (Gascon 1999). Also, inside those landscapes, the habitats and their connectivity play an important

role in providing resources and maintaining animal populations (Kozakiewicz 2014). Connectivity may facilitate or restrict the movement of organisms among fragments inserted within the landscape (Taylor et al. 1993) and considers both, the habitat in the landscape and the behavioral responses of

organisms to those elements (Goodwin 2003). In this respect, matrix management can be an important tool for the connectivity restoration in the landscape (Prevedello & Vieira 2010a).

The connectivity through the matrix varies according to its structural similarity in relation to the forest remnant and its ability to minimize the edge effect (Pardini 2004). Moreover, behavioral characteristics and habits of each species influence their perception and movement through the matrix (Forero-Medina & Vieira 2007; Umetsu et al. 2008; Prevedello & Vieira 2010a), with species more or less tolerant to different degree of vegetation opening. Matrices can therefore function as a habitat filter in order to facilitate or restrict movement, reproduction, gene flow, and species permanence in fragmented habitats (Gascon 1999).

In some cases, matrix favors generalist species due to the creation of open areas (Oliifiers et al. 2005; Forero-Medina & Vieira 2007). Thus, species that occur in small patches and edge of fragments frequently occur in the matrix, on contrary those species typically found in primary forest (Gascon 1999). For instance, species characteristic from forest environments are influenced by the presence of corridors (Pardini et al. 2005; Metzger 2009), while more generalist species are more affected by the matrix quality (Umetsu et al. 2008; Metzger 2009).

Even though most fragmentation studies consider the size and isolation of forest remnants as major determinants of species richness in the landscape, matrices also influence biodiversity and deserve more attention (Prevedello & Vieira 2010a). Considering that the type of matrix can influence the structure and composition of small mammals inside patches, the aim of this study was to evaluate if there is a difference in the community richness, abundance, composition and structure of small mammals between forest fragments when surrounded by different matrix type. We also evaluated the adjacent coffee plantation and pasture matrices to verify if there is a difference in the community of small mammals inside each matrix type.

MATERIALS AND METHODS

Study area

This study was performed in the municipality of Lavras, southern Minas Gerais, southeastern Brazil (21°14'43"S, 44°59'59"W). The annual average rainfall and temperature of the region are 1 530 mm and 19°C, respectively, and the climate is subtropical with dry winters and rainy summers (Cwa) (Brasil MA DNM 1992). The region is located in the transition zone between the Atlantic Forest and the

Cerrado domains. The landscape is composed by semi-deciduous forest patches inserted in a matrix formed by coffee plantation and pastures (Rocha et al. 2011; Mesquita & Passamani 2012; Fialho et al. 2017).

Sample design and data analysis

The first sampling season occurred from August 2012 to December 2012 and the second from May 2013 to August 2013. Each sampling point were sampled for five nights monthly for 5 months. A total of 24 areas were sampled: Six forest fragments surrounded by coffee plantation matrix (FC), six areas in the adjacent coffee plantation matrix (CM), six forest fragments surrounded by pasture matrix (FP), and six areas in the adjacent pasture matrix (PM) (Fig. 1). The size of FC ranged from 5 ha to 42 ha and the size of FP ranged from 2 ha to 66 ha. The permission for site sample were obtained by verbal approval of the owners. The forest fragments were sampled from 15 m from the border perimeter in a line transect of 170 m, containing 18 trapping points. Each point received a Sherman trap on the ground, and in the interspersed points it also received a trap in the middle stratum of vegetation (1.5 to 2 m above the ground). In the matrices, three transects were arranged parallel to the fragment, at 10 m, 30 m, and 50 m apart from the fragment border and six trapping points were arranged in each transect. In the coffee matrix, due to the stratification, traps were arranged on the ground and on the coffee shrubs (1.5 m high) at alternate points.

Traps were baited with a mixture of banana, peanut flour, cornmeal and cod liver oil. All caught animals were identified, marked with numbered ear tags (National Band & Tag Co.) and released at the same collection point. These procedures were in accordance with the recommendations of COBEA (Brazilian College of Animal Experimentation) and FIOCRUZ (Oswald Cruz Institute Foundation) and license of IBAMA (number: 14083-1).

