# Biodiversity in a fragmented sugarcane landscape

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**ABSTRACT**
Sugarcane production is increasingly expanding into biodiversity rich and highly fragmented areas in Brazil. This stresses the need for management practices that merge production with conservation, however knowledge on the effects of the sugarcane landscape on biodiversity is currently limited. In this article we analyzed the effects of the fragmented sugarcane landscape on mammals, by relating the presence of mammal species to knowledge about preferred habitat. Comparison of camera trap data from the sugarcane matrix with the remaining fragments revealed that the matrix appeared to be permeable to a large share of the mammal species occurring in the region. Different reasons might underlie these results, such as scarcity of natural habitat, or the predominance of habitat generalists in the Cerrado region. Our data indicated a few negative effects with regards to the use of the matrix by mammal species, suggesting that the matrix does have a lower habitat quality compared to the Cerrado. Our habitat preference hypothesis was supported as the habitat generalists showed the highest capture frequencies in the matrix. It is too early to tell whether the limited effects of sugarcane plantations on biodiversity suggested by our results will sustain over time or worsen due to an extinction debt in this region.

**Keywords:** Sugarcane, biodiversity, Cerrado, matrix management, habitat preference

**INTRODUCTION**
Due to the growing markets for biofuel, the global production of biomass as feedstock for bioenergy is expanding. Although this expansion is expected to meet future energy demands in a sustainable manner, significant impacts on biodiversity are already observed (Immerzeel et al. 2013). One of the major energy crops used for bio-ethanol is sugarcane (*Saccharum* spp.), although the ecological effects of this crop are poorly understood yet. Sugarcane expansion is mainly taking place in Brazil, which is the world's first producer of sugarcane based bio-ethanol. The sugarcane production area in Brazil increased from about 5.4 million hectares in 2003 to 9.8 million hectares in 2013 (FAOSTAT, 2014). Due to the rapidly growing market for this renewable fuel, Brazil is expected to expand its biomass production further in the future (Martinelli and Filoso, 2008; OECD-FAO 2007-2016 (2007).

Currently, sugarcane cultivation is expanding into the biodiversity rich and highly fragmented Cerrado biome (Sparovek et al., 2007, Carvalho et al, 2009; Myers et al., 2000) The Cerrado consists of a wide variety of habitats, ranging from open grasslands to dry forests and dense woodlands, in a mosaic pattern (Diniz-Filho *et al*., 2009). Over the past 40 years, more than 50% of the natural vegetation has been converted to agricultural lands and pastures (Carvalho *et al.* 2009). Accroding to the Brazilian Forest Code, 20% of the agricultural land has to remain under native vegetation, which leads to maintenance of forest fragments of native vegetation of different Cerrado habitats in and around the sugarcane matrices.

In fragmented landscapes, such as those in the Cerrado, the quality of the agricultural matrix is crucial for biodiversity in various ways. It is considered one of the main factors that determines the susceptibility to species extinction (Laurance, 1991; Gascon et al., 1999; Fahrig, 2001; Viveiros de Castro and Fernandez, 2004). Furthermore, negative impacts of fragment isolation on biodiversity in the fragments are demonstrated to diminish when the quality of the matrix increases (Carroll and colleagues, 2004). The significance of the matrix is moreover expected to increase during progressing fragmentation, as the chance that individuals leave the fragments and enter the matrix increases (Fahrig, 2003). Recent studies even suggest that conservation efforts should primarily focus on matrix quality, instead of native fragments in the landscape (Prugh et al. 2008; Franklin & Lindenmayer, 2009). However, before entering the debate on how crop production can be reconciled with biodiversity, it is crucial to understand the relationship between biodiversity and the sugarcane matrix.

The response of biodiversity to the agricultural matrix is species-specific. Field studies demonstrated that species that use a wide variety of habitats and food types have higher tolerance to habitat loss and fragmentation and find human-altered environments more attractive than specialists at the population level (Laurance, 1991; Andrén, 1994; Swihart et al., 2003, Pardini et al. 2009). Habitat generalists are therefore expected to be more tolerant to the sugarcane matrix than habitat specialists.

This study aimed at gaining a better understanding of the effects of sugarcane production on biodiversity (on a species specific level) in fragmented areas. We chose to focus on medium- to large sized mammals, as this taxonomic group is crucial for biodiversity. Mammals drive key ecosystem processes, such as predation, grazing and seed dispersal, that are necessary to maintain biodiversity (Kerley et al. 2002; Schipper et al. 2008). Moreover, 25% of all mammals worldwide are threatened and 52% of all mammals have declining population trends, with habitat loss and degradation being the main threat, affecting 40% of the mammals (Schipper et al. 2008). Especially larger mammals are of great conservation concern as those are more vulnerable to threatening factors such as fragmentation and hunting, due to lower population densities, larger home ranges and longer life histories (Cardillo et al. 2005).

In this study, we used camera trapping to study mammal occurrence. To link mammal occurrence to effects of sugarcane, we analyzed to what extent species that occur naturally in the Brazilian Cerrado region occur in the fragmented sugarcane landscape of our study area. Further, we looked at the permeability of the matrix and how species in the remaining fragments within the sugarcane landscape relate to the sugarcane matrix. Furthermore, we studied habitat preference as a potential factor that determines species occurrence in the matrix.

