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DIRETORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM BIODIVERSIDADE E CONSERVAÇÃO

DIVERSIDADE, DISTRIBUIÇÃO E CONSERVAÇÃO DE MAMÍFEROS DE MÉDIO E GRANDE PORTE EM UMA ZONA DE TRANSIÇÃO CERRADO – MATA ATLÂNTICA

Autor: Roniel Freitas Oliveira
Orientadora: Dra. Levi Carina Terribile
Coorientador: Dr. Alessandro Ribeiro de Morais

RIO VERDE – GO
Fevereiro - 2018

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Autor: Roniel Freitas Oliveira
Orientador: Levi Carina Terribile

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Prof. Dr. Wellington Hannibal
Avaliador externo
UEG/Quirinópolis

Prof. Dr. Matheus de Souza Lima Ribeiro *Avaliador interno*
UFG/Jataí

Prof[a]. Dr[a]. Levi Carina Terribile
Presidente da banca
UFG/Jataí

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BIBLIOGRAFIA DO AUTOR

Roniel Freitas Oliveira, filho de Leontina Santos Freitas Oliveira e Divino Caciano de Oliveira, nascido em Caçu – GO, no dia 17 de abril de 1994. Em janeiro de 2012, ingressou no curso de Licenciatura em Ciências Biológicas pela Universidade Estadual de Goiás, Campus Quirinópolis, onde se graduou em fevereiro de 2016. Em março de 2016, iniciou no curso de mestrado no programa de Pós-Graduação em Biodiversidade e Conservação, no Instituto Federal Goiano, Rio Verde, previsto para concluir em 2018.

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LISTA DE SIMBOLOS, SIGLAS, ABREVIAÇÕES E UNIDADES

m	Metros
km	Quilômetros
e.g.	Exemplo grátis
FD	Diversidade funcional
LFD	Baixa dependência florestal
HFD	Alta dependência florestal
NDVI	Índice de vegetação da diferença normalizada
PS	Tamanho da mancha
PA	Quantidade de vegetação
MDNN	Média da distância para o vizinho mais próximo
ED	Densidade da borda
AIC	Critério de informação de Akaike
kg	Quilograma
MS	Mean shape
%NC	% vegetação nativa
MPS	Mean patch size
c	Câmera trap
B	Toca
D	Observação direta
V	Vocalização
T	Rastros
ha	Hectares
cd	Cerradão
ef	Floresta estacional
Ef	Floresta riparia
Hrs	Horas

RESUMO GERAL

OLIVEIRA, RONIEL FREITAS. Instituto Federal Goiano – Campus Rio Verde – GO, fevereiro de 2018. **Diversidade, distribuição e conservação de mamíferos de médio e grande porte em uma zona de transição Cerrado – Mata Atlântica**. Orientadora: Dr.ª Levi Carina Terribile. Coorientador: Dr.ª Alessandro Ribeiro de Morais.

Mudanças no uso do solo tem sido um dos principais fatores que influenciam negativamente a biodiversidade. Médio e grandes mamíferos desempenham diversas funções no ecossistema, tais como dispersão e predação. Portanto, são extremamente importantes para manter o funcionamento dos ecossistemas, e a diversidade funcional é um índice que reflete este papel da espécie no ecossistema. Apesar de ser extremamente importante, estudos têm mostrado que a diversidade funcional de médio e grandes mamíferos é influenciada pelo tamanho da mancha florestal na Mata Atlântica. Mas, para o Cerrado, não se sabem como características das manchas florestais influenciam a diversidade funcional, e ainda, até onde conhecemos, não existem trabalhos relacionando uma abordagem de múltipla escala (e.g. métricas de manchas e de paisagem) sobre a diversidade funcional. Aqui, inventariamos a fauna de médio e grandes mamíferos, no centro-sul do Brasil. E ainda, apresentamos a diversidade funcional deste grupo, e o efeito da mudança no uso do solo sobre a diversidade funcional em uma abordagem de múltiplas escalas. No geral, nossos resultados mostraram que apesar de altamente fragmentada, a região de estudo ainda abriga uma expressiva riqueza de médio e grandes mamíferos, com uma diversidade funcional relativamente alta em relação ao Cerrado. Observamos também que a diversidade funcional de médio e grandes mamíferos na área de estudo foi influenciada por métricas de mancha e de paisagem de forma diferente. Destacamos que este é o primeiro estudo a utilizar uma abordagem de mancha e paisagem para investigar médios e grandes mamíferos do Cerrado, bem como sua diversidade funcional em paisagens com intensivas atividades antrópicas.

PALAVRAS-CHAVE: Ameaça, Diversidade funcional, Atributos de mancha.

ABSTRACT

OLIVEIRA, RONIEL FREITAS. Instituto Federal Goiano – Campus Rio Verde – GO, fevereiro de 2018. **Diversity, distribution and conservation of medium - and large – sized mammals in a transition zone Cerrado – Atlantic forest.** Orientadora: Dr.ª Levi Carina Terribile. Coorientador: Dr.ª Alessandro Ribeiro de Morais.

Change in land use has been the main factor negatively influencing the biodiversity. Medium and large sized mammals perform various functions in the ecosystem, such as seed dispersers and predation. Therefore, they are extremely important for keeping the functioning of ecosystem, and the functional diversity is an index that reflects the role of the species in the ecosystem. Despite being extremely important, some studies have shown that functional diversity of medium and large sized mammals is influenced by forest patch size in Atlantic Forest. However, for the Cerrado, it is unknown how characteristics of forest patch influence the functional diversity, and still, as far as we know, there are no studies relating functional diversity through a multi-scale approach (e.g. patch and landscape metrics). Here, we inventoried the fauna of medium and large sized mammals in the Central South of Brazil. Still, we present the functional diversity of this group and the effect of change in the land use on functional diversity in a multi-scale approach. In general, our results showed that, despite of highly fragmented, the study region still keep an expressive richness of medium and large sized mammals, with a functional diversity relatively high in relationship to the Cerrado Biome. Still, our results demonstrated that the functional diversity of medium and large sized mammals in the study area was influenced by patch and landscape metrics in different way. We

emphasize that this is the first study using a patch and landscape approach to investigate medium and large sized mammals of the Cerrado biome, as well as its functional diversity in landscapes with intensive anthropic activities.

1.INTRODUÇÃO

O Antropoceno tem sido um período de intensa ameaça a biodiversidade (Dirzo et al., 2014), em que espécies de mamíferos são os que mais tem sofrido com essa ameaça, seguido pelas aves, anfíbios, répteis e peixes (Ceballos et al., 2015). Pesquisadores alertam que essa ameaça, impulsionada principalmente por efeitos antrópicos, tem acelerado as taxas de extinções, e podemos estar direcionando nossa biodiversidade para uma sexta extinção em massa (Ceballos et al., 2015, Dirzo et al., 2014, Young et al., 2016). Nesse contexto, a mudança no habitat nativo (e.g. conversão da cobertura original em agricultura) é um dos principais fatores que influenciam a extinção de espécies (Young et al., 2016).

Em se tratando de mudança no uso do solo, biomas brasileiros se destacam, principalmente o Cerrado, o qual é um *hotspots* para a conservação da biodiversidade (Myers et al., 2000) mas que, apesar disso, são continuamente ameaçados. O Cerrado é o segundo maior bioma brasileiro, o qual tem sido continuamente ameaçado por conversão de sua vegetação nativa em áreas cultiváveis, e já perdeu quase 50% de sua vegetação original (MMA, 2015). E apesar desses dados, ambos os biomas mantem uma expressiva fauna de mamíferos.

No Brasil, existem cerca de 701 espécies de mamíferos, dessas 35% se encontram no Cerrado (Paglia et al., 2012). Dentro do grupo dos mamíferos, devido a sua ampla diversidade, existem divisões em grupos distintos, e um desses grupos são os mamíferos de médio e grande porte. Mamíferos de médio e grande porte são considerados como aqueles que possuem massa igual ou superior a 1kg (Chirello 2000). Esse grupo, embora a massa corporal nos proporciona uma certa facilidade para visualizá-los (e consequentemente, estudá-los), diferente dos demais mamíferos, essa mesma característica é motivo de preocupação, pois essa facilidade pode acarretar em ameaças.

Acredita-se, que a ameaça e a extinção de mamíferos estejam relacionadas com a massa corporal (Dirzo et al., 2014). Portanto, médios e grandes mamíferos necessitam de uma maior atenção, principalmente em uma região de constante mudança no uso do solo. Mas a atenção para este grupo não está relacionada somente à ameaça de extinção, mas também às consequências do seu desaparecimento ao funcionamento do ecossistema.

Médios e grandes mamíferos possuem importantes funções no ecossistema, tais como controladores de níveis das populações de suas presas, dispersores de sementes e predadores de semente (Norrdahl and Korpimaki 1995; Galetti et al., 2001; Wright, 2003; Terborgh et al., 2001). Portanto, preservar a diversidade de médio e grandes mamíferos é extremamente importante para manter a funcionalidade do ecossistema. Sendo assim, índices de diversidade, principalmente a funcional, são extremamente importantes para verificar se determinada área está conservada, pois esse índice reflete o papel da espécie no funcionamento do ecossistema (Petchey & Gaston 2006). Porém, em um estudo na Mata atlântica, verificou-se que a diversidade funcional é influenciada pelo tamanho da mancha florestal (Magioli et al., 2015). Além de atributos de mancha florestal, existem trabalhos relacionando a diversidade, riqueza ou distribuição de médio e grandes mamíferos utilizando atributos de paisagem, tais como densidade da borda, número de manchas na paisagem, média do isolamento da mancha e qualidade da matriz (Lyra-Jorge et al., 2010; Garmendia et al., 2013). Porém, para o Cerrado, não existem pesquisas a respeito do efeito de atributos de mancha e de paisagem na diversidade funcional de médio e grandes mamíferos.

