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Patterns of taxonomic and functional diversity of dung beetles in a human-modified variegated landscape in Brazilian Cerrado

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Abstract

The Brazilian Cerrado harbors great floristic and structural diversity composed of a mosaic of natural vegetation types and anthropogenic environments such as introduced pastures. Here, our goal was to evaluate the patterns of taxonomic and functional diversity of dung beetles in a human-modified landscape in Brazilian Cerrado. For this, we evaluated the species richness, species composition and abundance (non-weighted by abundance) and species diversity (Shannon index—weighted by abundance) and three functional indexes (functional richness, functional evenness and functional dispersion). We collected the insects in fragments of Cerrado (Cerrado *stricto sensu*), riparian forests under pressure of timber removal and livestock and exotic pastures (*Urochloa* spp.) in Anastácio and Aquidauana, Mato Grosso do Sul, Brazil. We used pitfall traps baited with human feces and fresh capybara dung, a large native rodent, as a representative of the mammal regional fauna. Dung beetle richness was higher in Cerrado fragments, while the abundance was higher in exotic pastures and riparian forests. Species composition differed among vegetation types. Finally, the species diversity and functional diversity did not differ among vegetation types. Thus, we demonstrated the information generated by conceptually similar indexes (e.g. functional richness, species richness and species diversity) may not provide similar information on dung beetles responses to disturbance due to differences in the weighting on species abundance. Finally, the use of taxonomic and functional metrics generate complementary information that can helps us to reach more efficient conclusions in terms of biodiversity conservation and ecosystem functionality in human-modified variegated landscape.

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Introduction

Agriculture and livestock farming has been the one of the major causes of the transformation of natural ecosystems, resulting in landscapes with an environmental mosaic, characterized by fragments of natural areas mixed with anthropized areas (e.g. pastures, agriculture, agroforestry) (Barlow et al. 2016). Human-modified landscapes often result in the loss of native species (Tabarelli et al. 2010; DeClerck et al. 2010). Despite over one quarter of planet terrestrial surface being covered by ecosystems modified by agricultural activities (Foley et al. 2005), some types of anthropized systems may serve as complementary habitats for native species in human-modified landscapes, thus contributing to biodiversity conservation (Costa et al. 2017) and ecosystem function (Santos-Heredia et al. 2018).

The Brazilian Cerrado is the largest, richest and possibly the most threatened tropical savannah on the Planet, being an important hotspot (Myers et al. 2000; Silva and

Bates 2002). However, only 7% of this biome is preserved in protected areas (Soares-Filho et al. 2014). This biome harbors great floristic and structural diversity composed of a mosaic of vegetation types (e.g. grasslands, savannas, and forests) (Oliveira-Filho and Ratter 2002), providing high levels of species richness due to the interchange of species among vegetation types (Almeida and Louzada 2009; Gries et al. 2012). However, the deforestation and land use intensification in Brazilian Cerrado are producing variegated landscapes with modified natural environments and anthropogenic environments, such as exotic pastures, which are expanding and negatively impacting the biodiversity of this biome (Marris 2005; Almeida et al. 2011; Ferreira et al. 2014; Queiroz et al. 2017).

Dung beetles (Coleoptera: Scarabaeinae) perform important ecological functions in the habitats in which they live, acting on nutrient cycling and improving soil fertility and control of livestock parasites (Nichols et al. 2008). They are also considered efficient indicators of environmental changes because they undergo changes in community metrics (e.g. abundance, species richness, composition and/or functional diversity) when subjected to environmental changes (Nichols et al. 2007; Barrágan et al. 2011; Bicknell et al. 2014; França et al. 2016; Beiroz et al. 2018) and their collection methods are relatively inexpensive (Gardner et al. 2008). In addition, dung beetles have a high degree of habitat specificity in the Cerrado (Almeida and Louzada 2009; Gries et al. 2012), and can be useful as focal organisms to assess anthropic impacts (Braga et al. 2013; Korasaki et al. 2013; Correa et al. 2016a; França et al. 2016) in this biome.

Different metrics have been used to assess the impacts of land use change on biodiversity. Within the taxonomic diversity, there are metrics that give weight to rare and abundant species differently (Gotelli and Colwell 2001; Chao and Shen 2003). For example, there is no weight for rare and abundant species to calculate species richness (number of species), abundance (number of individuals) and composition (which species are present in a certain area) (Gotelli and Colwell 2001). In contrast, the Shannon-Wiener index is weighted by species abundance to assess species diversity, being based on the contribution of all individuals to their respective species. However, the information would not be dependent only on the total number of individuals and the total number of species, but also on the proportion of the number of individuals of each species, implying that species are not equally likely (Shannon and Wiener 1949). It can reflect species richness and species evenness, being most sensitive to land use change when there is a high number of rare species in the community (Chao and Shen 2003).

