SABRINA NASCIMENTO CARVALHO

RESPONSE OF THE DUNG BEETLE COMMUNITY TO DIFFERENT CLIMATIC ZONES: DOES THE LAND USE SYSTEM MATTER?

LAVRAS-MG
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Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Conservação de Recursos Naturais em Ecossistemas Fragmentados e Agrossistemas, para a obtenção do título de Mestre.

Prof. Dr Júlio Neil CassaLouzada
Orientador

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RESPOSTA DA COMUNIDADE DE BESOURO ROLA BOSTA A DIFERENTES ZONAS BIOCLIATICAS: O SISTEMA DE USO DA TERRA IMPORTA?

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Aos meus pais, Chico Eloi e Rosângela, ao meu querido irmão Raffael e principalmente a <u>Deus</u>, **DEDICO.**

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RESUMO

A conversão das savanas brasileiras em pastagens exóticas leva à perda da biodiversidade dos besouros rola bosta e à diminuição de suas funções ecológicas. As comunidades de insetos ativas nesses ecossistemas são simplificadas e, portanto, são mais suscetíveis às variações ambientais climáticas do que as comunidades de habitats mais complexos e estáveis. Nossa hipótese é que as comunidades de escaravelhos de pastagens exóticas apresentarão diferenças mais significativas entre as zonas bioclimáticas, quando comparadas às comunidades de savana brasileira na mesma região. Verificamos quais variáveis (objetivo de produção, tipo de manejo, porcentagem do habitat por buffer, resistência do solo à penetração, área de pastagem e tamanho do rebanho) afetam mais a comunidade de escaravelhos em pastagens exóticas. Realizamos este estudo em 48 áreas de savanas nativas brasileiras e pastagens exóticas distribuídas em quatro zonas bioclimáticas (BZ): BZ1 - quente com três meses secos, BZ2 - quente com 4-5 meses secos, BZ3 - subquente com 4-5 meses secos meses e BZ4 - mesotérmico com 4-5 meses secos do Estado de Minas Gerais - Brasil. Em cada BZ foram selecionadas seis áreas de savana brasileira e seis áreas de pastagens exóticas. Nas áreas de Cerrado, a riqueza de espécies, abundância e biomassa de besouros não diferiram entre as zonas bioclimáticas, ao contrário das pastagens exóticas. A composição da comunidade de escaravelhos era diferente entre os sistemas de uso da terra e entre as zonas bioclimáticas; a interação entre os dois fatores também foi significativa. O melhor modelo sugeriu que todas as seis variáveis combinadas explicaram cerca de 91% da variabilidade total na composição de espécies observada entre os locais de amostragem.

Palavras-chaves: Biodiversidade. Rola bosta. Zona Bioclimáticas.

ABSTRACT

The conversion of Brazilian savannas into exotic pastures leads to biodiversity loss of dung beetles and decrease in their ecological functions. The insect communities active in these ecosystems are simplified, and therefore they are more susceptible to climatic environmental variations than communities from more complex and stable habitats. We hypothesize that the dung beetle communities from exotic pastures will present more significant differences between climatic zones, when contrasted to communities from Brazilian savannah at the same region. We verify which variables (purpose of production, type of management, percentage the habitat por buffer, soil penetration resistance, pasture area and herd size) affect more the dung beetle community in exotic pastures. We carried out this study in 48 areas of native Brazilian savannas and exotic pastures distributed across four bioclimatic zones: BZ1 - hot with three dry months, BZ2 - hot with 4-5 dry months, BZ3 - sub-hot with 4-5 dry months and BZ4 - mesothermal with 4-5 dry months of Minas Gerais State - Brazil. In each BZ were selected six areas of Brazilian savanna and six areas of exotic pasture. In natural areas, the species richness, abundance, and biomass of beetles did not differ between the bioclimatic zones, unlike the exotic pastures. The composition of the dung beetle community was different between land-use systems and between bioclimatic zones; the interaction between the two factors was also significant. The best model suggested that all the six variables combined explained about 91% of the total variability in species composition observed between sampling sites.

Keywords: Biodiversity. Dung Beetle. Climatic Zones.