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3. OBJETIVO GERAL

Inventariar a fauna de médio e grandes mamíferos no centro sul do Brasil. E ainda, apresentar a diversidade funcional deste grupo, e o efeito da mudança no uso do solo sobre a diversidade funcional.

3.1. Objetivos específicos

Capítulo I. Inventariar a fauna de médio e grandes mamíferos em uma região impactada com intensiva mudança no uso do solo, e descrever o status de ocorrência baseado em frequência e período de atividade das espécies consideradas comuns.

Capítulo II. Apresentar a diversidade funcional de médio e grandes mamíferos em uma região impactada com intensiva mudança no uso do solo, e investigar-se atributos de mancha e paisagem influenciam na diversidade funcional de dois grupos distintos de médio e grandes mamíferos.

CAPÍTULO I- **Medium and large sized mammals in forest remnants in a transition zone between Cerrado and Atlantic Forest in central-south Brazil: diversity and ecology**

(Normas de acordo com a revista Iheringia série zoologia)

Abstract

Here we present a complete dataset about richness of medium and large sized mammals for the central-south of Brazil. We described species frequency, occurrence status and activity period of the most common species. In each remnant, the community of medium and large sized mammals was inventoried across the following methods: traces, vocalization, directed visualization, burrows, and recording by photographic trap during August 2016 and January 2017. We recorded 23 species of medium- and large- sized mammals in the region, o which seven are national or international threatened. The study area presented a great potential for the distribution of medium and large sized mammals, as we recorded 45.1% of all medium and large size mammal species present in the Cerrado. *Myrmecophaga tridactyla* (Linnaeus, 1758), *Dasypus novemcinctus* (Linnaeus, 1758), *Tapirus terrestris* (Linnaeus, 1758), *Cerdocyon thous* (Linnaeus, 1766) and *Cuniculus paca* (Linnaeus, 1766) were classified as common according to the frequency of record, which was expected since they have large living area, and therefore, can be recorded more frequently. Species with large body size such as *T. terrestris, M. tridactyla* and *C. thous* were also the ones with the greater variation in the period of activity, occurring both in the nocturnal and diurnal period. Therefore, our study underline here that this transition area, although fragmented, still keeps an expressive fauna of medium and large sized mammals, including endangered species.

Keywords. Ecotone area, Endangered species, Frequency, Inventory, *Puma yagouaroundi.*

Resumo. Médio e grandes mamíferos em remanescentes florestais em uma zona de transição entre Cerrado e Mata Atlântica no Centro Sul do Brasil: diversidade e ecologia. Aqui apresentaremos um completo conjunto de dados sobre a riqueza de médio e grandes mamíferos para o centro sul do Brasil, em uma região de transição entre os biomas Cerrado e Mata Atlântica. Descrevemos a frequência da espécie, status de ocorrência e período de atividade das espécies mais comuns. Em cada remanescente, a comunidade de médio e grandes mamíferos foi inventariada através dos seguintes métodos: pegadas, vocalizações, visualizações diretas, tocas e registros por armadilhas fotográficas durante agosto de 2016 a janeiro de 2017. Registramos 23 espécies de médio e grandes mamíferos na região, sete das quais estão incluídas em alguma lista nacional ou internacional de categoria de ameaça. A area de estudo apresentou um grande potencial for a distribuição de médio e grandes mamíferos, onde nós recordamos 45.1% de todos as espécies de médio e grandes mamíferos presentes no Cerrado. *Myrmecophaga tridactyla* (Linnaeus, 1758), *Dasypus novemcinctus* (Linnaeus, 1758), *Tapirus terrestris* (Linnaeus, 1758), *Cerdocyon thous* (Linnaeus, 1766) e *Cuniculus paca* (Linnaeus, 1766) foram classificados como comum de acordo com a frequência de registro, o que era esperado, uma vez que eles possuem uma grande área de vida, e portanto, podem ser registrados mais frequentemente. Espécies com grande massa corporal, tais como *T. terrestris, M. tridactyla* e *C. thous* também foram os que apresentaram maior variação no período de atividade, ocorrendo no período noturno e diurno. Portanto, nosso estudo realça que esta área de transição, embora fragmentada, ainda mantem uma expressiva fauna de médio e grandes mamíferos, incluindo espécies ameaçadas de extinção.

Palavras – chave. Área de ecotono, Espécies ameaçadas, Frequência, Inventory, *Puma yagouaroundi.*

1.1. INTRODUCTION

In the world, there are about 6.399 mammal species, 701 of them distributed in Brazil and from which 194 can be considered medium and large sized mammals (Paglia *et al.,* 2012; Burgin et al., 2018). Due to the recurring threat to the remaining populations, most of mammal species, especially those of medium and large size, are under some risk of extinction in Brazil (e.g., Grelle *et al.*, 2006). Previous empirical works have demonstrated that medium and large sized mammals are specifically sensitive to the effects of fragmentation (Chiarello, 1999; Calaça *et al.*, 2010; Magioli *et al.*, 2016) and changes in the landscape configuration (Garmendia *et al.*, 2013). However, although the studies about the consequences of population fragmentation for these mammals are common in the literature (e.g. Calaça *et al.*, 2010; Magioli *et al.*, 2015), effective actions for species conservation depend of more basic information related to species distribution and diversity (Hortal *et al.*, 2015). In fact, the unevenness in survey effort and basic knowledge may result in high spatial variation in the quality and reliability of the data available for biodiversity research and conservation planning (Gaston & Rodrigues, 2003; Mace, 2004; Hortal *et al.*, 2015), which is particularly serious for threat ecosystems like the Cerrado.

The Cerrado, besides of being the second largest biome of Brazil, is a world hotspot of biodiversity due to its species richness and high degree of endemism and anthropic threats (Myers *et al.*, 2000; Klink & Machado, 2005). For instance, the biome holds a high diversity of medium and large sized mammals, with 56 species distributed in the orders Artiodactyla, Carnivora, Cingulata, Lagomorpha, Perissodactyla, Pilosa, Primates and Rodentia (Paglia *et al.*, 2012). Beyond its great extension and diversity, the Cerrado borders with other Brazilian biomes, such as Amazonian, Atlantic Forest, Pantanal e Caatinga (Ratter *et al.*, 1997). Due to the potential for dispersion of medium and large sized mammals, conservation of the Cerrado may be directly influencing the biodiversity of neighboring biomes.

The south portion of the Cerrado, in the south of the Brazilian Goiás state, has a history of high landscape fragmentation due to monoculture of sugar cane and livestock, causing drastic changes in landscape connectivity. Consequently, this process may result in the reduction of dispersion for medium and large sized mammals through the neighboring biome of Atlantic Forest. However, few studies have documented the diversity and ecology of mammals for this region (see e.g. Hannibal *et al.*, 2015a). Thus, considering that the inventory of the fauna of medium and large sized mammals in this impacted region is the first step to propose conservation actions, here we present a complete dataset for the richness of this group in the south of Goiás state, and also describe the occurrence status based on frequency and activity period of the most common species.

1.2. Material and Methods

1.2.1. *Study area*

The study area is located in the south of the Goiás state, in the central-south of Brazil, (Fig. 1). This region has undergone intense anthropic activity (e.g., farming and ranching), which has caused a great loss of habitat and fragmentation. In this fragmented landscape, we selected six remnants for sampling (Table I, Fig. 1), three of them entirely inserted in the Cerrado domain and the other three in the transition zone between Cerrado and Atlantic Forest. The remnants have from 1.5 to 427.52 ha, and are composed by different physiognomies, such as: woodland savanna, semi-deciduous forest, riparian forest and vereda (Table I). The climate is Aw (Koppen), with one season dry (April to September) and one wet (October to March) (Alvares *et al.*, 2014), and an elevation that varies from 500 to 640m.

1.2.2. *Data collection*

Medium and large sized mammals were defined as those over 1kg in body mass (Chiarello, 2000). In each remnant, the community of medium and large sized mammals was inventoried across the following methods: tracks, vocalization, directed visualization, burrows, and recording by camera trap during August 2016 and January 2017. The sample effort was dependent on the size of the remnants, where larger remnants had a greater effort than the smaller ones (Table I).

The active search was performed in linear transections inside the patches and at the edge. Each remnants had two transactions,one inside and other in the edge. The transections inside the remnants had a minimum distance of at least 200 m of edge, while transections in the edge were made on the outside of the remnants, in the division between the remnant and the matrix. Which varied, therefore, was the size of the transect in each remnants. Still, two field incursions were performed, registering only the presence/absence of the species. Seven camera traps were installed in trunks of trees at 40 cm on pre-existing mammalian trails and left operating 24h a day, at least 1km apart from each other. The camera trap has been programmed to take three consecutive photos when triggered, and after an interval of 30 seconds if the animal continues in front, re-trigger the sensor. The remnant one received two cameras, the other received only one camera. So, our sampling effort was of 19.3 km of active search, along with photographic trap, and 20.16 hours of cameras – night.

Images and tracks were identified based on Lima-Borges & Tomás (2004), and Hannibal *et al.* (2015b). Cervids from the genus *Mazama*, were only identified at the species level when recorded in camera trap, due to the difficulty of differentiating the tracks among species (Lima-Borges & Tomás, 2004). The taxonomic classification followed Paglia *et al.* (2012).

1.2.3. *Data analysis*

For the species richness analysis was estimated the 1st order Jackknife with 1000 randomizations (Colwell *et al.*, 2004), where each camera trap and active search per day were considered as one sample unit. In other words, the number of days that the camera were activated added to the amount of days of active search. We quantified the frequency of registration of medium and large size mammals through the total records of each species, divided by the total of records for each remnant. To obtain the average frequency of the species through the six remnants, we added the frequency of each species in the six remnants and divided by six, that is the total of sampled remnants. From this mean, we classify species according to the occurrence status as being common, frequent or rare. When the mean frequency of a species was greater than six it was classified as common (C), when it was less than six was classified as frequent (F) and, when it was less of one was classified as rare (R). Along with this, we describe the activity period of the species classified as common according to the occurrence status. For this, we used only the record per camera trap, because we need the time the individuals were registered, therefore, each camera register was considered as independent.