Functional diversity is a measure of biodiversity that quantifies the diversity of characters; capturing differences in species morphology and physiology, life history traits, and ecological niches that affect community responses to

the disturbance, and consequently, changes in ecosystem functions (Cadotte et al. 2011; Gerisch et al. 2012; Audino et al. 2014; Derhé et al. 2016). Recently, functional diversity is being used to evaluate responses of dung beetle communities to land use change in order to obtain more efficient information in terms ecosystem functionality (Barragán et al. 2011; Audino et al. 2014; Derhé et al. 2016; Gómez-Cifuentes et al. 2017; Beiroz et al. 2018). Although, there is research that has evaluated the taxonomic response (e.g. species richness, composition and abundance) of dung beetle community to land use change (e.g. Almeida et al. 2011; Gries et al. 2012; Martello et al. 2016) and species diversity in different vegetation types (e.g. Almeida and Louzada 2009) in Brazilian Cerrado, the functional patterns of dung beetle communities in this biome has yet to be investigated. In this sense, using only the taxonomic metrics (species composition, species richness, abundance and diversity) of the community to predict changes in the ecosystem could leave important questions on the maintenance of ecosystem functions and services unanswered (Mouillot et al. 2013a, b).

Due to this, our objective was to evaluate the taxonomic and functional patterns of dung beetle communities in a human-modified landscape in the Brazilian Cerrado. We investigated how abundance, species richness, species composition, species diversity and functional diversity are affected by different vegetation types. For this, we collected the insects in Cerrado fragments (Cerrado *stricto sensu*), riparian forests under pressure of timber removal and livestock and in exotic pastures (*Urochloa* spp.) to answer the following questions: (1) Do exotic pastures have a higher dung beetle abundance but lower dung beetle richness and species diversity than natural environments (Cerrado and riparian forests)? We expect higher dung beetle abundance in exotic pastures due to increased cattle dung availability, since this resource is abundant, predictable and frequent in Neotropical pastures (Louzada and Carvalho e Silva 2009), and higher dung beetle richness and diversity in natural environments due to greatest resource variability (Driscoll and Weir 2005); (2) Does the species composition differ among the three vegetation types? We expect that species composition is different among the vegetation types due to clear differences in vegetation structure (Halffter and Arellano 2002; Costa et al. 2017) and (3) Does the lower species diversity translate into a reduced functional diversity in exotic pastures? We expect that the reduction of functionally specialized species in exotic pastures results in lower functional diversity. In addition, we discuss the results found using the two metrics; taxonomic (weighted and non-weighted by abundance) and functional diversity, and how it can useful to understand the possible impacts of land use change in the Brazilian Cerrado.

Materials and methods

Study sites and experimental protocol

The study was carried out in a region of Cerrado, in the Brazilian municipalities of Anastácio (20°45′45″S, 55°43′49″W) and Aquidauana (19°54′36″S, 55°50′16″W), that are neighbors and are separated by the Aquidauana river. The climate of the region, according to the Köppen classification is Aw, tropical hot-wet, with a rainy summer and a dry winter (Alvares et al. 2014). Annual precipitation ranges from 1200 to 1300 mm and average annual temperature is 26 °C.

The studied area has been historically modified by livestock farming activities, which generated the variegated landscapes. Overall, the landscape is composed of fragments of Cerrado (*stricto sensu*), riparian forest under pressure of timber removal and livestock and exotic pastures (*Urochloa* spp.) (Fig. 1).

Cerrado fragments (Cerrado *stricto sensu*) are characterized by a mixture of plants of two distinct strata: (often 3–8 m; canopy covering 50–90%), and a ground layer composed of grasses, herbs, and small shrubs (Oliveira-Filho and Ratter 2002), with typical wild animals of the Cerrado biome (anteaters, deer, manned wolf, peccaries, rodents, and others). The Cerrado fragments, ranging in size from 3 to 18 ha, are located in a Legal Reserve Area, being conserved with little sign of anthropogenic action.

Riparian forests were degraded initially for timber use and later by the entry of domestic animals (cattle) under pressure from timber removal and livestock. The areas are characterized by a woody layer composed of trees and large shrubs, and there are also wild animals typical of the region. We used a degraded riparian forests because in the study region there were no conserved riparian forests (without high sign of anthropogenic action).