Data Analysis

After applying log transformation on data, we tested normality. After verified the normality of the data, we choose the analysis for evaluating richness ($W = 0.908$, $p = 0.032$, d.f. = 23) and abundance of small mammals ($W = 0.982$; $p = 0.928$, d.f. = 23). To evaluate whether the fragments and pasture and coffee matrices differ in the richness of small mammal species, a Kruskal-Wallis was used, with a posteriori Mann-Whitney test using R. To evaluate whether the fragments and pasture and coffee matrices differ in the abundance of small mammal species we used an ANOVA with a posteriori Tukey's Test.

The composition of species and the community structure (relative abundance of each species) of each sampled area were evaluated using the non-metric multidimensional scaling (NMDS) with a posteriori test of ANOSIM in the Primer software. To perform NMDS we used similarity index of Bray-Curtis. The ANOSIM was performed in order to test the difference among groups. The Analysis of Indicator Species (Dufrêne & Legendre 1997) was used to verify if there was a higher occurrence of species separately in some environment type using Primer software.

RESULTS

In total, we obtained 322 captures of 217 individuals from 11 species (7 rodents and 4 marsupials) with a

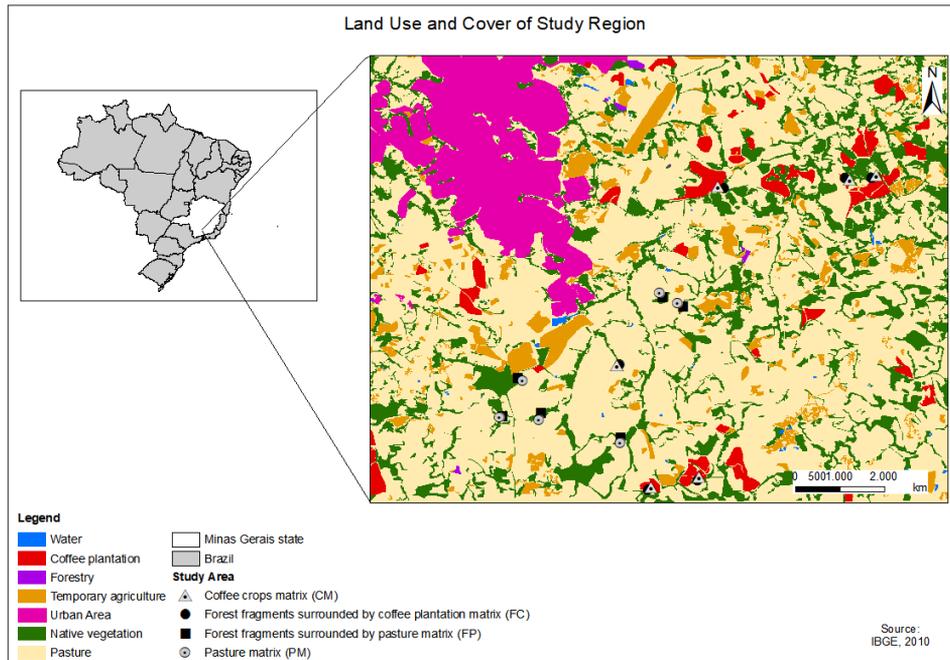


Fig. 1. Location map of the study area. It contains classes of use and soil cover and sampled areas.

total effort of 9.504 trap-nights, which corresponds to a capture success rate of 3.38% (Table 1).

The FC had the highest mean of richness and abundance of small mammals, followed by FP, CM and PM (Fig. 2a and 2b). Regarding species richness, the habitats were significantly different ($H = 10.84$; $p = 0,009$, d.f. = 11.44). However, fragments surrounded by coffee plantation and fragments surrounded by pasture did not show any significant difference ($p = 0.155$), and coffee plantation matrix did not differ from pasture in relation to the richness ($p = 0.089$). Further, fragments surrounded by coffee plantation differed from the coffee matrix (0.045) and pasture matrix ($p = 0.004$) presenting the former greater species richness. Regarding specie abundance, the habitats also differed ($F = 5.336$; $p = 0.007$, d.fbg. = 3), d.fwg = 23. There was no difference in abundance among FC, FP and CM. But PM differed in abundance in comparison to FC ($p = 0.004$).

In relation to the composition of species, two statistically different (ANOSIM, RGlobal = 0.57, $p = 0.001$) groups were identified (Fig. 3a), being one of them formed by fragments surrounded by coffee plantation and pasture, and the other group formed by coffee and pasture matrices. The results also show that fragments surrounded by coffee plantation are

Table 1

Total abundance of species in each type of habitat (FC: fragment surrounded by coffee plantation, FP: fragment surrounded by pasture, CM: coffee plantation matrix, PM: pasture matrix).