1.3. Results

We recorded 23 species of medium and large sized mammals, distributed in the orders Carnivora (9 species), Cingulata (3 species), Rodentia (3 species), Artiodactyla (2 species), Pilosa (2 species), Perisodactyla (1 species), Primates (1 species) and Didelphimorphia (1 species) (Table II, Fig. 2). Ten species were registered exclusively by camera trap, while four species were registered exclusively by active search (Table II), reinforcing the importance of working with complementary methodologies. The species accumulation curves demonstrated an asymptote (Jackknife 1= 8.71± 5.0 species, Fig. 3) for the remnants, suggesting that the sampling effort was sufficient to inventory the actual diversity of medium and large sized mammals in the study area.

Seven species are classified as Vulnerable in national or international red lists (ICMbio, 2014; IUCN, 2017; see Table 2), such as the two species of puma (*Puma concolor* (Linnaeus, 1771) and *Puma yagouaroundi* (É. Geoffroy, 1803)) and the Brazilian tapir *Tapirus terrestris* (Linnaeus, 1758). In addition, *Dasyprocta azarae* (Lichtenstein, 1823) is Data Deficient (IUCN, 2017). In general, these species did not presented preference for some remnants, occurring in all (Table II).

In total, five species were classified as common according to the frequency of record, for example *Tapirus terrestris* and *Cerdocyon thous* (Linnaeus, 1766). Eight species were classified as frequent, such as *Mazama gouazoubira* (G. Fischer, 1814) and *Dasyprocta azarae*. Finally, ten species are classified as rare, such as *Puma yagouaroundi* and *Priodontes maximus* (Kerr, 1792) (Table III).

Regarding their pattern of activity, *Myrmecophaga tridactyla* (Linnaeus, 1758) and *Dasypus novemcinctus* (Linnaeus, 1758) were classified as twilight and nocturnal. *Tapirus terrestris* was active during the day, but with nocturnal preference, *Cerdocyon thous* was active during the day and the night, but with twilight preference and *Cuniculus paca* (Linnaeus, 1766) was strictly nocturnal (Fig. 4).

1.4. Discussion

The study area presented a richness of medium and large sized mammals, as we recorded 45.1% of all species present in the Cerrado biome. The order Carnivora had the highest richness, which was expected since this biome holds the highest diversity of this group in relation to other biomes (Paglia *et al.,* 2012). Most important, we registered species that were not inventoried in the last list of mammals for the southern region of the biome (Hannibal *et al.,* 2015), were they: *Puma yagouaroundi*, *Priodontes maximus*, *Mazama gouazoubira,* and *Cuniculus paca*. Two of these species (*P. yagouroundi* and *P. maximus*) are classified as vulnerable in the red lists national or international (ICMbio, 2014; IUCN, 2017), and their living in the region depends on the maintenance of preserved habitats. This finding denotes the importance of such studies, and also, the importance of the area for the preservation of medium and large sized mammals.

Indeed, although the southern region of the Goiás state is highly fragmented, it still harbor an expressive fauna of medium and large sized mammals, including species threatened. The occurrence of these species from small to large remnants indicates that they are widely distributed throughout the landscape. However, any conservation plan should consider that the presence of these species in small remnants may be only for temporary use of resource (Calaça *et al.,* 2010). Thus, conservation strategies should take into account the delimitation of corridors to connect these remnants, thus enabling the effective conservation of the threatened species in the region.

The frequency of occurrence of the species is more related to biological and ecological characteristics, such as detection degree, habitat use, and home range (Kasper *et al.*, 2007), but still, it can tell us how often the species move through the remnants. *Myrmecophaga tridactyla*, *Dasypus novemcinctus*, *Tapirus terrestris*, *Cerdocyon thous* were reported as common or with occurrence in several remnants in the nearby, which was expected since they have large home range, and therefore, can be recorded more frequently (Reis *et al.,* 2011; Bernardo & Melo, 2013; Hannibal *et al.,* 2015). Other species classified as rare (e.g., *Chrysocyon brachyurus* (Illiger, 1815), *Euphractus sexcinctus*, *Lontra longicaudis* (Olfers,1818), and *Puma concolor*) are cited in other works as difficult to be found (Hannibal *et al.,* 2015a, Kasper *et al.,* 2007). We believe that this rarity is related to characteristics of the species itself, which have small size, efficient camouflage and are sensitivity to anthropic presence.

According to the literature (Van Schaik & Griffiths, 1996) there is a relationship between period of activity and body size for Indonesian rainforest mammals and we believe this may be the case for some species recorded in our study, since species with large body size as *Tapirus terrestris, Myrmecophaga tridactyla*, and predatory species as *Cerdocyon thous* had a greater variation in the period of activity, occurring both in the nocturnal and diurnal period. Species with smaller body size such as *Dasypus novemcinctus* and *Cuniculus paca* prefer night periods, which according with Gómez *et al.* (2005) is an anti-predation behavior.

Therefore, we underline that the southern portion of the Cerrado in the Goiás state, although fragmented, still harbor an expressive fauna of medium and large sized mammals, including threatened species distributed through all the landscape and without remnant selectivity. However, we reinforce the necessity for conservation measures that should be planned for the region, in order to these remnants can continue, or even increase, the potential for dispersal and surviving of these species.

1.5. Acknowledgements

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Table legends:

Table I. Data for the sampled remnants. Physiognomy type: ws: woodland savanna, sf: semi-deciduous forest, rf: riparian forest, ve: vereda, of the remnants (ha) and sampling effort for the camera trap and active search by remnants, for six patches studied in the central-south of Brazil.

Table II. Species list of medium and large-sized mammals from the six remnants in the central-south of Brazil. National threat category according ICMBIO (2014), and international threat category according to IUCN (2016): vulnerable (VU), near threatened (NT), data deficient (DD). Methods: camera trap (C) burrow (B), direct observation (D), vocalization (V), tracks (T).

Table III. Frequency of record for each species in percentage (%), and status the occurrence: C (common), F (frequent) and R (rare), for six remnants in the central-south of Brazil.

Figure legends:

Fig. 1. Distribution of the six sampled remnants studied in the central-south of Brazil.

Fig. 2. Photographic records, footprints and burrows of medium and large sized mammals: A) *Priodontes maximus*, B) *Chrysocyon brachyurus*, C) *Leopardus pardalis*, D) *Tapirus terrestris*, E) *Pecari tajacu*, F) *Eira Barbara* in the six remnants in the central-south of Brazil.

Fig. 3. Species accumulation and rarefaction curves (jackknife) for medium and large sized mammals in the six remnants in the central-south of Brazil.

Fig. 4. Activity period for the common species of medium and large sized mammals (*Dasypus novemcinctus, Tapirus terrestris, Cerdocyon thous, Cuniculus paca* and *Myrmecophaga tridactyla*) for the six remnants in the central-south of Brazil. The central axis indicate the amount of records by photographic, and the bars indicate the amount of records for each hour of the day (1 to 24:00 hrs).

Table I.

					Sample effort	
Patch	Latitude	Longitude	Physiognomy	Area (ha)	Camera Trap (H)	Active Search (km)
1	18°14'40.29"S	51°10'19.60"W	ws	427.52	5.760	6
2	18°15'31.78"S	51° 8'49.04"W	ws, rf	13.64	2.880	2.6
3	18°15'28.99"S	51° 9'0.71"W	ws	1.5	2.880	1.2

4	18°29'8.51"S	50°46'35.47"W	rf, ve	28.33	2.880	3.6
5	18°28'46.65"S	50°46'4.85"W	rf, ,sf, ve	18.52	2.880	3
6	18°29'1.97"S	50°45'26.23"W	ws	14.42	2.880	2.7
				Total	20.16	19.3

Table II.

ORDEM/Family/*Species*	Patches	ICMbio	IUCN	Methods
DIDELPHIMORPHIA – Didelphidae				
Didelphis albiventris (Lund, 1840)	5,6			C
PILOSA – Myrmecophagidae				
Myrmecophaga tridactyla (Linnaeus, 1758)	1,3,6	VU	VU	C
Tamandua tetradactyla (Linnaeus, 1758)	1,3,6			C
CINGULATA – Dasypodidae				
Dasypus novemcinctus (Linnaeus, 1758)	1-6			C,T,B
Euphractus sexcinctus (Linnaeus, 1758)	2			T
Priodontes maximus (Kerr, 1792)	1	VU	VU	C,B
Cabassous unicinctus (Linnaeus, 1758)	2			
PRIMATES – Cebidae				
Sapajus libidinosus (Spix, 1823)	1,4			C,V
CARNIVORA – Felidae				

Leopardus pardalis (Linnaeus, 1758)	2			C
Puma concolor (Linnaeus, 1771)	1	VU		C,T
Puma yagouaroundi (É. Geoffroy, 1803)	5	VU		C
CARNIVORA – Canidae				
Cerdocyon thous (Linnaeus, 1766)	2,3			C,T
Chrysocyon brachyurus (Illiger, 1815)	2	VU	NT	T
Lycalopex vetulus (Lund, 1842)	1,2	VU		T
CARNIVORA – Mustelidae				
Eira barbara (Linnaeus, 1758)	1,3,5			C,T
Lontra longicaudis (Olfers, 1818)	4			T
CARNIVORA – Procyonidae				
Procyon cancrivorus (G. Cuvier, 1798)	2,5			C,T
PERISSODACTYLA – Tapiridae				
Tapirus terrestris (Linnaeus, 1758)	1-5	VU	VU	C,T
ARTIODACTYLA – Tayassuidae				
Pecari tajacu (Linnaeus, 1758)	1,2,6			C,T
ARTIODACTYLA – Cervidae				
Mazama gouazoubira (G. Fischer, 1814)	1,2			C
RODENTIA – Caviidae				
Hydrochoerus hydrochaeris (Linnaeus, 1766)	4,5			T
RODENTIA – Dasyproctidae				

Dasyprocta azarae (Lichtenstein, 1823)	1,2	DD	C,T
RODENTIA – Cuniculidae			
Cuniculus paca (Linnaeus, 1766)	4,5		C,T

Table III.