Exotic pasture areas are large open areas, ranging in size from 5 to 20 ha, cultivated with African grasses (*Urochloa* ssp.), without intensive management (no use of fertilization, and no application of herbicides), with stocking rates between 0.8 and 1.3 livestock per hectare. They are managed in a rotational system where the cattle remain for ~45 days before being moved to other pastures and return after ~60 days.
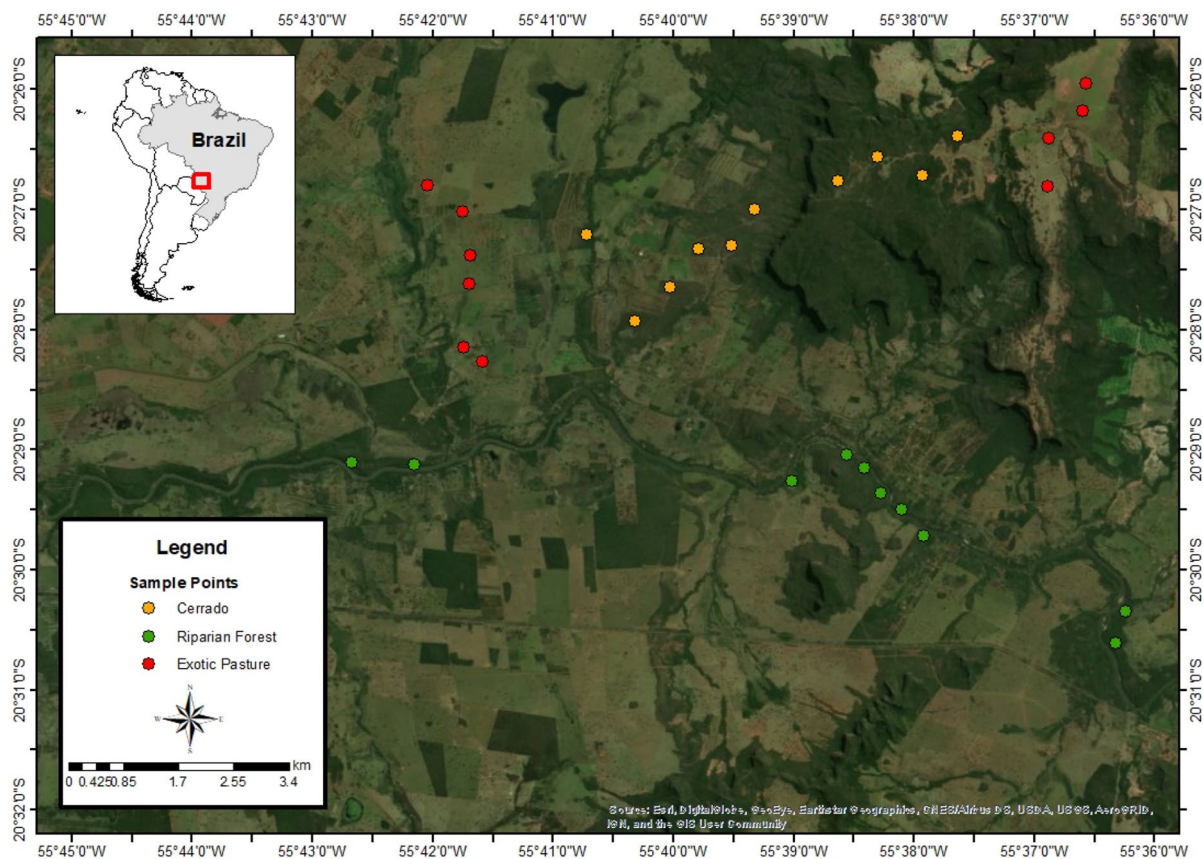

Fig. 1 Localization of the studied area in Brazil, highlighting the 30 sites of sampling in the Brazilian Cerrado

We sampled dung beetles in 30 areas, 10 Cerrado areas, 10 areas of degraded riparian forests and 10 exotic pasture areas. The areas within the same system were separated by, at a minimum, 300 m to insure independence of the samples (Silva and Hernandez 2015), while areas of different systems were separated by approximately 1 km. Regions surrounding the sampling sites are dominated by extensive exotic pastures and patches of the Brazilian Cerrado (Puker et al. 2013).

We considered each area as replicates ($n = 10$ areas) for each system. In each area, we delimited a transect of 400 m located approximately 50 m from the edge habitat, with five sample points separated by 100 m. At each point we installed a set with two traps, one baited with fresh capybara dung (~ 40 g) and the other baited with human feces (~ 40 g), each set of traps from the same point was separated by 20 m, totaling 10 traps per area. Thus, the sample effort was 300 traps, with 100 traps installed in each land use system. Human feces is more appropriate when the target is to sample greater abundance and richness of dung beetles independent of the vegetation structure (Correa et al. 2016b). We also used dung of capybara, a large native rodent, as representative of mammalian fauna that occur frequently in the three studied habitats in order to better sample the community (Puker et al. 2013).

Dung beetle sampling and identification

We sampled dung beetles in December 2011 and January 2012 (middle of the rainy season). In tropical ecosystems, the rainy season is the period of greatest activity and dung beetle richness (Halffter 1991). The traps were composed of a plastic pot (15 cm in diameter, 9 cm high) covered with a plastic cap supported by bamboo sticks. They were installed at ground level, and contained approximately 250 ml of a 1.5% liquid detergent saline solution. The baits were placed in plastic containers (50 mL) in the center of each trap using a wire as a bait holder. Traps remained in the field for 48 h.

The beetles were identified by Dr. Fernando Zagury Vaz-de-Mello. The voucher specimens are deposited in the Entomology Section of the Zoological Collection of the Federal University of Mato Grosso (UFMT, Cuiabá, Mato Grosso, Brazil).