## RESULTS

### Which share of the natural Cerrado species assemblage occurs in the fragmented sugarcane landscape?

The number of species detected by camera traps in the overall fragmented sugarcane landscape was compared with the natural species assemblage. Of the 36 medium- to large sized mammals known to occur naturally in the Cerrado region (Marinho-Filho et al. 2002; Rodrigues et al. 2002), 31 (86,1%) were detected by camera traps in the fragmented sugarcane landscape during both surveys. Of the 31 detected species, 11 were at risk of extinction according to the IUCN Red List (table 1).

### Zooming in on the fragmented sugarcane landscape

To study how native Cerrado species are related to the sugarcane matrix, we assessed species presence, capture frequencies and average species richness per sampling point for both the native Cerrado fragments and the sugarcane matrix.

*Detected and estimated richness in sugarcane plantations vs fragments*

Of the 31 medium- to large-sized mammal species found in the fragmented sugarcane landscape, 25 were detected in sugarcane plantations and 26 species in the native fragments. Of the species detected in sugarcane, 10 are included in the IUCN Red List, compared with 9 species in the fragments (table 1).

| Species | Common name | IUCN Red List | SC | FR |
|---|---|---|---|---|
| **C. brachyurus** | Maned wolf | NT | X | X |
| **S. venaticus** | Bush dog | NT | X | - |
| **P. onca** | Jaguar | NT | X | X |
| **L. pardalis** | Ocelot | VU | X | X |
| **L. wiedii** | Margay | VU | - | X |
| **L. colocolo** | Pampas cat | VU | X | - |
| **P. concolor** | Puma | VU | X | X |
| **M. tridactyla** | Giant anteater | VU | X | X |
| **P. maximus** | Giant armadillo | VU | X | X |
| **T. terrestris** | Lowland tapir | VU | X | X |
| **T. pecari** | White-lipped pecary | EN | X | X |

More species are expected to occur in the sugarcane matrix and native fragments than recorded in the camera trap survey, as the estimated species accumulation curves were not fully saturated yet (appendix, figure …). The species accumulation curve of the fragments leveled off at the end of the survey, while the curve of the sugarcane survey did not reach an asymptote (figure XX). The estimated species richness was 30,73 ± 3,09 species in the sugarcane matrix, and 26,9 ± 1,61 in the fragments. Therefore, the estimated number of species was similar to the observed number of species in the overall fragmented sugarcane landscape (n = 31), while the estimated values in the fragments were lower than the observed value of both the surveys. It should be noted, however, that the standard deviation was also larger for the estimate of the sugarcane surveys compared with the fragments, indicating a larger uncertainty.

*Overlap and differences between both habitat types*

Although the number of detected mammal species was similar between the matrix and native fragments, the total number of mammal species found in both habitats by camera traps was higher (n=31) (appendix 1), which implies both overlap and differences between the environments. There was an overlap of 20 species (64.5%) between the matrix and the surrounding fragments. Six species were uniquely detected in the native fragments. These included the naked-tailed armadillo (*Cabassous sp*.), bearded capuchin (C. libidinosus), margay (*L. wiedii)*, spotted paca (*C. paca),* capybara (*H. hydrochaeris*) and southern tamandua (*T. tetradactyla*). Five species were detected only in the sugarcane environment: the bush dog (*S. venaticus*), hoary fox (*P. vetulus*), howler monkey (*A. caraya.*), pampas cat (*L. colocolo*) and grey brocket deer (*M. gouazoubira*).

*Capture frequencies*

The highest capture frequencies (> 5 records/100 days) in the sugarcane matrix were obtained for tapir (*T. terrestris*; 11,10 records/100 days), crab-eating fox (*C. thous*; 10,80 records/100 days) and collared peccary (*P. tajacu*; 5,21 records/100 days). These were followed by six-banded armadillo (*E.* sexcinctus: 2,02 records/100 days), crab-eating raccoon (*P. cancrivorus*; 1,68 records/100 days), white-lipped peccary (*T. pecari*; 1,47 records per 100 days) and maned wolf (1,35 records/100 days).

For most species detected in both types of habitat, the capture frequencies were higher for the fragments than for the sugarcane matrix. Species with higher capture frequencies in the matrix compared with the fragments were the six-banded armadillo (*E. sexcinctus*), maned wolf (*C.* brachyurus), striped hog-nosed skunk (*C. semistriatus*), crab-eating fox (*C. thous*), crab-eating raccoon (*P. cancrivorus*), grey brocket deer (*M. gouazoubira*) and the jaguar (*P. onca*).

*Average species richness per sampling point in the matrix and surrounding fragments*

The average species richness per sampling point differed significantly between the two habitat types (figure XX). One-sample t-test gave a significance difference (two-tailed, $p < 0,0001$) between the average species richness detected in the sugarcane matrix (average richness=4.3; N = 30 and S.D. = 1.769) and the surrounding fragments (average richness=6.9;N=24 and S.D. = 2,10).

**Habitat preference**

<u>Composition in terms of habitat preference</u>

Of all species detected in sugarcane, 64% are considered habitat generalists, 24% prefer open habitat and 12% prefer the forest environment. These findings resemble the composition of the whole medium- to large-sized mammal assemblage of the Cerrado to a great extent; with 67% of the species being generalists, 19% preferring open habitat and 14% forest habitat.