SUMÁRIO

PRIMEIRA PARTE

1 INTRODUÇÃO GERAL

1.1 Mudança do uso de solo

A demanda da espécie humana por recursos vem crescendo demasiadamente nos últimos anos. Ainda não se sabe quando essa era geológica chamada "Antropoceno" se iniciou, porém é notório que os ecossistemas estão sofrendo mudanças devastadoras à medida que se aprofunda esse cenário de ação humana sobre os sistemas naturais (CORTELETT, 2015). A humanidade já modificou quase 50% da cobertura terrestre (LAMBIN *et al.,* 2003; MCGILL *et al.,* 2015) e já explorou cerca de 40% da produtividade primária da Terra (MCGILL *et al.,* 2015).

Desde a década de 70 o Cerrado no Brasil vem sendo intensamente explorado e convertido em áreas para atividades agropastoris, objetivando expandir a economia. Mesmo o Cerrado sendo considerado um ambiente com solo pobre em nutrientes, neste bioma são produzidos cerca de 25% dos grãos da safra brasileira (SILVA, 2000) e comporta aproximadamente 35% do rebanho nacional (MULLER; MARTHA, 2008) que causa a compactação do solo e modificação de toda estrutura vegetal do ambiente (MARTINEZ; ZINCK, 2004; SILVA, 2000). Atualmente, o Brasil possui o maior rebanho comercial do mundo (FAO, 2014) 15,3% da produção mundial (ABIEC, 2019), o que pode ter reflexos na redução acelerada dos recursos naturais do Cerrado desde os últimos 30 anos (SILVA, 2000).

A conversão do uso da terra em áreas naturais de cerrado para atividades agropastoris está acontecendo em uma extensão territorial muito grande, com isso afetando organismos em larga escala, com impacto na biodiversidade local e no pool de espécies regional (YACHI; LOREAU, 1999). Análises em escalas mais amplas permitem detectar que o impacto local pode ser mais sutil quando comparado ao impacto causado à biodiversidade em larga escala (ALMEIDA; LOUZADA, 2009; ALMEIDA *et al.,* 2011), já que a capacidade humana de proteger o mundo natural muitas vezes é impedida por não considerar a particularidade dos ambientes medidos em diferentes escalas espaciais (MCGILL *et al.,* 2015).

1.2 Insetos como bioindicadores – besouros rola bosta

Uma maneira eficiente e rápida de medir impactos antrópicos em ambientes naturais é utilizando organismos bioindicadores, sendo os insetos geralmente os mais usuais. Os insetos

são eficientes bioindicadores por serem sensíveis às mudanças ambientais, ao curto ciclos de vida e geralmente são de fáceis amostragem. (OLIVEIRA *et al.,* 2014). Segundo Luçardo et al. (2014) cerca de 64% dos trabalhos que se trata da importância ecológica da biodiversidade no bioma Cerrado utilizam coleópteras Scarabaeoidea como organismo modelo, considerados, portanto, bioindicadores valiosos dos distúrbios antrópicos (HALFFTER; FAVILA 1993).

Os besouros Scarabaeinae (Scarabaeoidea) é uma subfamília bastante sensível às perturbações ambientais, respondem rapidamente à mudança do uso do solo, são bem conhecidos e de fácil amostragem (ALMEIDA; LOUZADA, 2009; NICHOLS *et al.,* 2008; BORGES *et al.,* 2011; GRIES *et al.,* 2012). São organismos importantes para o ecossistema, pois devido ao seu hábito de vida em utilizar fezes de outros animais como recurso alimentar e de ovoposição, acabam prestando serviços importantes 6 para o ecossistema (CAMBEFORT; HANSKI, 1991), como remoção de fezes do solo que atrai parasitas como moscas, revolvimento do solo e dispersão secundária de sementes (NICHOLS *et al.,* 2008; GRIFFITHS *et al.*, 2015). Compreender as respostas da biodiversidade em relação à perda da heterogeneidade do habitat é um passo importante para entender a distribuição espacial desses besouros (SILVA, 2010).