Species	Mean %	Status the occurrence
Didelphis albiventris	1.77	F
Myrmecophaga tridactyla	10.07	C
Tamandua tetradactyla	4.09	F
Cabassous unicinctus	0.28	R
Dasypus novemcinctus	34.94	C
Euphractus sexcinctus	0.28	R
Priodontes maximus	0.12	R
Sapajus libidinosus	1.0	F
Leopardus pardalis	0.41	R
Puma concolor	0.25	R
Puma yagouaroundi	0.73	R
Cerdocyon thous	6.44	C
Chrysocyon brachyurus	0.28	R

Lycalopex vetulus	0.41	R
Eira barbara	1.04	F
Lontra longicaudis	0.79	R
Procyon cancrivorus	0.53	R
Tapirus terrestris	16.91	C
Pecari tajacu	4.34	F
Mazama gouazoubira	1.97	F
Hydrochoerus hydrochaeris	1.03	F
Dasyprocta azarae	2.54	F
Cuniculus paca	9.61	C

Fig.1

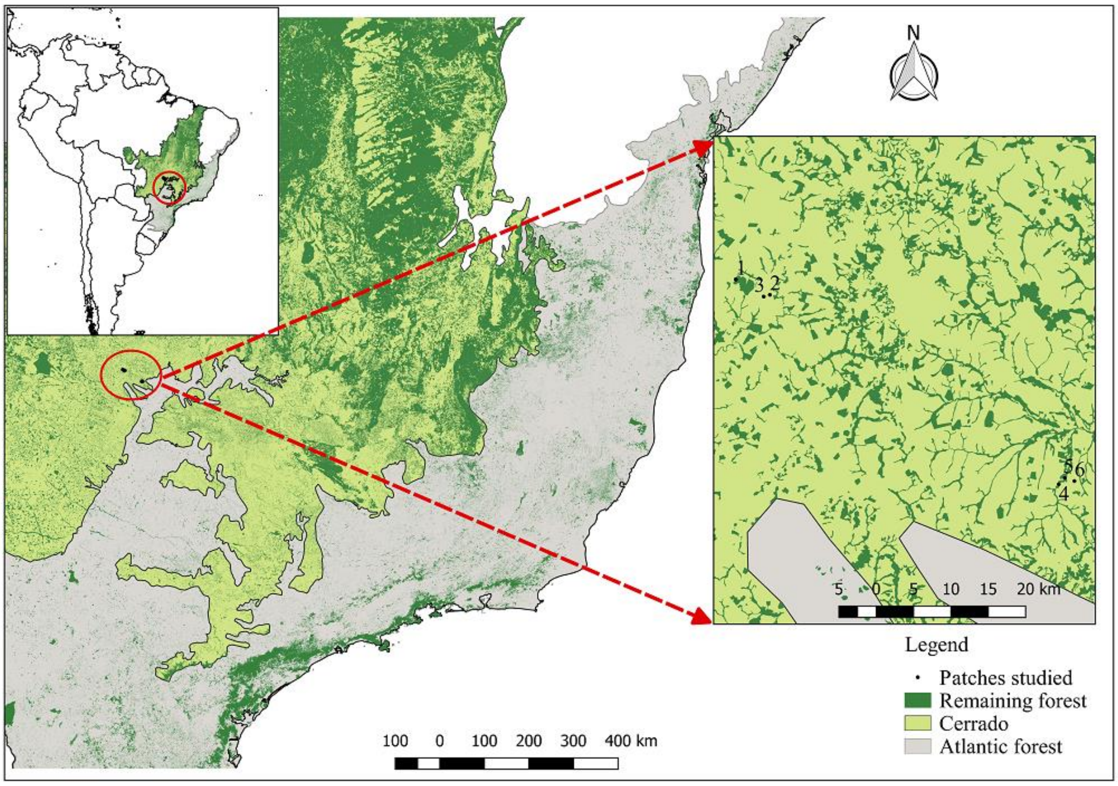

N
1
3 2
5 6
4
5 0 5 10 15 20 km
100 0 100 200 300 400 km
Legend
Patches studied
Remaining forest
Cerrado
Atlantic forest

Fig.2

Fig.3

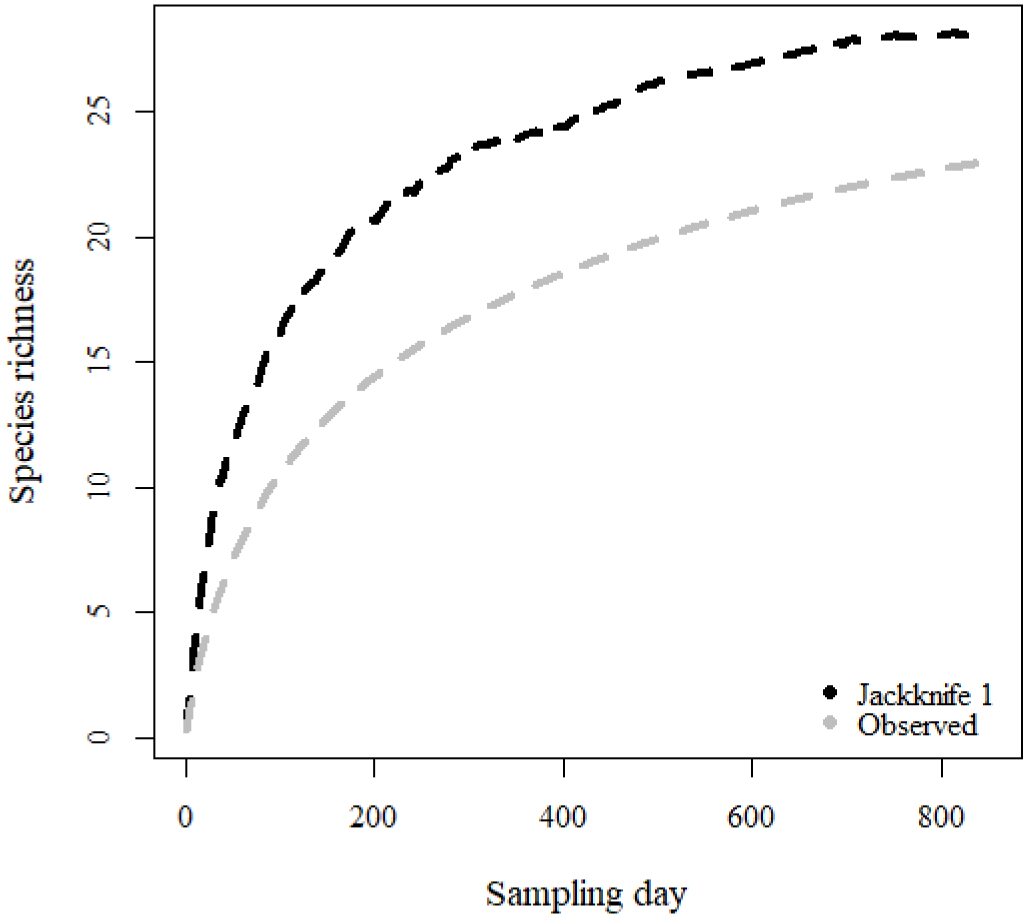
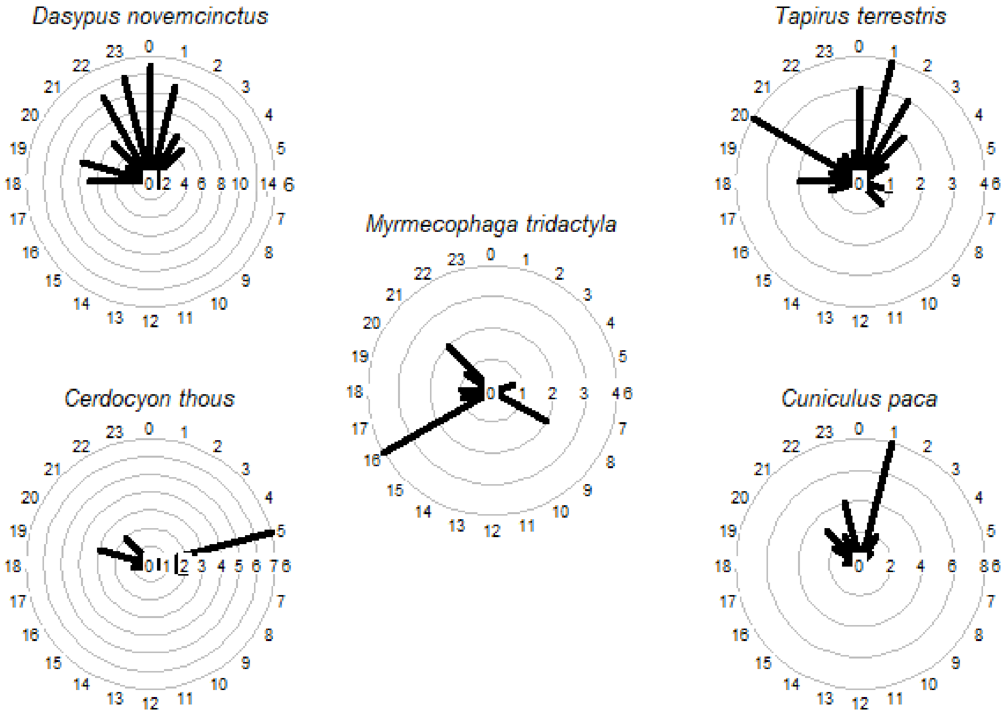