Functional traits

Three functional traits were analyzed that could directly influence the ecological functions performed by dung beetles: habit resource allocation (tunnelers, rollers or dwellers), diet preference (human feces, capybara dung or generalist feces) and body size (Supplementary Material).

Data analysis

Pattern of species richness, abundance and diversity

To assess the completeness of our dung beetle survey in the three habitats, we calculated the number of observed species (Sobs) as a percentage of the total species richness, which was estimated based on the average of four abundance based nonparametric estimators: ACE, CHAO1, JACK1 and BOOTSTRAP, using the formula: Sampling efficiency = [Sobs × 100/((ACE + CHAO1 + JACK1 + BOOTS)/4)]. The richness estimates were calculated with the software EstimateS v. 9.1.0, with 999 randomizations (Colwell 2013).

To evaluate differences in dung beetle abundance, species richness and species diversity (Shannon index) among habitats, we used Generalized Linear Models (GLMs). All GLMs were submitted to residue analysis, in order to evaluate the adequacy of the distribution of errors (Crawley 2002). We used Poisson errors corrected for over-dispersion (quasi-Poisson) for dung beetle abundance and richness. All analyzes were performed using the R v3.3.1 (R Development Core Team 2016).

Species composition and dispersion patterns

To graphically express the changes in dung beetle community composition among habitats we used a non-metric multidimensional scaling analysis (NMDS) based on Bray–Curtis dissimilarity matrix with standardized and square-root transformed abundance data (Anderson and Willis 2003). To verify these differences we used a permutational multivariate analysis of variance (PERMANOVA) (Anderson 2001). To test heterogeneity of multivariate dispersions between different habitat types, we used permutational multivariate analysis of dispersion (PERMDISP) (Anderson 2001). NMDS, PERMANOVA and PERMDISP were performed using the Primer v.6 software with PERMANOVA+ (Clarke and Gorley 2006).

Functional diversity

To calculate three functional diversity indexes, we used the dbFD function of the 'FD' package (R Development Core Team 2016): (1) Functional richness (FRic) represents the range of traits in a community quantified by the volume of functional trait space occupied; (2) Functional evenness (FEve) summarizes how species abundances are distributed along the occupied functional space (Villéger et al. 2008); and (3) Functional dispersion (FDis) which indicates the distribution of abundances in the space of functional traces in

relation to a weighted centroid in abundance and the volume of space occupied (Laliberté and Legendre 2010).

To evaluate differences in the three functional diversity indexes among habitats, we also used GLMs with gaussian errors. All GLMs were submitted to residual analysis, in order to evaluate the adequacy of the distribution of errors (Crawley 2002). All analyzes were performed using the R v3.3.1 (R Development Core Team 2016).

Results

Patterns of species richness, abundance and species diversity

In the Cerrado, we captured 30 species and 2577 individuals; 26 species and 6020 individuals in the riparian forests; and 26 species and 6224 individuals in the exotic pastures (Table 1). The Cerrado shared 24 species with riparian forest, and 23 species with exotic pastures. Riparian forest pastures shared 19 species with exotic pastures.

The four species richness estimators indicate high sampling efficiency, with 91% in the Cerrado, 87% in the riparian forests and 67% in the exotic pastures (Table S1). The species accumulation curves suggest that the sampling effort was adequate to characterize the local dung beetle community (Fig. 2).

In the Cerrado, of the 2577 individuals sampled, the dominant species were: *Uroxys* sp. (22.82%), *Onthophagus* aff. *hirculus* (16.41%) and *Canthon* aff. *tristis* (16.06%) (Table 1). In riparian forests, of the 6020 individuals sampled, the dominant species were: *Trichillum externepunctatum* Preudhomme de Borre (59.87%), *Dichotomius opacipennis* (Luederwaldt) (7.66%) and *Onthophagus* aff. *hircullus* (7.49%). In exotic pastures, of the 6224 individuals sampled, the dominant species were: *Uroxys* sp. (34.77%), *Dichotomius bos* (Blanchard) (16.96%) and *Ontherus appendiculatus* (Manerrheim) (19.84%) (Table 1).

The species richness was higher in the Cerrado, and similar in the riparian forests and exotic pastures ($F_{(2,27)} = 4.01$, $p = 0.03$) (Fig. 3). Dung beetle abundance was lower in the Cerrado and similar in exotic pastures and riparian forests ($F_{(2,27)} = 3.77$, $p = 0.03$) (Fig. 3). Dung beetle diversity did not differ among the systems ($F_{(2,27)} = 1.76$, $p = 0.19$) (Fig. 4).

Species composition

The dung beetle species composition differed among the three vegetation types, each habitat forming distinct groups (PERMANOVA, pseudo-F = 8.08, p = 0.001) (Fig. 5; Table 2; Table S3). Vegetation types showed no differences

in the multivariate dispersion of points (PERMDISP, F = 0.45, p = 0.68) (Table 2).