Unique detection and non-detection in the matrix

Five species were exclusively detected in the sugarcane environment. Of these species, the hoary fox and the pampas cat are open grassland species. The howler monkey is a forest specialist and the bush dog and grey brocket deer are known to occur in both open and closed habitats. Of these species, only the pampas cat and grey brocket deer were captured more than once.

Of the six species that were exclusively detected in the fragments, the bearded capuchin and spotted paca are forest specialists and were, moreover, frequently detected in this environment. The other four species (naked-tailed armadillo, margay, capybara and southern tamandua) were detected only once in the fragments and are known to occur in various habitats.

Capture frequencies sugarcane

Except for the six-banded armadillo and the maned wolf, which are open habitat specialists, the species with the highest capture frequencies in sugarcane are all habitat generalists. The remaining species detected in sugarcane had capture frequencies of lower than one per 100 days.

Of the species detected in both sugarcane and Cerrado fragments, the species with higher capture frequencies in the matrix compared with the forest were mostly species that prefer open habitat: six-banded armadillo (*E. sexcinctus*), maned wolf (*C.* brachyurus), pampas cat (*L.* colocolo) and striped hog-nosed skunk (*C. semistriatus*). The crab-eating fox (*C. thous*), crab-eating raccoon (*P. cancrivorus*), grey brocket deer (*M. gouazoubira*) and the jaguar (*P. onca*) had higher capture frequencies in the matrix compared with the fragments and are known to occur in both open and closed habitat.

**DISCUSSION**

Our results demonstrate that potential negative effects of the fragmented sugarcane landscape on species presence were limited in this region. A large share of the species was detected in the matrix itself, amongst which both habitat generalists and specialists, indicating that species occurring in the landscape were often not restricted to presence in the remaining fragments. Species not detected in the matrix are not necessarily absent (MacKenzie et al., 2002), as the jackknife estimator predicted higher richness in the matrix than currently found. Hence, most species detected in the fragmented sugarcane landscape can occur in the sugarcane matrix, which indicates permeability of the matrix and potential connectivity between the remaining fragments. In the study of Dotta & Verdade (2011), lower species richness was found in the sugarcane matrix of South-East Brazil. Further comparisons can however not be drawn as saturation levels of species accumulation were not analyzed in their survey (Dotta & Verdade, 2011).

However, an indication of the matrix being less suitable habitat for the observed species was also found. The spatial extent of species in sugarcane was lower compared with the native fragments, as mammal richness per camera station was on average lower. Moreover, most species that were detected in both native fragments and sugarcane had higher capture frequencies in the native fragments (13 out of 20). These findings indicate that the fragments are preferred over the matrix.

High capture frequencies in the matrix were obtained for generalist species and open habitat species. For the seven species with higher capture frequencies in the matrix compared with native fragments, three were open habitat specialists and four were habitat generalists. Species with high capture frequencies in the matrix, independent of the native fragments, were obtained for habitat generalists and two open habitat specialists.

The higher capture frequencies for the open habitat specialists could be explained by the detectability through the method used. Srbek-Araujo & Chiarello (2013) demonstrated that different habitat use of species can result in different detectability. When cameras are placed along trails, a bias is expected towards species that prefer exposed areas (Harmsen et al. 2009). Sampling in our study area was conducted along human-made trails in sugarcane plantations, therefore a bias towards open habitat specialists was expected as they are less reluctant to increased visibility, compared with species that prefer to hide within sugarcane vegetation and consequently were not caught on camera.

Considering the potential bias of the method regarding open habitat specialists, generalist species seemed to be influenced less by potential negative effects of the matrix in terms of capture frequencies, which supports by the habitat preference hypothesis.

The high richness in the matrix can be explained by three different factors. Firstly, biodiversity in the matrix depends on the wider landscape context (Pardini et al. 2010). Richness in the area is high, probably due to the presence of a National Park which acts as a buffer with source populations (Pardini et al. 2010). However, the national park is by itself too small to maintain viable populations of large mammals through which species are dependent on the surroundings for survival (Silva & Diniz-Filho, 2008). The surrounding landscape is highly fragmented and natural habitat is scarce, which increases both the chance that species enter and the time species are spending in the matrix (Fahrig 2002, Fahrig, 2003).

Secondly, the high richness in the matrix might be attributed to the composition of mammals in the Cerrado, which consists of predominantly habitat generalists (Marinho-Filho et al. 2002). Therefore, effects of sugarcane might be limited in this region as the species that occur here are more tolerant to the matrix. This would also imply that different results can be expected in sugarcane areas of Brazil with different composition of habitat generalists and specialists.

Thirdly, the high richness in the matrix indicates permeability of the matrix. Permeability can be interpreted in different ways, based on the behaviour of the species considered. The habitat specialists are more likely to be forced into the matrix due to the scarcity of natural habitat (Fahrig, 2003), while the habitat generalists are expected to be more tolerant and able to use the matrix for for example food resources and therefore enter the matrix on a 'voluntary basis' (Laurance, 1991; Andrén, 1994; Swihart et al., 2003, Pardini et al. 2009).