Species richness
0
5
10
15
20
25
0
200
400
600
800
Sampling day
Jackknife 1
Observed

Fig.4


Dasypus novemcinctus
Tapirus terrestris
Myrmecophaga tridactyla
Cerdocyon thous
Cuniculus paca

CAPÍTULO II - **Patch attributes affect the functional diversity of forest medium-and large-sized mammals**

(Normas de acordo com a revista Journal of Mammalogy)

Abstract: Here, we inventoried the medium and large sized mammals in nine patches in the South of Central Brazil and investigated if patch and landscape attributes influence their functional diversity (FD). We inventoried the species from August 2016 to January 2017 by considering traces, vocalization, burrows and recording by photographic trap. For patch attributes, we considered the variables Patch size, Shape and NDVI. For landscape, we considered Patch Amount (PA), Mean distance to nearest neighbor (MDNN), Edge density (ED), Mean shape (MS), Percentage of native cover (% NV) and Mean patch size (MPS). FD was calculated using the ecological traits body mass, behavior, locomotion form, dietary and environmental sensitivity. For the analyses, the species were separated in two groups, High forest dependency (HFD) and Low forest dependency (LFD). We used Akaike information criterion to select the best generalized linear model explaining the FD at the local (patch) and landscape scale separately. In the patch scale, medium and large sized mammals with HFD were influenced by patch size, and species with LFD were influence by the shape of the patch. Already in landscape scale, medium and large sized mammals with HFD were influenced by edge density, and mammals with LFD were influenced by mean distance to nearest neighbor (MDNN) and edge density. Our results showed that analyses in two scales with distinction of HFD and LFD groups is a better approach to evaluate the patterns of diversity for medium and large sized mammals.

Keywords: Edge density, High forest dependent, Low forest dependent, Patch sized.

Resumo: Aqui, inventariamos médio e grandes mamíferos in nove manchas no sul do Brasil central e investigamos se atributos de mancha e paisagem influenciam sua diversidade funcional (FD). Inventariamos as espécies de agosto de 2016 a janeiro de 2017 considerando vestígios, vocalizações, tocas e registros por armadilhas fotográficas. Para atributos de mancha, consideramos as variáveis Tamanho da mancha (PS), Forma and NDVI. Para paisagem, consideramos Quantidade de mancha (PA), Média da distância paro vizinho mais próximo (MDNN), Densidade da borda (ED), Média da forma (MS), Porcentagem de vegetação nativa (% NC) e Média do tamanho das manchas (MPS). FD foi calculada usando os traços ecológicos, massa corporal, comportamento, forma de locomoção, dieta e sensibilidade ambiental. Para as análises, as espécies foram separadas em dois grupos, Alta dependência florestal (HFD) e Baixa dependência florestal (LFD). Utilizamos o Critério de informação de Akaike para selecionar os melhores modelos lineares generalizados que explicasse a FD no local (mancha) e paisagem separadamente. Na escala de mancha, médio e grandes mamíferos com HFD foram influenciados pelo tamanho da mancha, e espécies com LFD foram influenciadas pela forma da mancha. Já na escala de paisagem, médio e grandes mamíferos com HFD foram influenciados pela densidade da borda, e mamíferos com LFD foram influenciados pela média da distância para o vizinho mais próximo e densidade da borda. Nossos resultados demonstram que análise em duas escalas com diferenciação em grupos de HFD e LFD é uma boa abordagem para avaliar o padrão de diversidade para médio e grandes mamíferos.

Palavras-chave: Densidade da borda, Alta dependência florestal, Baixa dependência florestal, Tamanho da mancha.

2.1. Introduction

The world's biodiversity has been continuously under threat since the influence of the contemporary human civilization on the ecosystems (Steffen et al., 2011), in which most of the Earth biomes are currently severally impacted (Myers et al., 2000). The Cerrado is one of the biomes considered as a biodiversity hotspot, which has been threat in the last years mainly due to changes in land use practices (Myers et al., 2000; Klink and Machado, 2005). This biome keeps a high richness of mammals, with a total of 251 species, of what 32 are considered endemic (Paglia et al., 2012). Within the mammals group, the medium and large sized species are of great ecological importance, which, due to their high diversity, occupy distinct niches performing different functions (Paglia et al., 2012). The ecological function of medium and large sized mammals can be, for instance, controlling population levels of their prey, seed dispersers, seed predators and folivores (Norrdahl and Korpimaki, 1995; Galetti et al., 2001; Terborgh et al., 2001; Wright, 2003). Besides that, they are found in a variety of environments, occupying the terrestrial, arboreal and semi-aquatic environments (Paglia et al., 2012). The loss of these ecological functions owing to the conversion of native vegetation may reduce future options to ensure provision of ecosystem goods and services (Díaz et al., 2007). Unfortunately, the functional diversity (FD hereafter) of medium and large sized mammals has been shown to be strongly affected by landscape characteristics such as patch size in the Atlantic forest (Magioli et al., 2015). Thus, understanding how the functional diversity of this group is influenced by change in the patch and landscape is of utmost importance for conservation, especially in highly threatened biomes such as the Cerrado.

The FD is characterized as the variation in species and their characteristics that influence the functioning of communities (Cianciaruso et al., 2009), and its measure reflects, therefore, the role of species interactions and trait diversity that are supposed to be linked to ecosystem functioning (Petchey and Gaston, 2006). However, measuring the effects of land use in the FD of medium and large sized mammals of the Cerrado is challenge, because this biome is very heterogeneous in its vegetal formations, with open and forested physiognomies (Ratter et al., 1997), which harbor a different diversity of mammals (Pinho et al., 2017). Due to their wide diversity, in general, groups as carnivores, marsupials, anteaters and armadillos seem to occupy both physiognomies of open and forested environments, whereas groups such as ungulates, rodents, and primates are more limited to forested environments. Canids, in turn, prefer open areas (Paolino et al., 2016). In addition, this pattern of occupying different physiognomies is related with life historic and biogeographic factors, but also influenced by effect of land use change on different groups of mammals. For example, Silva et al. (2015) described that patch sized is crucial for explaining Neotropical primate occurrence. On the other hand, Calaça et al. (2010) did not found significant relationship between patch size versus richness of carnivore. Therefore, it is clear that within the medium and large sized mammals, subgroups are affected in different ways by land-cover changes. Still, even within the subgroups some variation has been observed, as for example, the different forms in which forest cover influences carnivore species in the Atlantic Forest (Regolin et al., 2017). Therefore, to minimize these challenges, we propose a new approach to evaluate diversity patterns for medium and large sized mammals. It consists in separating the species in two groups: mammals with "High forest dependency (HFD)" and those with "Low forest dependency (LFD)". This classification is important because mammals with LFD theoretically should not suffer from patch attributes, and similarly, mammals with HFD should not suffer from landscape attributes. Analyzing these groups separately should provide better understanding about the factors, from local to large scale, influencing FD of mammals in heterogeneous environments (Turner, 2005).

Recent studies have showed the influence of landscape and patch metrics at more than one scale for mammals occurrence (see Lyra-Jorge et al., 2010 for carnivore; Arroyo-Rodríguez et al., 2013 for primates, and Garmendia et al., 2013 for medium and large sized mammals), but no one study has analyzed the FD of medium and large sized mammals taking into account the differences in patch and landscape scales for the Cerrado biome so far. Therefore, here we inventoried the species diversity and presented the FD for medium and large sized mammals in nine patches in the south of Central Brazil. We also investigated if patch and landscape attributes affected FD in the two groups, HFD and LFD mammals (Table 1).

At the patch scale, internal factors such as resource and habitat quality, are probable to determine the occurrence of species (Oliveira and Hannibal, 2017; Santos-Filho, et al., 2012). In this case, we expect that these variables will only influence the group of HFD, based on previous observations that these mammals cannot utilized the matrix as easily as they use the landscape (Paolino et al., 2016). For example, primates (HFD) are more influenced by patch scale than by landscape (Carretero-Pinzón et al., 2016). Forward, we believe that mammals with LFD not are influenced by patch scale, because they use the matrix with same facility as the patch. For instance, previous studies did not find relationship between patch size and richness for carnivora, which in general, have low forest dependency, with greater occurrence in buffer areas (Calaça et al., 2010; Paolino et al., 2016). At the landscape scale, the variables implicated are configuration and colonization rates. Thus, and based on previous observations that mammals with LFD are able to use the landscape as a whole due its high dispersion capacity though the matrix (Lyra-Jorge et al., 2010; Garmendia et al., 2013), we expect that the FD of both groups will be influenced for any variable of landscape (Table 1).

2.2. Material and Methods

2.2.1. *Study area*

The study area was located in South of Central Brazil, inside the Cerrado Biome, where we sampled nine patches (Fig. 1, and Table S1, Supplementary Material), varying from 1.5 to 1712.01 ha. In general, the patches are composed by the physiognomies of "woodland savanna", "semi-deciduous forest", "gallery forest", "riparian forest" and "vereda", with elevation varying from 500 to 650 m. The landscape is composed of monoculture, tree crop, and pasture for livestock. The climate is Aw (Koppen), with one season dry (April to September) and one wet (October to March) (Alvares et al., 2014).

2.2.2. *Data collection*

We inventoried the medium - and large - sized mammals from August 2016 to January 2017. For this, in each patch, we considered: tracks, vocalization, burrows and recording by camera trap. Here, medium and large sized mammals were defined as those over 1kg (Chiarello, 2000). The sample effort was dependent on the size of the patch, therefore, larger patches had greater sampling effort than small patches (Table S1, Supplementary Material).