Functional diversity

The functional richness ($F_{(2,27)} = 2.28$, $p = 0.09$), functional evenness ($F_{(2,27)} = 0.67$, $p = 0.52$) and functional dispersion ($F_{(2,27)} = 0.44$, $p = 0.64$) did not differ among the three habitats (Fig. 6).

Discussion

Patterns of species richness, abundance and diversity

This study evaluated, for the first time, the patterns of taxonomic and functional diversity of dung beetles among different vegetation types in Brazilian Cerrado. Despite the differences in sample effort and sampling protocols, we recorded a dung beetle community in Brazilian Cerrado which presented a larger number of species in Cerrado fragments and exotic pastures, when compared to previous studies in the same region (i.e. Correa et al. 2016a, b; Cerrado: S = 38 and exotic pastures: S = 24 species). Although our sampling efficiency was high in Cerrado and Riparian forest, above 85%, in exotic pastures it was low. This can be related the high number of rare species sampled in exotic pastures (e.g. *singletons* or *doubletons*) (Gotelli and Colwell 2001).

The species richness was higher in Cerrado fragments. Dung beetle richness is influenced by the vegetation structure (Hanski and Cambefort 1991); in particular the richness of the land use system (Lobo and Martín-Piera 2002) and also of the vertebrate fauna (Estrada et al. 1999), especially richness of large mammals (Nichols et al. 2013). Anthropic actions (e.g. land use change, selective logging, grazing and others) alter environmental conditions that directly affect species biology, such as luminosity, temperature and humidity, resulting in biodiversity loss (Hanski and Cambefort 1991). Studies have demonstrate that vegetation type is a key factor in the organization of dung beetle communities in tropical landscapes, where more simplified environments, such as exotic pastures, have lower species richness (Braga et al. 2013; Korasaki et al. 2013; Correa et al. 2016a). This can explain the lower dung beetle richness in riparian forests of our study. Although riparian forests are a natural system, the riparian forests of our study have been suffering anthropogenic actions, which may be negatively affecting the dung beetle community (Viegas et al. 2014). Riparian forests show very different characteristics from more open areas such as pastures and Cerrado, this was corroborated by the differentiated composition among these three systems, furthermore, these areas help to maintain biodiversity and

Table 1 Biodiversity of dung beetles sampled in Cerrado (CE), riparian forest (RF) and exotic pasture (EP)

Species	CE		RF		EP		Total
	CD	HF	CD	HF	CD	HF	
Ateuchini							
Ateuchus aff. *carbonarius*	1	1	0	0	0	0	2
Ateuchus sp. 1	18	28	5	1	3	32	87
Ateuchus sp. 2	2	0	0	0	0	1	3
Genieridium bidens (Balthasar)	6	16	1	96	6	324	449
Trichillum externepunctatum Preudhomme de Borre	3	32	4	3600	32	574	4245
Uroxys aff. *corporaali*	0	0	2	0	0	0	2
Uroxys sp.	118	470	181	2	0	2164	2935
Coprini							
Canthidium aff. *barbacenicum*	12	164	11	400	7	11	605
Canthidium aff. *breve*	0	9	3	1	0	1	14
Canthidium aff. *viride*	8	41	0	91	0	147	287
Dichotomius aff. *cuprinus*	1	3	0	1	0	0	5
Dichotomius bos (Blanchard)	26	0	66	172	24	1032	1320
Dichotomius glaucus (Harold)	1	15	0	1	0	81	98
Dichotomius nisus (Olivier)	18	57	21	134	0	201	431
Dichotomius opacipennis (Luederwaldt)	8	12	84	377	0	15	496
Dichotomius sexdentatus (Luederwaldt)	0	0	0	0	1	0	1
Dichotomius zikani (Luederwaldt)	4	3	5	2	2	3	19
Ontherus appendiculatus (Manerrheim)	41	180	3	128	31	1204	1587
Deltochilini							
Anomious pereirai (Martínez)	1	0	0	0	1	0	2
Canthon aff. *tristis*	58	356	2	9	0	0	425
Canthon chalybaeus Blanchard	2	51	0	1	0	0	54
Canthon histrio LePeletier & Serville	0	19	0	26	0	0	45
Canthon obscuriellus Schmidt	1	3	1	1	0	1	7
Canthon sp.	1	0	0	0	0	3	4
Deltochilum aff. *komareki*	7	77	1	45	0	1	131
Malagoniella puncticollis (Blanchard)	0	1	0	2	0	32	35
Oniticellini							
Eurysternus caribaeus (Herbst)	0	14	0	18	0	0	32
Eurysternus nigrovirens Génier	3	6	1	50	0	0	60
Onthophagini							
Digitonthophagus gazella (Fabricius)	0	0	2	4	1	0	7
Onthophagus aff. *hircullus*	119	308	24	427	43	70	991
Phanaeini							
Coprophanaeus ensifer (Germar)	0	0	0	0	0	1	1
Coprophanaeus spitzi (Pessôa)	0	1	0	14	0	169	184
Diabroctis mimas (Linnaeus)	0	2	0	0	0	3	5
Phanaeus kirbyi Vigors	0	4	0	0	0	3	7
Number of individuals	459	2126	417	5603	151	6073	14,829
Number of species	23	28	18	25	11	23	34

CD Capybara dung, *HF* human feces

their associated ecological functions in agricultural landscapes (Gray et al. 2014).