**Management implications**

*1. Sustainable management*

Of the species detected in the matrix, 40% were threatened to some extent according to IUCN redlist. Different factors might have negative effects on the species present in the matrix, such as ingestion of pesticides, disturbance caused by humans, increased disease exposure, and interaction with/hunting by domestic dogs (Vynne et al., 2011). Sustainable management of the matrix should take these factors into account, and also certification of sugarcane plantations, such as the Bonsucro and Renewable Fuel Standard providing guidelines for sustainable sugarcane production.

*2. Species specific management*

Management practices should include group specific responses. Next to generalists, forest and open grassland specialists were detected in the matrix. With regards to connectivity, ecological corridors are demonstrated to be especially important for gene flow of habitat specialists (Rosenberg 1997; Mech & Hallett, 2001). However, corridor management requires a distinction between the needs of different groups of specialists. Connectivity for open grassland species might be increased by corridors with patches of grass, while forest specialist require trees in order to use the corridors.

*3. Sugarcane land use strategies*

For managerial choices with regards to land sparing or sharing (ref) it is of significant importance to know if such options would be valid in the region. In this article, we demonstrate that one key criterion for land sharing, namely permeability, is largely met in the sugarcane landscape, as the matrix is permeable to a large share of mammals in the region. The presence of fragments due to the Brazilian forest code and the national park is most likely the only reason for the high richness found in the area. Therefore, we stress the importance of the Brazilian Forest Act legislation that ensures the conservation of fragments of native vegetation on these private lands.

4. *Monitoring over time*

Although the high richness in sugarcane suggests limited effects of the matrix in terms of species presence, there can be a time-lagged response of the biodiversity present in the fragmented sugarcane landscape. Future research and management should therefore focus on monitoring over larger time periods. Specific attention should be paid to specialist species.

This article demonstrates limited effects of the sugarcane matrix in this Cerrado region on species presence. The matrix is permeable to a large share of mammal species in the region. Different factors might underlie these findings, such as scarcity of natural habitat and the predominance of habitat generalists in the Cerrado. Our findings support the habitat preference hypotheses, with varying permeability for different groups of species, and highest permeability for the habitat generalists. The fragments and the national park play a key role in facilitating the high diversity and abundance of species in the fragmented sugarcane landscape and are therefore of vital importance for species presence in the area in the future. Next to this Cerrado 'biodiversity hotspot' region, the management implications in this article might be applicable for other tropical regions where sugarcane is expected to expand in the future, such as Central-Africa and South-east Asia.

## MATERIALS AND METHODS

### STUDY AREA

To study the effects of fragmented sugarcane landscapes on mammals, the sugarcane landcape surrounding the Emas National Park (ENP) (18°19'S;52°45'W), located in the southwestern state Goiás of the Brazilian Cerrado, were selected as study area (**figure 2**). The ENP is one of the most significant protected areas in the Cerrado. The park and its surroundings are a global priority for large-mammal conservation because it is one of only 12 places in South-America that has an intact large mammalian fauna (Morrison *et al*., 2007). The ENP, covering 1320 km$^2$, is an island of natural vegetation surrounded by agricultural lands (Silveira *et al*., 2009), among which expanding sugarcane fields. The park is by itself too small to maintain viable populations of large mammals and, therefore, species depend for their survival also on the surroundings, consisting of a sugarcane matrix and remaining Cerrado fragments.

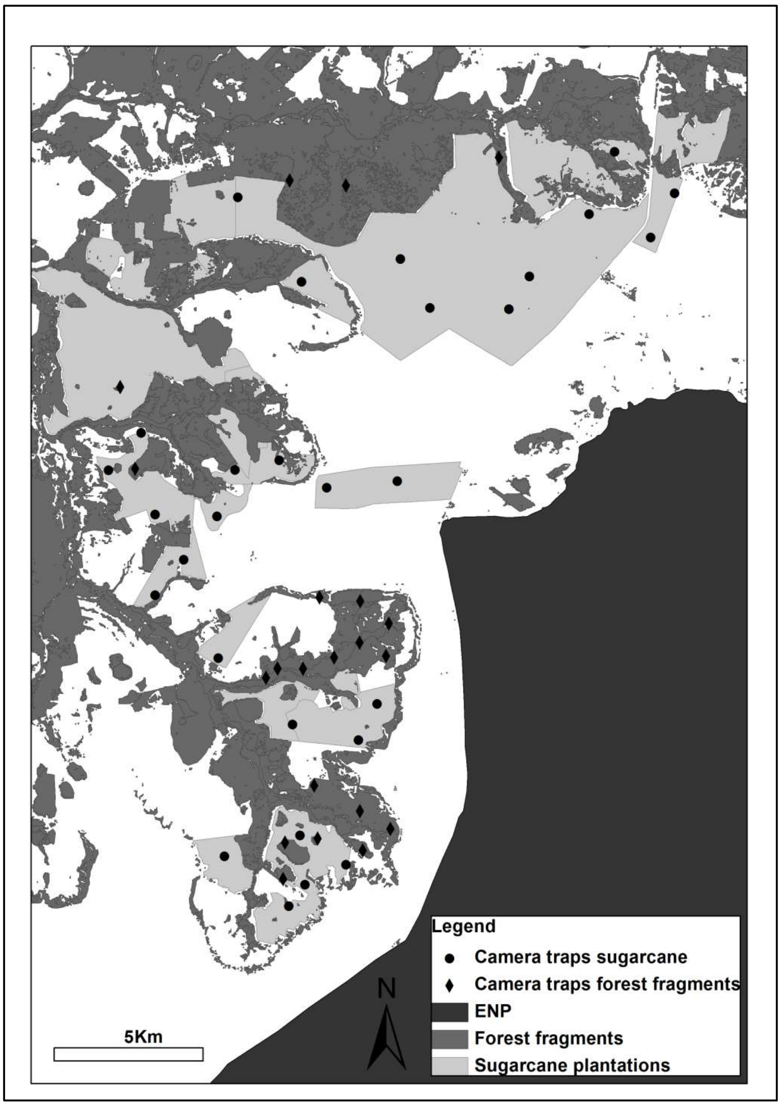


***Figure 2***. *Study area. Locations of the camera traps in the sugarcane matrix and fragments in the surroundings of the Emas National Park (ENP).*