We made the active search in linear transections within the patches. In total, two field incursions were performed in each patch registering only as presence/absence of the species. The active search was performed in linear transections in edge (between the matrix and patch) and inside of patch (the last, obeying a minimum distance from the edge of 200 m). The size transections varied in function of the patch size.

In addition, we use 15 camera traps of model Bushell 119436, which were distributed according to the size patches and obeying a minimum distance of 1km from one to another and installed in trunks of trees at 40 cm on pre-existing mammalian trails operating 24h a day, at least 1km apart from each other (Table S1, Supplementary Material). The camera trap has been programmed to take three consecutive photos when triggered and after an interval of 30 seconds if the animal continues in front, re-trigger the sensor. Resulting in a total effort of 43.120 h cameras/night, photographic trap and 42.3 km of active search.

Images, traces among others were identified on the bias of in Lima-Borges and Tomás (2004), and Hannibal et al. (2015b). The taxonomic classification follows that of Paglia et al. (2012).

2.2.3. *Extracting the patch and landscape attributes*

Patch and landscape metrics were extracted for the nine patches. For patch metrics, we consider each patch as a sampling unit, but for landscape attributes, we created buffers at 5km from the edge of each patch. We use satellite image Landsat-8 for the year of 2016 available in INPE (http://www.inpe.br/) to extract the metrics. To represent the patch scale, we select the variables normalized difference vegetation index (NDVI), shape and patch size of the patch (see Table S2, Supplementary Material). For NDVI, we used the bands Red and Near Infrared. For shape and area, we classify imagens and extracted these parameters with the QGIS software (version 2.18.1). For landscape analyses, we used Patch amount (PA), Mean distance to nearest neighbor (MDNN), Edge density (ED), Mean shape (MS), Percentage of native cover (% NV) and Mean patch size (MPS), however, we excluded some due to the multicollinearity between the same(see Statistical analyzes and for importance of metrics, see Table S2, Supplementary Material).

2.2.4. *Data analysis*

2.2.4.1. *Functional diversity analysis*

We use the measure described for Patchey and Gaston (2002, 2006) to calculate FD for medium and large size mammals, where we: (1) created a trait matrix for assemblage of each patch (see Table S3, and S4, Supplementary Material), (2) converted the trait matrix in a distance matrix, (3) produced a functional dendrogram with grouping species, (4) and, summed the total length of each branch of the dendrogram to calculate a value of FD for each patch. We also use the modified distance of Gower for the distance matrix (Pavoine et al., 2009).

First, we estimated the FD for all species of medium and large size mammals and then separately for the two groups: HFD and LFD (see Table S3 and Table S4, Supplementary Material). We used the FD value of the complete assemblage (with all medium and large sized mammals for the region) for each patch, and we use the same to standardize values for all other assemblages (of each patch), with values ranging of 0 to

1. We use the functional traits type: Physical, Dietary and Ecological (see Table S5, Supplementary Material). For the functional group of LFD, we exclude the trait “arboreal” from the analyses.

2.2.4.2. _Statistical analyzes_

Due to the differences among the measures of the functional data, we utilized the function “decostand” of the package vegan (Jari Oksanen et al., 2017) of R software to standardize the metrics and make them comparable.

We calculated the spatial autocorrelation through the Mantel test for species composition with the vegan package (Jari Oksanen et al., 2017). The result (r= 0.21, p= 0.12) showed no significant spatial autocorrelation between mammal occurrence and the spatial locations of centroid of our nine patches sampled. Next, we checked for multicollinearity between predictor variables, for landscape and patch, through the Pearson’s correlation test. We found a high correlation (r> 0.6) for four variables, NDVI, MS, %NC and MPS, which were excluded from the analyzes (see Table S6 and S7, Supplementary Material). After, we use generalized linear model (GLM) to analyze the FD of two groups (HFD and LFD) and multi-scale attributes and used the Akaike’s Information Criteria (AIC) from the package mass (Venables and Ripley 2002) to select the best model with the set of variables related to each one of our hypotheses described in the Table 1. We performed all analysis in R 3.4.0 (R Core Team, 2017).

2.3. Results

We recorded 29 species of medium and large size mammals, distributed in eight orders and 15 families, in the nine sampled patches (see Table S8, Supplementary Material). The FD varied from 0.14 % to 0.40 % for LFD, and from 0.15 % to 0.49 % for HFD in relationship with the general assemblage distributed in the study area (Table 2).

2.3.1. *Influence of patch attributes in the FD*

The best model selected by AIC for patch scale influencing FD of medium and large size mammals with HFD was PS + Shape (Table 3). For this, Shape not presented a significant relationship (*p*= 0.07, *b*= 0.59). However, for PS, we obtained a relationship positive and significant (*p*=0.002, *b*= 0.95; Fig. 2), supporting our initial prediction P1 (Table 1).

For LFD species, the best model selected by AIC for patch scale was also PS + Shape (Table 3). However, the relationship was positive but not significant for PS (p=0.4, b= 0.27) and Shape (p=0.3, b=0.42). Therefore, this corroborate our initial prediction P2 that mammals with LFD would not be influenced by patch variables.

2.3.2. *Influence of landscape attributes in the FD*

The best model selected by AIC for landscape scale for FD of medium and large size mammals with HFD was ED (Table 3). The test showed a relationship negative and significant (p= 0.02, b= -0.61; Fig. 3). This corroborate our initial prediction P3 that medium and large size mammals with HDF would be influenced by landscape variables.

The best model selected by AIC for landscape scale for FD of medium and large size mammals with LFD was MDNN + ED (Table 3). Here, we obtained a negative and not significant relationship for MDNN (p= 0.11, b= -0.72) and for ED (p=0.17, b= -0.42), refuting therefore our initial prediction P4 that these species would be affected by landscape variables.

2.4. Discussion

The species inventoried in our study represent 56.86% of all medium and large sized mammals from the Cerrado biome. Comparing with other recent studies for the region (Hannibal et al., 2015a; Oliveira and Hannibal, 2017), our study contributes to the addition of four species: *Sapajus cay* (Illiger, 1815), *Leopardus wiedii* (Schinz, 1821), *Tayassu pecari* (Link, 1795) and *Mazama gouazoubira* (G. Fischer, 1814), suggesting that there is still a lack of knowledge about medium and large sized mammals in the South Central Brazil. Meanwhile, the FD values was very representative when dealing with this number of patches, where we recorded only in a patch, 40% of FD for all medium and large sized mammals with geographical distribution for the region of study. These values of FD, along with the addition of new species to the list of the region South of Central Brazil, shows that the region still lack studies that record the diversity of medium and large sized mammals.

2.4.1. *Influence of patch attributes in the FD*

The positive and significant influence of the patch size on FD of medium and large sized mammals with HFD suggests that large patches hold higher FD. A possible explanation for this result is that the greater the patch, the greater the heterogeneity, diversity and increase abundance of species (Tews et al., 2004), as expected by the specie-area relationship. Beyond that, small patches function as a temporary source of resources (Lindenmayer et al., 2000), so, cannot keep a large assembly of medium and large sized, resulting in low values of FD. Therefore, larger patches support greater occurrence, richness and FD of mammals than small patches (Chiarello, 1999; Arroyo-Rodríguez and Dias, 2010; Magioli et al., 2015). Consequently, these results support the observation that larger patches are priority for conservation, because they support more complex communities with HFD.

Medium and large sized mammals are a diversity group occupying diverse habitats (Reis et al., 2011), with species restricted to specific habitats (*Lontra longicaudis*, Olfers, 1818), while others (*Chrysocyon brachyurus* (Illiger, 1815), *Nasua Nasua* (Linnaeus, 1766)) are more generalist (Marinho-Filho et al., 2002). Analyses that ignore such differences and group together HFD and LFD species assume that FD for both groups is affected in the same way, however, we have showed that this is not true. The shape of the patch usually influences in its quality thus decreasing edge effects, and therefore, it should be expected that it did not affect the FD of LFD. When we have grouped only mammals with LFD, we believe that the effect of patch variables about FD would disappear, which in fact occurred, because mammals with LFD use the matrix in a similar way as they use the patches. This can happen due to large living area and high dispersion capacity of this group (Reis et al., 2011; Hannibal et al., 2015b; Paolino et al., 2016). As far as we know, this is the first work with medium and large sized mammals that use this criterion for separating the two groups in relation to the FD. We encourage other researches to use this grouping criteria approach, thus avoiding overestimating the effect of patch variables on medium and large sized mammals FD.

2.4.2. *Influence of landscape attributes in the FD*

Edge density best explained the FD of medium and large size mammals with HFD, which is related to the increasing connectivity and colonization rates. Garmendia et al. (2013) reported the influence of ED in the richness of medium and large sized mammals in a landscape with 100 ha. Lyra-Jorge et al. (2010) found a negative and significant relationship between occurrence of carnivorous and ED in landscape with scale of 2 km. Here, we added the influence of ED in functional diversity of medium and large sized mammals with HFD with scale of 5km, and we suggest that this metric should be taken into account for conservation management.

Edge density and MDNN together influence the connectivity and colonization rates (Forero-Medina and Vieira, 2007; Garmendia et al., 2013). However, when we analyze the influence of these metrics on FD of medium and large sized mammals assuming that they have low forest dependency, we will not expect to find such effect because they can use the matrix easily. Indeed, previous study of Calaça et al. (2010) showed that due to their high dispersion capacity, carnivores are not influenced by the distance between patches. Thus, considering their high dispersion capacity and the LFD characteristic, the FD of this group are not expected to be influenced by landscape factors.