The riparian forest shared 24 species with Cerrado, indicating that, despite presenting very different vegetation characteristics, the Cerrado fragments can be used as refuge for dung beetles species from riparian forest. The Exotic pastures shared 23 species with Cerrado fragments and 19 with riparian forests, evidencing that dung beetle richness in exotic pastures may be increased by species of the natural systems. Although, in our study, there was the high
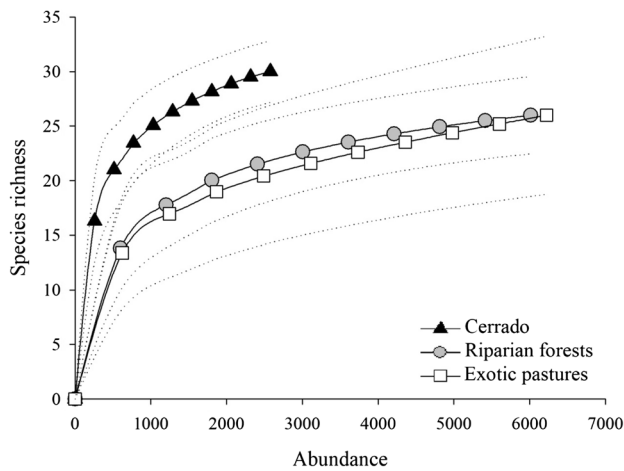
Fig. 2 Individual-based species accumulation curves for dung beetles sampled in two native vegetation and exotic pastures in Brazilian Cerrado. Shaded areas indicate 95% confidence intervals
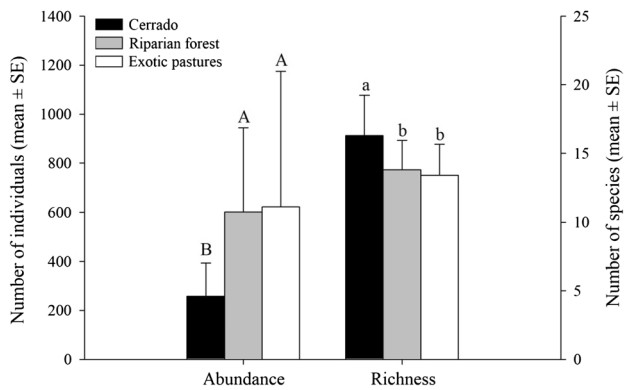

Fig. 4 Mean diversity (Shannon index) of dung beetle communities in three different habitats in the Brazilian Cerrado. Identical letters above the bars indicate that there were no significant differences among the habitats ($p > 0.05$)

Fig. 3 Mean abundance and species richness of dung beetle communities in three different habitats in the Brazilian Cerrado. Different letters above the bars indicate statistically significant differences among habitats ($p < 0.05$)

Fig. 5 Non-metric multidimensional scaling results (NMDS) constructed from Bray–Curtis matrices, for dung beetle communities in three different habitats in the Brazilian Cerrado

sharing between natural habitats and pastures, many species are with low abundance in pastures, which may mean that they are just using these pastures as transitional areas (e.g. ecological corridors or step-stones; Almeida et al. 2011). However, the species that could colonize the pastures in the Brazilian Cerrado could provide important ecosystem functions and services for livestock development, such as dung removal (Nichols et al. 2008), fly parasites control (Braga et al. 2012) and gastrointestinal worms (Nichols and Gómez 2014). These findings suggest that the conservation of natural systems may be a primary source of biodiversity for dung beetles in exotic pastures in Brazilian Cerrado. In this context, the management of pasture areas together with Cerrado and riparian forests areas, or agroforestry systems, may be an alternative to avoid the loss of dung beetle biodiversity.
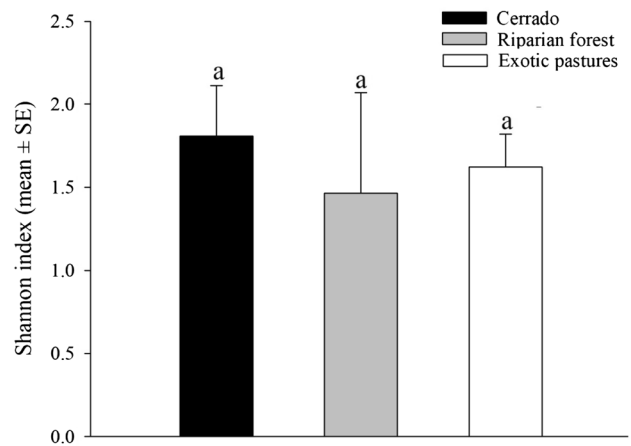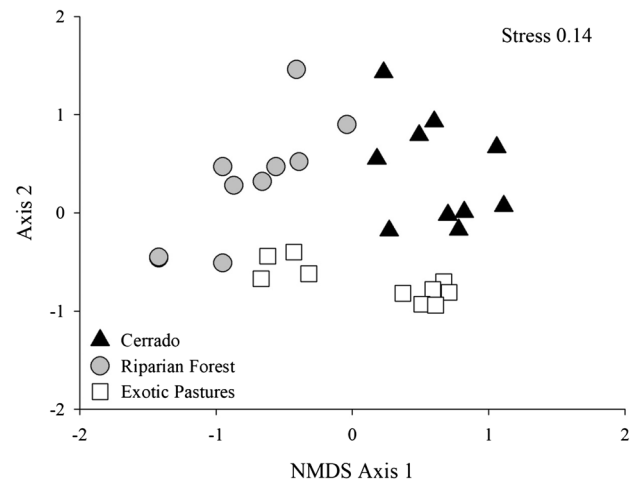
Table 2 PERMANOVA (difference in group position) and PERMDISP (difference in group dispersion) pairwise test to examine differences in species composition and differences in multivariate dispersion among three habitats in the Brazilian Cerrado