	FC	FP	CM	PM	Total
Rodents					
<i>Akodon montensis</i>	41	19	1	0	61
<i>Calomys cerqueirai</i>	0	4	9	19	32
<i>Cerradomys subflavus</i>	3	1	13	0	17
<i>Necomys Lasiurus</i>	0	0	0	2	2
<i>Nectomys squamipes</i>	1	0	0	0	1
<i>Oligoryzomys nigripes</i>	15	6	23	1	45
<i>Rhipidomys itoan</i>	8	7	0	0	15
Marsupials					
<i>Caluromys philander</i>	0	1	0	1	1
<i>Didelphis albiventris</i>	1	0	0	0	1
<i>Gracilinanus microtarsus</i>	18	13	3	0	34
<i>Marmosops incanus</i>	7	1	0	0	8
Abundance	94	52	49	22	219

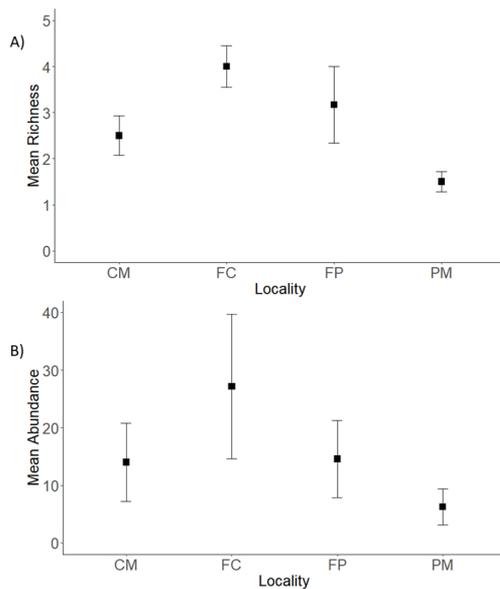


Fig. 2. A) Mean Richness of small mammals found in each locality with respective error bar; B) Mean Abundance of small mammals found in each locality with respective error bar.

similar to fragments surrounded by pasture ($p = 0.55$) and that coffee and pasture matrices are different ($p = 0.04$). All other comparisons between fragments and matrices showed significant differences.

The same pattern was observed for the community structure with the formation of two different groups (Fig. 3b) encompassing areas of fragments and matrices (RGlobal = 0.54; $p = 0.001$). The fragments are similar with one another ($p = 0.366$), and the matrices are similar with one another ($p=0.074$). However, the other comparisons among fragments and matrices are significantly different.

The Analysis of Indicator Species showed that four species have greater abundance in some type of environment. According to the values for indicator species, *Akodon montensis*, *Gracilinanus microtarsus* and *Rhipidomys itoan* can be considered as indicator species for forest fragments surrounded by coffee plantation, while *Calomys cerqueirai* for pasture (Table 2).

DISCUSSION

The response to fragmentation can be predicted according to the habitat specificity, in which most populations of specialist species have their dispersion reduced through small areas of forest cover in the landscape (Püttker et al. 2011), being restricted

Table 2

Results of the analysis of indicator species considering fragments and matrices. FC = fragment surrounded by coffee plantation; FP = fragment surrounded by pasture; PM= pasture matrix; CM= coffee plantation matrix. The p values marked with (*) were considered significant. OIV = Observed indicator value.

	Site	OIV	p	
<i>Akodon montensis</i>	FC	93.0	0.0010	*
<i>Calomys cerqueirai</i>	PA	58.4	0.0170	*
<i>Cerradomys subflavus</i>	CA	42.2	0.1010	
<i>Gracilinanus microtarsus</i>	FC	58.9	0.0130	*
<i>Oligoryzomys nigripes</i>	CA	47.6	0.0820	
<i>Rhipidomys itoan</i>	FC	58.3	0.0030	*

to the fragments. Although the matrix type in the environment may be determinant for richness and abundance of small mammal species within the fragments (Brady et al. 2011), our results show that the type of environment matrix does not influence the community richness (even considering the case of *N. lasiurus* which is exclusive of pasture matrix) and abundance (even considering that *C. cerqueirae* and *C. subflavus* are more abundant in the matrix) within the fragments close to each. But coffee matrix seems to harbor higher abundance and diversity of small mammals and, thus, to be more permeable to them.