In general, the study area, although being highly anthropized, still keeps a high FD of medium and large sized mammals, including threatened species. Besides that, for the first time we verified that for patch scale, the variables patch size and shape influenced the FD of groups differently: species with HFD were influenced by patch size, and species with LFD although not significant, had a relationship with the shape of the patch. In the landscape scale, the FD of HFD was influenced by ED and the FD of LFD although not significant, was most influenced by MDNN and ED. Therefore, we proposed for future researches of multi-scale analyses to use this approach of grouping separation, which can provide clearer results about the factors influencing FD.

2.5. Acknowledgments

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2.7. References

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Tables.

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Table 2. Functional diversity values (varying from 0 to 1) for the nine patches and for both functional groups, low forest dependence (LFD) and high forest dependence (HFD).

Table 3. AIC values from model selection for the variables of landscape and patch attributes in the nine patches in the South of Central Brazil. Patch size (PS), Shape, NDVI, Patch amount (PA), Mean distance to nearest neighbor (MDNN), Matrix quality (QM) and Edge density (ED).

Figures.

Figure 1. Distribution of the nine patches sampled in nine patch in the South of Central Brazil.

Figure 2. Relationship between functional diversity and patch size for medium and large-sized mammals with high forest dependency in the nine patches in South of Central Brazil.

Figure 3. Relationship between functional diversity and edge density for medium and large-sized mammals with high forest dependency in the nine patches in South of Central Brazil.

Supporting Information

Table S1. Geographic location data of the patches studied in the Cerrado in South of Central Brazil.

Table S2. Variables extracted from the nine patches in the Cerrado in South of Central Brazil, and their importance for mammal's occurrence. NDVI – Normalized Difference Vegetation Index.

Table.S3. Input table of presence and absence of mammals with high forest dependence used in the analyses of functional diversity, for the nine patches (A1 to A9), along with the sample A10 representing the general assemblage of all species for the region.

Table S4. Input table of presence and absence of mammals with low forest dependence used in the analyses of functional diversity, for the nine patches (A1 to A9), along with the sample A10 representing the general assemblage of all species for the region.

Table S5. Traits data used to calculate functional diversity of medium and large-sized mammal assemblages of the Cerrado in South of Central Brazil. Source references for these data are provided below.

Table S6. Correlation values between variables of patch scale for the nine patches sampled in South of Central Brazil. The variables with correlation values > 0.6 were removed (in bold). Patch size (PS), Normalized Difference Vegetation Index (NDVI).

Table S7. Correlation values between variables of landscape scale for the nine patches sampled in South of Central Brazil. The variables with correlation values > 0.6 were removed (in bold). Patch amount (PA), Mean distance of the nearest neighbor (MDNN), Matrix quality (MQ), Edge density (ED), Mean shape (MS), % Native cover (%NC) and Mean patch size (MPS).

Table S8. Species list of medium and large-sized mammals in nine forest patches in South of Central Brazil. International threat category: (IUCN, 2016) and ICMBIO (2014): vulnerable (VU), near threatened (NT), data deficient (DD). Methods: Camera trap (c) burrow (B), direct observation (D), vocalization (V), tracks (T).

Tables.

Table 1.

Hypotheses	Predictions	References
H1: In patch scale, variables that determine habitat quality, resources and less edge effects should affect mammals that are more dependent on forest, and which are more restrict to the patch.	P1: We expect a positive and significant relationship between some of the variables at patch scale and FD of HFD.	(Carretero-Pinzón et al., 2016 Garmendia et al., 2013 ;Magioli et al., 2015)
H2: In patch scale, mammals with LFD can move through the matrix, they only use patch as stepping-stones, and they use the edge; therefore, patch variables will have no effect on them.	P2: We expect no relationship between variables at patch scale and FD of LFD.	(Calaça et al., 2010, Pinho., 2017)
H3: In landscape scale, variables that determine resources, connectivity, individual distribution, and colonization can influence the success of a species to colonize a patch.	P3: We expect that the some of the landscape variables will be negative and significantly associated with FD of HFD.	(Andrén, 1994; Lyra-Jorge et al., 2010; Garmendia et al., 2013)
H4: In landscape scale, variables related to connectivity and colonization are determinant for mammals with LFD.	P4: We expect a positive and significant relationship of connectivity and colonization with FD of LFD.	(Andrén, 1994; Garmendia et al., 2013; Lyra-Jorge et al., 2010; Paolino et al., 2016)

Table 2.

Patch	LFD	HFD
1	0.40	0.42
2	0.29	0.44
3	0.16	0.44
4	0.26	0.49
5	0.40	0.28
6	0.14	0.23
7	0.08	0.29
8	0.21	0.20
9	0.15	0.15

Table 3.

Model	AIC
HFD~ Patch scale	
HFD ~ PS + Shape	3.93
FDL ~ Patch scale	
LFD ~ PS + Shape	11.72
FDH ~ Landscape scale	
HFD ~ PA ~ MDNN + ED	8.87
HFD ~ MDNN + ED	6.91
HFD~ED	5.42
FDL ~ Landscape scale	
LFD ~ PA ~ MDNN + ED	9.66
LFD ~ MDNN + ED	8.94

Figures.

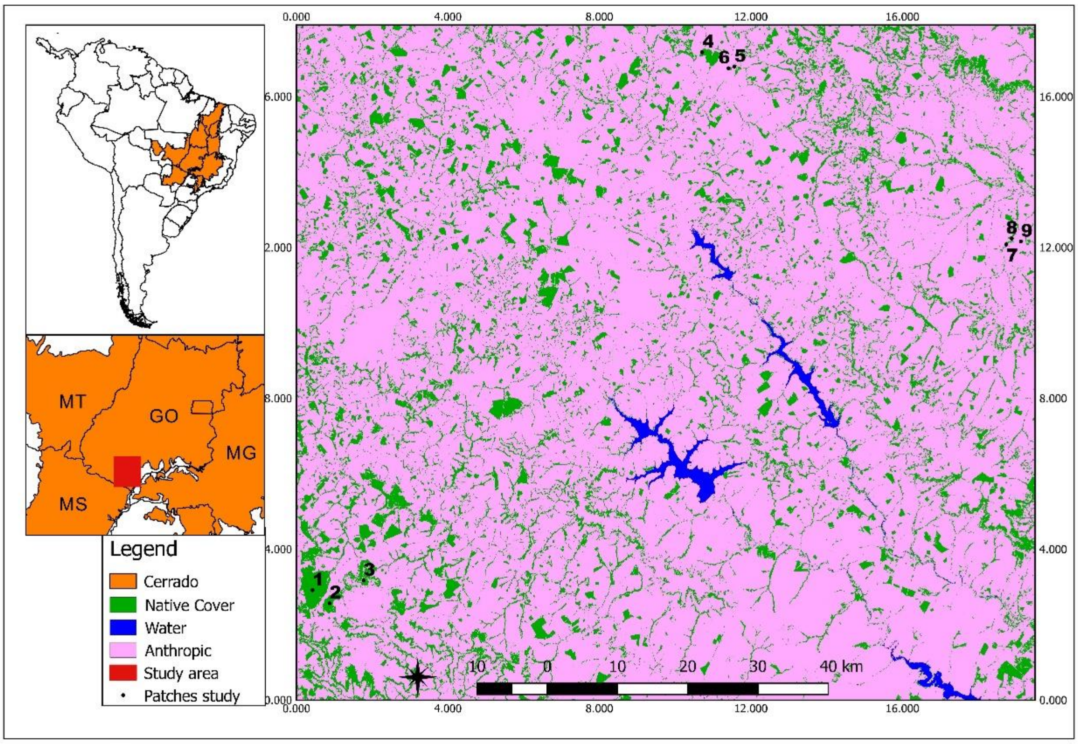

Figure 1.

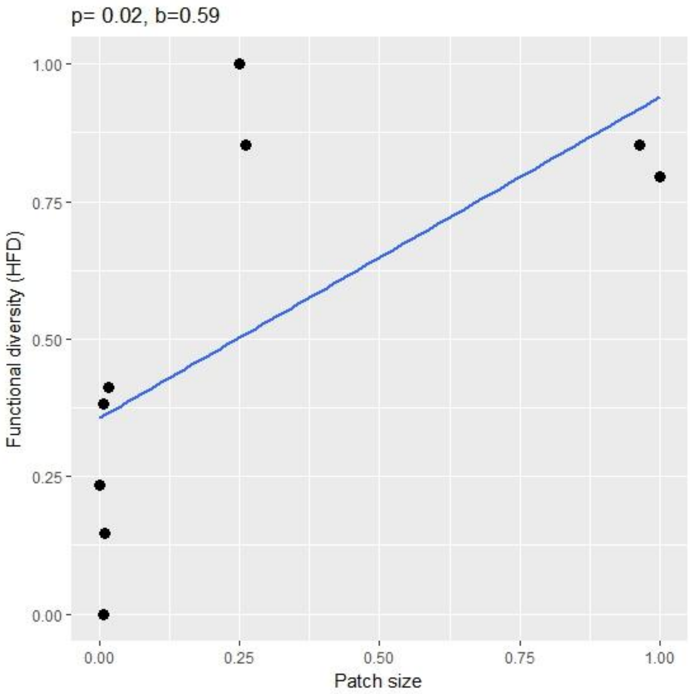

Figure 2.