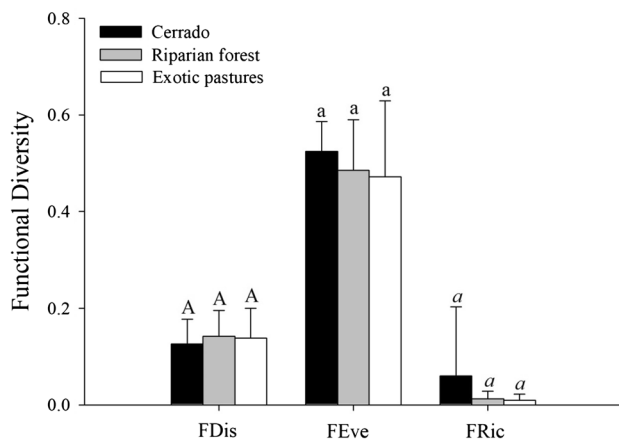| Group	PERMANOVA		PERMDISP	
	t value	p value	t value	p value
Cerrado versus exotic pasture	2.68	0.001	1.35	0.23
Cerrado versus riparian forest	2.75	0.001	0.35	0.75
Exotic pasture versus riparian forest	3.08	0.002	0.49	0.62

Fig. 6 Mean ± SE of functional dispersion (FDis), functional evenness (FEve) and functional richness (FRic) of dung beetle communities in three different habitats in the Brazilian Cerrado: identical letters above the bars indicate that there were no significant differences among the habitats (p > 0.05)

In addition, some actions to increase the biological value of pastures, such as diversification of use, with horse and cattle (Louzada and Carvalho e Silva 2009) or other domestic animals such as sheep (Correa et al. 2013) can aid in the dung beetles conservation.

The greatest abundance of dung beetles in exotic pastures compared with Cerrado fragments was due to the dominance of *Uroxys* sp. and *D. bos* in exotic pastures. These two dominant species are probably favored by forage capacity in exotic pastures for cattle dung, resulting in a competitive advantage for some species in this new food source (Louzada and Carvalho e Silva 2009). In addition, dominant species in pastures can develop under high temperatures, intense sun exposure (Navarrete and Halffter 2008), and cattle compacted soils (Halffter et al. 1992). However, dung beetle abundance was similar between exotic pastures and riparian forests, due to the dominance *T. externepuctatum* in riparian forests. Although pastures are simple and homogeneous systems (Louzada and Carvalho e Silva 2009), and the forests show modifications due to anthropogenic action, they can offer advantages to opportunistic species and species more tolerant to the changes in the environmental dynamics that result in an increase of its population, surpassing the communities of the most conserved natural system (Escobar et al. 2007).

Dung beetle diversity did not differ among systems. Despite there being the highest dung beetle species richness in Cerrado, there was highest abundance in Riparian forest and exotic pastures. This result demonstrates that, besides species richness, species evenness is also very important to maintain a high diversity (Gorelick 2006). Rodrigues et al. (2013) comparing dung beetle diversity among three land uses (pastures, agriculture and forest) found the highest

diversity in pastures. Thus, the increased resource supply and distribution during a longer and constant time for the dung beetles (cattle dung) in pastures and the adaptability of dung beetles to the modified environments (Riparian forest) can explain the high diversity of dung beetles in these systems.