**DATA COLLECTION**

*Experimental design*

Mammal occurrence was analyzed in the fragmented sugarcane landscape by camera trapping, which is considered an adequate method for mammal assessments (Silveira et al., 2003). Compared with other methods, an advantage of camera trapping to capture mammals is that the pictures provide unbiased evidence of a species presence (Rovero et al., 2010). Although relatively expensive, camera traps can be used in almost any field condition, it is a non-intrusive method, huge areas can be covered with a few people working and little experience is needed to work with camera traps.

We placed 30 digital cameras in sugarcane plantations in the study area in the period of December 2012 until March 2013. Nine of the digital cams were of the brand 'Bushnell' and 21 cameras were of 'Reconyx' (2 types: p800 and p900). Both types were active for 24h a day. The cameras were triggered by heath and movement. In total 57.096 hours were accumulated for the digital cameras in sugarcane plantations. Next to this dataset, a dataset of cameras in the fragments surrounding the sugarcane plantations (conducted in 2012 in the period of July until October) was used. In the fragments surrounding sugarcane plantations, 29 digital cameras accumulated 45.336 hours of data.

Furthermore, in both surveys data were collected by analogue cameras of the type 'Camtrakker' that were also placed in the study area. These cameras were active for 12h during the night. To keep consistency among the datasets, the analogue cameras are used only to complement the data of the digital cameras in terms of detected species and are not used for further analyses. The cameras were placed alongside small sandy roads in the plantations and secured on a wooden stick, with a minimum distance of 1 km between them. The cameras were visited approximately every week to check if the memory card was filled or if the films and batteries needed to be replaced and if there were no leafs in front of the camera. At the beginning and at the end of the camera trap survey, the height of the sugarcane around the camera was measured in order to measure the influence of the mean sugarcane height on species richness and the number of records per camera.

**DATA PREPARATION**

*Camera trap data*

In order to analyze species richness and capture frequency data, we filtered all the obtained pictures carefully and used only the photos with a (medium- to large sized) mammal (classified as > 1 kg in weight) in the analyses. When the same species appeared twice or more on photo on the same camera trap within one hour, only the first photo was counted as a record (Srbek-Araujo & Chiarello, 2013). The capture frequency was calculated by the number of records per species/sampling effort (expressed per 100 days).

*Species list and habitat preference data*

To compare species richness in the fragmented sugarcane landscape with species richness of the Cerrado region, and to analyze if habitat preferences determined mammal occurrence in the matrix, we used the published list of Cerrado mammals of Marinho-Filho *et al*. (2002). Species habitats of this list refer to the whole geographic range of a species instead of nice breadth of specific populations. Habitat is classified in two ways: open habitat, which covers all open environments of the Cerrado ('e.g., cerrado sensu stricto, campo cerrado, campo sujo, campo limpo, vereda, and campo rupestre': Marinho-Filho *et al*., 2002) and forest environments.

**DATA ANALYSES**

*Estimated richness – Jackknife estimator*

To investigate whether the number of species detected in the sugarcane matrix and fragments was similar to the total number of species that could be expected in the region, we used the program EstimateS 9.0 to draw species accumulation curves (Colwell, 2013). The curves were drawn through the rarefaction method, resulting in a statistical model of the species accumulation curve. We used 100 runs for randomizations, as recommended by Colwell (2013). The accompanying lower and upper bounds of the 95% confidence intervals were also drawn. To estimate the total mammal richness in the area, we used the first-order Jackknife (Jackknife 1), a non-parametric estimator based on the number of unique species (found in one sample) (Smith & Pontius, 2006; Gotelli & Colwell, 2011).

*Average species richness per sampling point*

We calculated the average species richness per sampling point in both environments to analyze how mammals occurring in the fragments are related to the sugarcane matrix. To optimize consistency within and between the datasets we corrected for the differences in sample size by using only data of a fixed activity period for every camera. Cameras covering a shorter period of time were excluded and for cameras that were active for a longer period, only data of the chosen period of activity were used. We used data accumulated up to 1.5 month (46 days) with exclusion of five cameras that were active for a shorter period of time (all cameras located in the fragments). We performed a t-test to compare the average species richness per sampling point in sugarcane plantations with that of the fragments.