1.3 Zonas bioclimáticas

Desde os anos 60 pesquisadores utilizam dados climáticos para classificação das regiões geográficas em zonas bioclimáticas, especialmente em regiões equatoriais onde há maiores variações (CASTRI; HAJEK, 1961). As zonas bioclimáticas são fortemente utilizadas para planejamento de edificações nas construções urbanas e civis (MARTINS *et al.,* 2012: GUARDA *et al.,* 2018), mas também como parâmetros de medição à características vegetais (HUESCA *et al.,* 2009) ou até mesmo para prever e analisar locação de gado e produção de leite (TURCO et al., 2006). Para análises em larga escala é evidente que as zonas bioclimáticas podem fornecer bons parâmetros a fim de classificar, analisar e/ou comparar variantes a serem pesquisados.

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<center>**SEGUNDA PARTE - ARTIGO**</center>

2 ARTIGO – RESPONSE OF THE DUNG BEETLE COMMUNITY TO DIFFERENT CLIMATIC ZONES: DOES THE LAND USE SYSTEM MATTER?

Artigo submetido de acordo com o periódico Ecology Entomology

2.1 Introduction

The conversion of natural areas into agriculture, pastures and other land-use systems is a major cause of biodiversity loss (Gibson et al. 2011; Jantz et al. 2015; Solar et al. 2016; Sala, 2000; De Marco Jr. et al. 2018). The exponential growth of the population, combined with the high demand of developed countries for produced in developing countries, has increased the replacement of natural systems, leading to biodiversity loss (Lenzen et al., 2012). Thus, this globalization process accelerates the rate at which agriculture and livestock are replacing or impoverishing tropical forests (Nepstad et al. 2006).

In Brazil, pasture expansion is the primary threat to biodiversity (Chaudhary et al., 2016), more than 20% of the territory is occupied by pastures, totalling 277 million hectares, 166 million hectares of native pastures and grassland vegetation and approximately 111 million hectares of introduced pastures (IBGE, 2018). The increase in beef consumption is a global and regional driver of land-use changes (McAlpine et al. 2009; Aide et al.; 2012), stimulating the demand in production and productivity (McManus et al. 2016). Currently, Brazil has the largest herd in the world, accounting for 15.3% of the world's production (ABIEC, 2019).

Areas defined as hotspots are a priority for conservation worldwide, as they have a large number of endemic species and have a loss of 70% or more of their primary vegetation (Myers, 2000). The Brazilian Cerrado is the second largest savanna in the world, covering 204.7 million hectares and, together with the Atlantic Forest forms the two hotspots in Brazil (Myers, 2003, Sano et al., 2010). Despite its importance, this biome receives less attention, whether through the media, research or conservation measures, when compared to other tropical forests (Redo et al. 2013). It is estimated that deforestation in the Cerrado will be around 13.5% by 2050, further increasing the risk for this hotspot (Ferreira et al., 2012). Currently, almost 30% of the biome is occupied by cultivated pastures (Sano et al. 2019). The Cerrado conversion into exotic

pastures, even though it may be considered subtle, promotes the loss of biodiversity (Almeida et al., 2011; Macedo et al., 2020).

Dung beetles are widely used as study tools, because they respond quickly and with excellent reliability to environmental changes (McGeoch et al. 2002; Nichols et al. 2007), such as land-use changes (Korasaki et al., 2013; Beiroz et al. 2018; França et al. 2020). In pasture systems, dung beetles respond to various environmental variables such as landscape structure (Alvarado et al. 2018), intensified management (Hutton and Giller, 2003; Alvarado et al. 2019), grazing intensity (Verdú et al. 2007), size area, grazing time (Imura et al. 2014; Buse et al. 2015), abandonment time (Correa et al. 2020), use of veterinary medical products (Sands and Wall, 2018), among others.

Brazil is a country with continental dimensions, different biomes and climates (IBGE, 2002; Ab'Sáber, 2003). The replacement of native savannas by exotic pasture causes a reduction in the vegetation complexity (Macedo et al. 2020), where this complexity has a positive influence on the biological community (Halaj et al., 2000; Ambrecht, 2005; Negro et al. 2011) because more complex environments are also stable. We hypothesize that exotic pastures, being an environment with less complexity (see Macedo et al. 2020), will present a difference in the community structure between different climatic zones, while the more complex native savannas will not present significant differences. Additionally, we also verified which variables most influence the dung beetle community in cultivated pastures.