In the sampled areas, the pasture matrix, besides having an herbaceous vegetation lower and distinct from the tree structure found in the fragments, still has the presence of cattle, which may explain its lower species richness. The low richness and the dominance of only one species (*C. cerqueirai*) evidence that this type of matrix is less used by the species found in the fragments, being used only by species characteristic from open areas.

The fragments had more species restricted to forest environments (*N. squamipes*, *C. philander*, *D. albiventris*, *M. incanus* and *R. itoan*), and greater abundance of *A. montensis* and *G. microtarsus*. The occurrence of these species only in the fragments shows a certain specificity for this environment type, being three of them (*A. montensis*, *G. microtarsus* and *R. itoan*) indicative of fragments surrounded by coffee plantation. In the coffee matrix, the most abundant species were *Cerradomys subflavus* and *Oligoryzomys nigripes*, which also occur in narrow vegetation corridors in the region (Rocha et al. 2011; Honorato et al. 2015). Thus, it seems that coffee matrices may provide some complementary resources

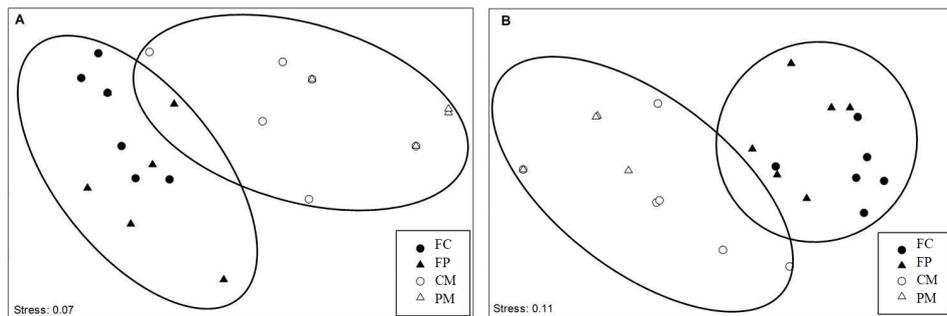


Fig. 3. A) NMDS for community composition, evidencing the grouping of fragments with a community of similar composition and the group formed by matrices also with similar composition. The overlap among points is observed when there is community overlap. B) NMDS for community structure, considering relative abundance of each species. It shows the grouping of fragments with a community structurally similar with one another and matrices with a community structurally similar with one another.

for small mammal species, as reported for other fragmented systems (Braga et al. 2015).

In the pasture matrix, the composition was restricted to three species (*C. cerqueirai*, *N. lasiurus* and *O. nigripes*), the first with high abundance and none of them being considered strictly forest-specialists. In this case, it seems that the creation of open areas favors a smaller number of species capable of using such environment type (Olifiers et al. 2005). Other studies have shown that these species were abundant in open areas in Brazil (Bezerra et al. 2009; Rocha et al. 2011; Honorato et al. 2015), and therefore they have the ability to colonize the pasture environment. Although the pasture matrix is considered the environment most hostile to biodiversity (Peres 2010), the management of this system may be an important strategy to allow greater permeability to the fauna (Santos-Filho et al. 2012).

Rhipidomys itoan was caught only in the fragments, being completely absent from the matrix environments. Although the species is able to use narrow vegetation corridors (Rocha et al. 2011; Mesquita & Passamani 2012), which may favor its movement in fragmented areas, its persistence is strictly dependent on more preserved forest areas. On the other hand, *Akodon montensis* and *G. microtarsus* have been considered of generalist habit, being recorded in fragments, narrow vegetation corridors, coffee growing matrices, and, specifically for *A. montensis*, in the pasture (Passamani & Ribeiro 2009; Mesquita & Passamani 2012). Conversely, *Calomys cerqueirai* is a specie of open areas (Almeida et al. 2007; Rocha et al. 2011), and it was shown to be indicative of pasture matrix in this study.

CONCLUSION

The matrix type can be determinant for the occurrence of small mammal species, and the shrub can be considered connective and more useful for the maintenance of small mammal species in landscapes with agroforestry and forest fragments. Possible mechanisms include the use of resources from the same plantation, linear orientation and protection against predation (Prevedello & Vieira 2010b), and thermal protection (Tuff et al. 2016).

The coffee matrix is more permeable than the pasture matrix for small mammals. The implications of this study for conservation include the maintenance of vegetation cover more similar to native vegetation in monoculture areas, and indicate that more shrub types, such as coffee plantations, are more efficient for the conservation of small mammal species than pasture matrices.

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