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**RESULT FIGURES AND TABLES**

SPECIES ACCUMULATION CURVE

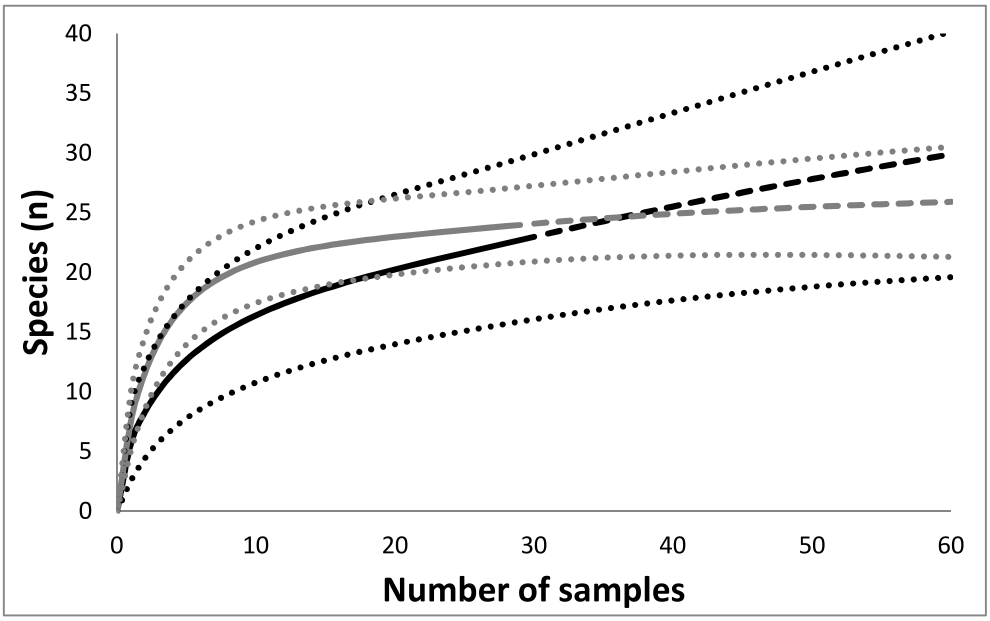
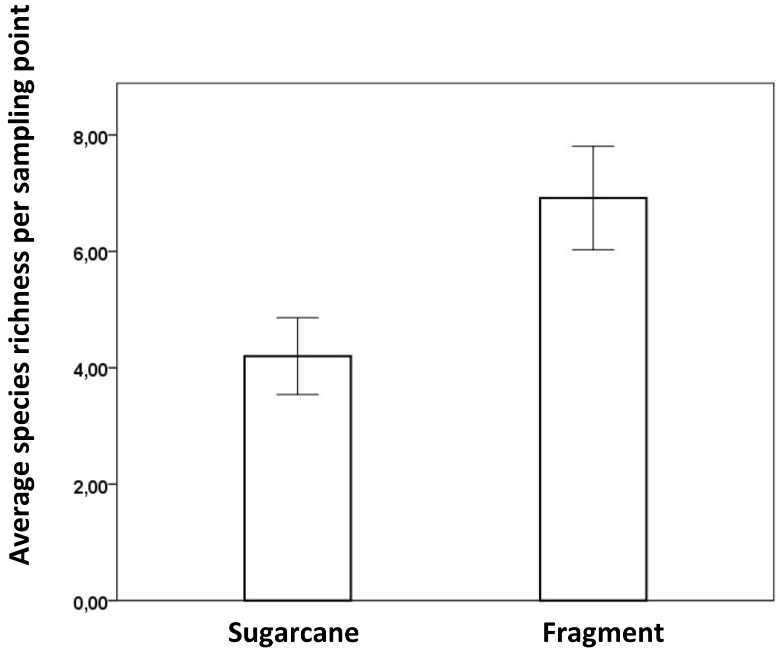



***Figure 3**. The randomized sample-based species accumulation curves  for the sugarcane (black) and the fragment survey (grey). The dashed lines demonstrate extrapolations from the reference samples. The dotted lines depict the 95% CI curves of the species accumulation curves.*

AVERAGE RICHNESS PER SAMPLING POINT




**Sugarcane plantations** (N=30)

Mean species richness: 4,3

Std. error = 0,323

Std. deviation = 1,769

**Forest fragments** (N=24)

***Figure XX****. Histogram of the average detected mammal richness per sampling point for sugarcane plantations and Cerrado fragments. p < 0,0001. Error bars: 95% CI. For both, a period of 46 sampling days was used.*