Species composition and dispersion patterns

The dung beetle species composition differed among the three vegetation types, while the dispersion patterns are similar among them. Our results demonstrate well-defined communities in each vegetation type, highlighting the importance of each of them for conserving diversity of dung beetles in the landscape studied. We recorded a segregation pattern of species composition between natural environments and exotic pastures; and between different natural vegetation types which also has been documented in other studies on dung beetle communities in Brazilian Cerrado (e.g. Almeida and Louzada 2009; Almeida et al. 2011; Gries et al. 2012), evidencing the high degree of habitat specificity of dung beetles in the Cerrado biome (Almeida and Louzada 2009; Gries et al. 2012). The difference in species composition may be associated with microclimatic factors (biotic and/or abiotic factors) that each environment provides for dung beetles (Hanski and Cambefort 1991). The maintenance of dung beetles in a habitat is regulated by the sensitivity of adults and larvae to factors such as temperature and humidity (Larsen 2012). Thus, microclimatic changes are considered key factors in the impoverishment and loss of dung beetle biodiversity, limiting the species dispersal and colonization capacity, resulting in the eventual extinction of habitat specialists (Gardner et al. 2008).

Functional diversity

We did not find differences for the functional diversity indexes FRic, FEve and FDis among the vegetation types. Differences in taxonomic and functional patterns may be a result of functional redundancy between species in native vegetation and exotic pastures; or replacement by functionally different species that could maintain similar FRic values (Rosenfeld 2002; Magnago et al. 2014). Thus, despite the higher dung beetle richness in the Cerrado fragments, the high rates of species sharing among vegetation types may be a good predictor of the maintenance of functional diversity in the landscape, causing possible functional redundancy of species. For dung beetles is common for species to be grouped in the extremes (high originality and low uniqueness), losing species without decreasing FRic (Beiroz et al. 2018). Therefore, even with the species richness reduction in pastures, it may not have occurred the loss of functionally specialized species, not leading to reduction of functional

diversity (Villeger et al. 2008). As for the FEve, an explanation for this pattern is that the dung beetle species of the Brazilian Cerrado can present characteristics that allow them to tolerate the environmental conditions created by the disturbance. Similar FEve values between natural and anthropized sites may suggest that niche space occupied in anthropogenic areas is really being exploited by species and not only underutilized (Audino et al. 2014). Finally, similar values of FD is among habitats may indicate a greater dispersion of functional traits in anthropic areas, corresponding to a gain in the variability of responses to disturbances between species that contribute in a similar way to the ecosystem function (Laliberté et al. 2010).

Complementarity between the results evaluating taxonomic (weighted and non-weighted by abundance) and functional diversity

In order to predict common or divergent changes in functional and taxonomic diversity, it is necessary to use different weights for rare and abundant species. However, many common species make unique and persistent contributions to functional diversity (Chapman et al. 2018). We found different patterns of taxonomic (non-weighted by abundance) and functional diversity. Recently, Beiroz et al. (2018) demonstrated that taxonomic metrics (species richness) are more sensitive than functional metrics in detecting the effects of strong habitat modification in dung beetle communities (e.g. eucalyptus plantation). However, the responses depend mainly on the intensity of the disturbed and the functional characteristics chosen (Mlambo 2014; Beiroz et al. 2018). A low intensity disturbance in highly diversified communities does not modify functional structure, but may alter species composition. On the other hand, high intensity disturbances tend to negatively affect both taxonomic and functional components of the local biodiversity (Mlambo 2014; Magnago et al. 2014). In contrast, we found similar patterns of taxonomic (weighted by abundance) and functional diversity. In ecological applications, the true number of species is often unknown and some rare species may not be discovered in a sample of individuals (Gotelli and Colwell 2001; Chao and Shen 2003). Since rare species usually contribute more to functional diversity than common species (Chapman et al. 2018), metrics that ignore the importance of species abundance may underestimate the impacts (Moullit et al. 2013a, b). In this sense, in contrast to species richness, species diversity is most sensitive to land use change when there is a high number of rare species in the community (Chao and Shen 2003). Thus, we demonstrated the information generated by conceptually similar indexes (e.g. FRic, species richness and species diversity) may influenced by differences in the weighting on species abundance, providing different information on dung beetles responses to disturbance.

Studies on the response animal groups that provide important services to the ecosystem are important to supply baselines for conservation policies, which may help protect tropical savannas around the world. Thus, we demonstrate the importance of the presence of native vegetation areas, besides conserving high taxonomic diversity, also favors species sharing by maintaining a large number of dung beetles in the exotic pastures. This may help to maintain the taxonomic (Barlow et al. 2007; Rös et al. 2012; Costa et al. 2017; Beiroz et al. 2018) and functional diversity of dung beetles in the human-modified variegated landscape (Beiroz et al. 2018), mitigating the possible effects of land use change on the Brazilian Cerrado. Although, in our study, the patterns of taxonomic (non-weighted by abundance) and functional diversity of dung beetles are different, these two metrics generate complementary information that can helps us to reach more efficient conclusions in terms of biodiversity conservation, as well as ecosystem functionality in human-modified variegated landscape (Beiroz et al. 2018).

Compliance with ethical standards

Conflict of interest There is no conflict of interest among authors.

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