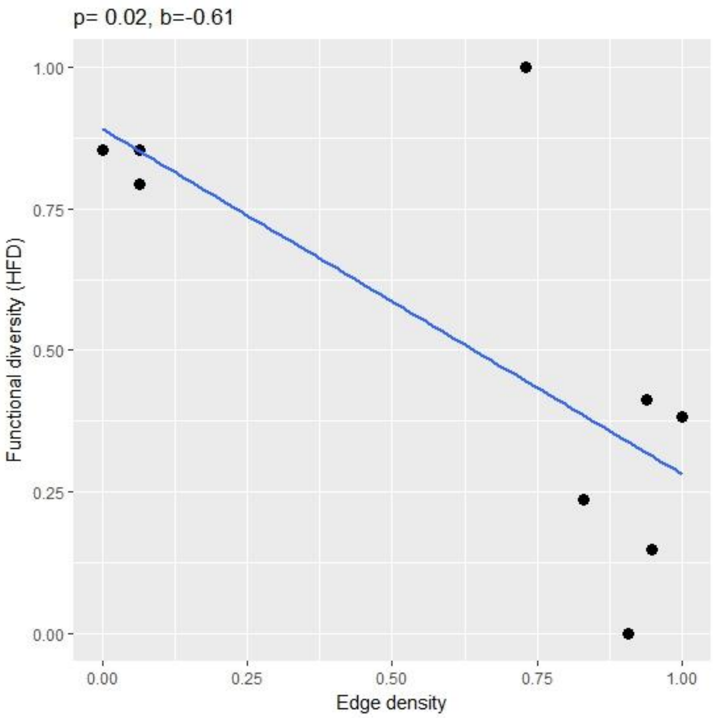

Figure 3.

Supplementary Material.

Table S1

Patches	Latitude (S)	Longitude (W)	Trap station	Camera trap night (H)	Number of transect	Active search km
1	18º55’50.16”	51°42'39.67"	4	11.520	4	9
2	18°56'51.34"	51°41'23.32"	2	5.760	3	6.2
3	18°55'6.12"	51°38'37.44"	2	5.760	3	8
4	18°14'40.29"	51°10'19.60"	2	5.760	3	6
5	18°15'31.78"	51° 8'49.04"	1	2.880	2	2.6
6	18°15'28.99"	51° 9'0.71"	1	2.880	2	1.2
7	18°29'8.51"	50°46'35.47"	1	2.880	2	3.6
8	18°28'46.65"	50°46'4.85"	1	2.880	2	3
9	18°29'1.97"	50°45'26.23"	1	2.880	2	2.7
		Total	15	43.120		42.3

Table S2

Patch scale		Reference
Variable	Importance	
Total area	Specie-area relationship, and resource availability	Fahrig (2003)
Area shape	More circular areas have less edge effects	Garmendia et al. 2013
NDVI	Habitat quality	Umetsu et al. (2008)
Landscape scale		
Variable	Importance	
Patch amount	Landscape connectivity and resources	Forero-Medina & Vieira (2007)
Mean distance from nearest neighbor	Landscape connectivity and flow of individuals	Forero-Medina and Vieira, 2007
Matrix quality	Landscape dynamics as well as distribution of individuals	Umetsu et al., 2008
Edge Density	Increased connectivity and colonization rates	Garmendia et al., 2013

Table S3

Species	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
t_tetradactyla	1			1		1			1	1
d_novemcinctus	1			1	1	1	1	1	1	1
t_terrestris	1	1	1	1	1	1	1	1		1
m_americana	1	1	1							1
p_tajacu	1	1	1	1	1				1	1
t_pecari	1	1								1
a_caraya			1							1
c_penicillata										1
s_cay		1								1

s_libidinosus				1			1			1
s_venaticus										1
e_barbara	1	1		1		1		1		1
l_longicaudis							1			1
p_brasiliensis										1
p_flavus										1
d_azarae	1		1	1	1					1
c_paca			1				1	1		1
c_prehensilis										1

Table S4

Species	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
d_albiventris		1	1					1	1	1
m_tridactyla	1			1		1			1	1
c_tatoaury										1
c_unicinctu		1								1
d_septemcinctus										1
e_sexcinctus					1					1
p_maximus	1			1						1
b_dichotomus										1
m_goauzoubira	1	1	1	1	1					1
o_bezoarticus										1
c_thous	1				1	1				1
c_brachyurus	1				1					1
l_vetulus				1	1					1

l_pardalis			1		1			1
l_tigrinus								1
l_wiedii		1		1				1
p_onca								1
p_concolo		1		1				1
p_yagouaroundi							1	1
c_simistriatus								1
g_cuja								1
n_nasua		1						1
p_cancrivorus	1				1		1	1
s_brasiliensis								1
h_hydrochaeris						1	1	1

Table S5

Trait type	**Trait**	**Range or Categories**	**Scale**
Physical	Body mass (kg)	0.25 to 260	Continuous
	Locomotion form	Terrestrial	Binary
		Fossorial	Binary
		Semi-aquatic	Binary
		Arboreal	Binary
	Social behavior	Yes or no	Binary
Dietary	Trophic guild	Carnivorous	Binary
		Frugivorous	Binary
		Insectivorous	Binary
		Herbivorous	Binary
		Omnivorous	Binary
	Food type	Small-sized vertebrates	Binary
		Large-sized vertebrates	Binary
		Invertebrates	Binary
		Fish	Binary
		Fruit	Binary
		Grasses	Binary
		Plants	Binary
		Leaves	Binary
		Seeds	Binary
	Foraging substrate	Water	Binary
		Tress	Binary
		Ground vegetation	Binary

		Ground	Binary
Environmental sensitivity	Species sensitivity	Low	Binary
		Average	Binary
		High	Binary

Table S6

Variables	PS	Shape	NDVI
PS	1.0	-0.02	0.72
Shape	-0.02	1.0	0.25
NDVI	**0.72**	0.25	1.0

Table S7

Variables	PA	MDNN	ED	MS	% NC	MPS
PA	1.0	0.51	-0.39	-0.65	0.35	0.20
MDNN	0.51	1.0	-0.33	-0.70	0.30	0.29
ED	-0.39	-0.33	1.0	0.60	-0.97	-0.96
MS	**-0.65**	**-0.70**	**0.6**	1.0	-0.67	-0.56
% NC	0.35	0.30	**-0.97**	**-0.67**	1.0	0.97
MPS	0.20	0.29	**-0.96**	-0.57	**0.97**	1.0

Table S8

ORDEM/Family/*Species*	Patches	ICMbio	IUCN	Methods
DIDELPHIMORPHIA – Didelphidae				
Didelphis albiventris (Lund, 1840)	2,3,8,9			C
PILOSA – Myrmecophagidae				
Myrmecophaga tridactyla (Linnaeus, 1758)	1,4,6,9	VU	VU	C
Tamandua tetradactyla (Linnaeus, 1758)	1,4,6,9			C
CINGULATA – Dasypodidae				
Cabassous unicinctus (Linnaeus, 1758)	2			T
Dasypus novemcinctus (Linnaeus, 1758)	1,4,5,6,7,8,9			C,T,B
Euphractus sexcinctus (Linnaeus, 1758)	5			T
Priodontes maximus (Kerr, 1792)	1,4	VU	VU	C,B
PRIMATES – Cebidae				
Sapajus libidinosus (Spix, 1823)	4,7			C,V
Sapajus Cay (Illiger, 1815)	2	VU		C
PRIMATES- Atelidae				
Alouatta caraya (Humboldt, 1812)	3			V
CARNIVORA – Felidae				
Leopardus pardalis (Linnaeus, 1758)	3,5			C
Leopardus wiedii (Schinz, 1821)	2,4	VU	NT	C
Puma concolor (Linnaeus, 1771)	2,4	VU		C,T
Puma yagouaroundi (É. Geoffroy, 1803)	8	VU		C
CARNIVORA – Canidae				
Cerdocyon thous (Linnaeus, 1766)	1,5,6			C,T
Chrysocyon brachyurus (Illiger, 1815)	1,5	VU	NT	T
Lycalopex vetulus (Lund, 1842)	4,5	VU		T
CARNIVORA – Mustelidae				
Eira barbara (Linnaeus, 1758)	1,2,4,6,8			C,T
Lontra longicaudis (Olfers, 1818)	7			T
CARNIVORA – Procyonidae				
Nasua nasua (Linnaeus, 1766)	2			C
Procyon cancrivorus (G. Cuvier, 1798)	1,5,8			C,T
PERISSODACTYLA – Tapiridae				
Tapirus terrestris (Linnaeus, 1758)	1,2,3,4,5,6,7,8	VU	VU	C,T
ARTIODACTYLA – Tayassuidae				
Pecari tajacu (Linnaeus, 1758)	1,2,3,4,5,9			C,T

Tayassu pecari (Link, 1795)	1,2	VU	VU	C,T
ARTIODACTYLA – Cervidae				
Mazama americana (Erxleben, 1777)	1,2,3		DD	C
Mazama gouazoubira (G. Fischer, 1814)	1,2,3,4,5			C
RODENTIA – Caviidae				
Hydrochoerus hydrochaeris (Linnaeus, 1766)	7,8			T
RODENTIA – Dasyproctidae				
Dasyprocta azarae (Lichtenstein, 1823)	1,3,4,5		DD	C,T
RODENTIA – Cuniculidae				
Cuniculus paca (Linnaeus, 1766)	3,7,8			C,T

3. CONCLUSÃO GERAL

Apesar de altamente antropizada, a área de estudo ainda apresenta uma expressiva fauna de médio e grandes mamíferos, e com uma alta diversidade funcional, incluindo espécies ameaçadas de extinção. Destacamos também a importância da paisagem para a manutenção da fauna de médio e grandes mamíferos, pois as espécies ocorreram de modo contínuo na paisagem.

Nossos resultados indicam que apesar dessa riqueza e alta diversidade de médio e grandes mamíferos, os mesmos são ameaçados por variáveis de mancha e paisagem, onde mamíferos com uma maior dependência florestal foram afetados principalmente por atributos de mancha (local). Por outro lado, mamíferos com uma menor dependência florestal, mesmo que não significativamente, foram afetados por atributos de paisagem. Assim, nossos resultados demonstraram que abordagens de mancha e paisagem são necessárias para conhecer e conservar a fauna de mamíferos da região.