CAPTURE FREQUENCIES

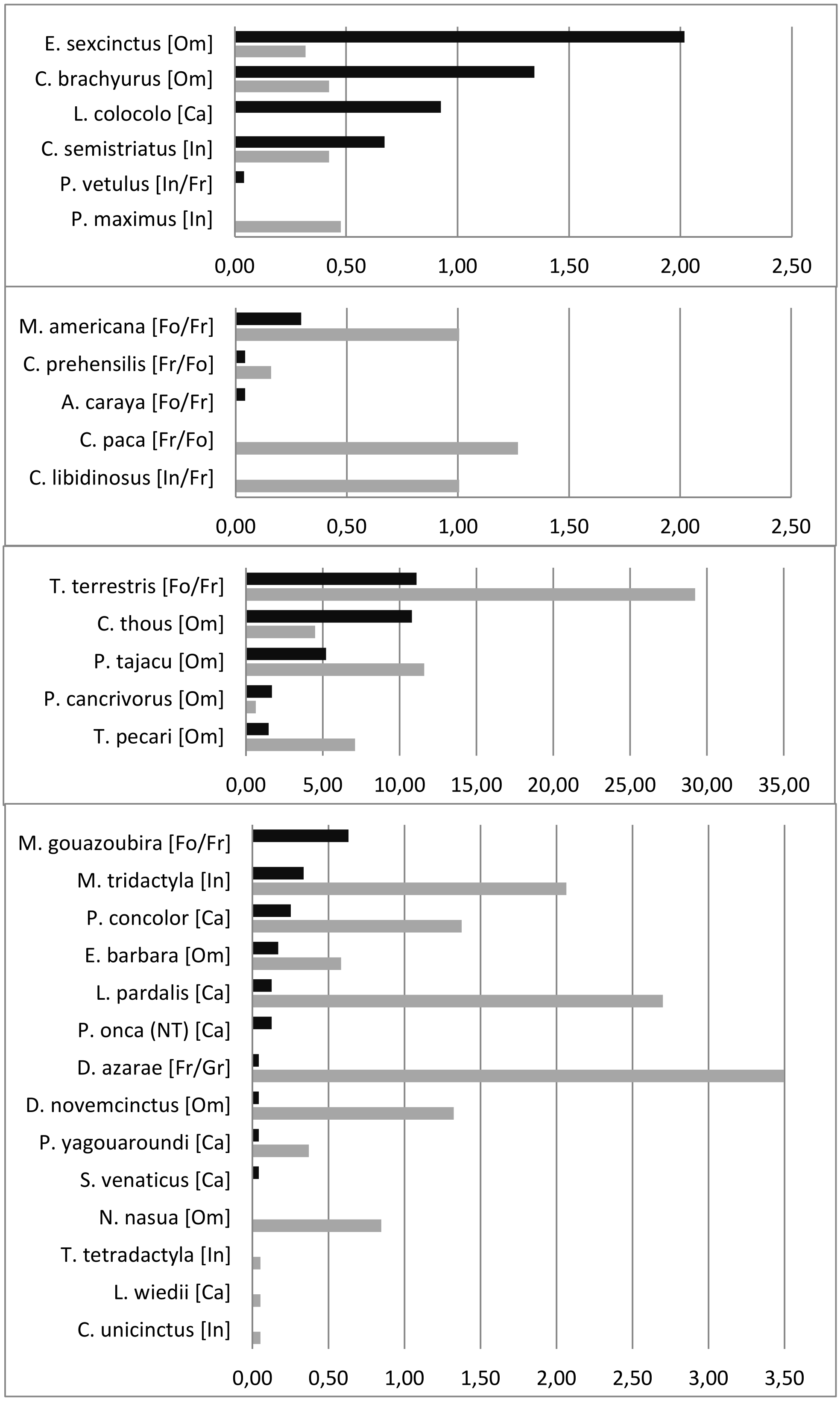



***Figure 4**. Capture frequencies for mammal species per sampling effort (per 100 days) in sugarcane plantations (black bars) and in the surrounding forest fragments (grey bars). The species in this figure are grouped by: open habitat species, forest species and habitat generalists, according to Marinho-Filho et al. (2002).*

**APPENDIX 1**: Species characteristics and captures in both sugarcane and the surrounding forest fragments

| MAMMAL SPECIES & CHARACTERISTICS | | | | CAPTURES IN HABITAT | | | |
|---|---|---|---|---|---|---|---|
| | IUCN status | Habitat | Diet | Sugarcane | | Fragment | |
| **SPECIES** | | | | Nr of records | Records/ 100 days | Nr of records | Records/ 100 days |
| **Cingulata** | | | | | | | |
| **Dasypodidae** | | | | | | | |
| **Cabassous unicinctus** | LC | O & F | In | 0 | 0 | 1 | 0,05 |
| **Dasypus novemcinctus** | LC | O & F | Om | 1 | 0,04 | 25 | 1,32 |
| **Euphractus sexcinctus** | LC | O | Om | 48 | 2,02 | 6 | 0,32 |
| **Priodontes maximus** | VU | O | In | * | * | 9 | 0,48 |
| **Primates** | | | | | | | |
| **Cebidae** | | | | | | | |
| **Cebus libidinosus** | LC | F | In/Fr | 0 | 0 | 19 | 1,01 |
| **Atelidae** | | | | | | | |
| **Alouatta caraya** | LC | F | Fo/Fr | 1 | 0,04 | 0 | 0 |
| **Carnivora** | | | | | | | |
| **Canidae** | | | | | | | |
| **Cerdocyon thous** | LC | O & F | Om | 257 | 10,80 | 85 | 4,50 |
| **Pseudalopex vetulus** | LC | O | In/Fr | 1 | 0,04 | 0 | 0 |
| **Chrysocyon brachyurus** | NT | O | Om | 32 | 1,35 | 8 | 0,42 |
| **Speothos venaticus** | NT | O & F | Ca | 1 | 0,04 | 0 | 0 |
| **Felidae** | | | | | | | |
| **Leopardus pardalis** | VU | O & F | Ca | 3 | 0,13 | 51 | 2,70 |
| **Leopardus wiedii** | VU | O & F | Ca | 0 | 0 | 1 | 0,05 |
| **Leopardus tigrinus** | VU | O & F | Ca | - | - | - | - |
| **Herpailurus yagouaroundi** | LC | O & F | Ca | 1 | 0,04 | 7 | 0,37 |
| **Puma concolor** | VU | O & F | Ca | 6 | 0,25 | 26 | 1,38 |
| **Panthera onca** | NT | O & F | Ca | 3 | 0,13 | * | * |
| **Leopardus colocolo** | VU | O | Ca | 22 | 0,92 | 0 | 0 |
| **Mustelidae** | | | | | | | |
| **Eira barbara** | LC | O & F | Om | 4 | 0,17 | 11 | 0,58 |
| **Galictis cuja** | LC | O & F | Om | - | - | - | - |
| **Lontra longicaudis** | DD? | O & F | Fi | - | - | - | - |
| **Procyonidae** | | | | | | | |
| **Nasua nasua** | LC | O & F | Om | * | * | 16 | 0,85 |
| **Procyon cancrivorus** | LC | O & F | Om | 40 | 1,68 | 12 | 0,64 |
| **Rodentia** | | | | | | | |
| **Cuniculus Paca** | LC | F | Fr/Fo | 0 | 0 | 24 | 1,27 |
| **Dasyproctidae** | | | | | | | |
| **Dasyprocta Azarae** | DD (?) | O & F | Fr/Gr | 1 | 0,04 | 66 | 3,49 |
| **Caviidae** | | | | | | | |
| **Hydrochoerus hydrochaeris** | LC | O & F | Fo | 0 | 0 | * | * |
| **Artiodactyla** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Cervidae** | | | | | | | |
| **Mazama americana** | DD | O & F | Fo/Fr | 7 | 0,29 | 19 | 1,01 |
| **Mazama gouazoubira** | LC | O & F | Fo/Fr | 15 | 0,63 | 0 | 0 |
| **Blastocerus dichotomus** | VU | O & F | Fo | - | - | - | - |
| **Ozotoceros bezoarticus** | NT | O | Fo | - | - | - | - |
| **Myrmecophagidae** | | | | | | | |
| **Tamandua tetradactyla** | LC | O & F | In | 0 | 0 | 1 | 0,05 |
| **Myrmecophaga tridactyla** | VU | O & F | In | 8 | 0,34 | 39 | 2,06 |
| **Erethizontidae** | | | | | | | |
| **Coendou Prehensilis** | LC | F | Fr/Fo | 1 | 0,04 | 3 | 0,16 |
| **Tayassuidae** | | | | | | | |
| **Pecari tajacu** | LC | O & F | Om | 124 | 5,21 | 219 | 11,59 |
| **Tayassu pecari** | EN | O & F | Om | 35 | 1,47 | 134 | 7,09 |
| **Mephitidae** | | | | | | | |
| **Conepatus semistriatus** | LC | O | In | 16 | 0,67 | 8 | 0,42 |
| **Tapiridae** | | | | | | | |
| **Tapirus Terrestris** | VU | O & F | Fo/Fr | 264 | 11,10 | 552 | 29,22 |
| **TOTAL DAYS** | | | | 2379 | | 1889 | |
| **Species** | | | | 23 | | 24 | |

The number of records and the records/100 trap days are given for the different mammal species.* = species detected only by analogous cameras. The status according to the IUCN Red List (LC = least concern, NT=near threatened, VU = vulnerable and EN = endangered. DD = data deficient) and the habitat preferences are presented in the table. Habitat and diet preferences are derived from the published list of Marinho-Filho *et al.*, (2002). Habitat categories are F = forest and O = open habitat (e.g. campo cerrado, cerrado sensu stricto, vereda, campo sujo, campo limpo and campo rupestre). Diet categories are Ca = carnivore, Fi = fish specialist, Fo = folivore, Fr = frugivore, Gr = grainivore, In = insectivore, Om = omnivore.

**APPENDIX 2**: Correlation matrix of the different variables considered for the multi-linear regression analyses.

| | **Distance to nearest fragment** | **Distance to ENP** | **Distance to nearest river** | **Mean height sugarcane** | **Tapir records** | **Total records** |
|---|---|---|---|---|---|---|
| **Species richness** | p=0,108<br>Corr coef =0,585 | P=0,583<br>Corr coef = 0,108 | P=0,605<br>Corr coef = 0,102 | P = 0,270<br>Corr coef =0,216 | P = 0,676<br>Corr coef = 0,083 | P = 0,000<br>Corr coef = 0,659 |
| **Total records** | Corr coef=,229<br>Sign=,242 | Corr coef=,226<br>Sign=,249 | Corr coef=-,014<br>Sign=,942 | Corr coef=,137<br>Sign=,486 | P = 0,003<br>Corr coef = 0,539 | ** |
| **Tapir records** | Corr coef=-,212<br>Sign=,278 | Corr coef=,415*<br>Sign=,028 | Corr coef=-,520**<br>Sign=,005 | Corr coef=0,05<br>Sign=,799 | ** | |
| **Mean height Sugarcane** | P=0,697<br>Corr coef=-0,077 | P=0,115<br>Corr coef = -0,305 | P=0,095<br>Corr coef =-0,321 | ** | | |
| **Distance to nearest river** | P=0,008<br>Corr coef = 0,492 | P=0,622<br>Corr coef = -0,097 | ** | | | |
| **Distance to ENP** | P=0,949<br>Corr coef = -0,013 | ** | | | | |

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