2.2 Materials and methods
2.2.1 Study sites and experimental protocol

We carried out this study in 48 areas (sampling site) of native Brazilian savannas (Cerrado) and exotic pastures distributed over four Minas Gerais State bioclimatic zones (Figure 1). For areas selection, we used cross-section metadata of bioclimatic zones 2002, biomes 2018 and land use and occupation 2017, available on the online platform of the Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geograph and Statistics IBGE), as proposed by Nimer (1974), where we selected the four most representative bioclimatic zones (BZ) within the State of Minas Gerais: BZ1 - hot with 3 dry months, BZ2 - hot with 4-5 dry months, BZ3 - sub-hot with 4-5 dry months and BZ4 - meso-thermal with 4-5 dry months (Figure 1). In each BZ were selected six area of Brazilian savanna and six areas of exotic pastures. Each sampling area received five sampling points, 50 m apart, placed along a linear transect, where we considered the areas (sampling sites) as replicates.

2.2.2 Dung beetle sampling and identification

We sampled dung beetles in January and February 2018 using pitfall traps (19 cm diameter, 11 cm depth), buried at ground level, and baited with 25 g of human feces. We used human feces as bait because it is the most attractive bait to sample dung beetles in native and exotic habitats, with apparent structural differences (Correa et al. 2016). Traps were exposed for 48 h period in each area, and then the content of each one was transferred to plastic bags and taken to the Laboratory of Pesquisas Ambientais da Universidade do Estado de Minas Gerais (UEMG). We weighed up to 15 individuals of each species on a precision scale (0.0001 g) to obtain an estimate of the total biomass of dung beetles. The average mass of each species was then multiplied by its abundance in each area. Dung beetles were identified at the genus level (Vaz-de-Mello et al. 2011) and then identified to species by Dr. Fernando Z. Vaz-de-Mello. The voucher specimens were deposited in the Coleção de Referência de Escarabeíneos Neotropicais (CREN) of Universidade Federal de Lavras and the Entomology Collection of Universidade Federal de Mato Grosso (UFMT).

2.2.3 Environmental variables

The spatial data of the sampling units were recorded and processed in the ArcGIS 10.5 software (ESRI, 2017), applying a buffer of 2 km in diameter based on the use and coverage classification of the state of Minas Gerais. The acquisition of this data was generated by the Brazilian Annual Land Use and Mapping Project (MapBiomas - collection 4.1). The platform aims to map land use in Brazil based on satellites such as Landsat (5-TM, 7-ETM + and 8-OLI), the classes were divided in forest formation, savanna formation, forest plantation, grassland, pasture, annual and perennial crop, semi-perennial crop, urban infrastructure, non-vegetated area and river/lake (MapBiomas - collection 4.1) (Figure 2).

We measure the resistance to soil penetration (kPa) with the aid of a handheld digital penetrometer. Next to each trap, a measurement was made, totaling five points per area. The average penetration resistance per sampled area was used. For each area of exotic pasture, the following data were surveyed: area size, number of the herd, purpose of production (cutting, milk or mixed) and type of management (extensive, semi-intensive or semi-confinement).

2.2.4 Data analysis

We used generalized linear models (GLMs) to examine differences in the number of individuals and species and biomass between the bioclimatic zone. We used Gaussian error structure for richness, abundance and biomass in Brazilian Cerrado and quasi-Poisson's error structure for richness, abundance and biomass in exotic pastures because an overdispersion was detected. Minimal models were adjusted by excluding nonsignificant variables and verifying effects on deviance (Crawley 2007). All GLMs were submitted to residual analyses, to evaluate the adequacy of error distribution (Crawley 2013). All analyses were performed using the software R 2.9.0 (R Development Core Team 2020).

The NMDS was based on a similarity matrix constructed using the Bray-Curtis index calculated on standardized, square-root transformed data. Statistical differences in community composition between and within bioclimatic zones and land-use categories, as well as the possible interaction between these two factors, were analyzed using a two-way crossed permutational multivariate analysis of variance (PERMANOVA; Anderson, 2001) design with fixed factors bioclimatic zone and land use categories.

The relationships between dung beetle composition of exotic pasture and environmental variables were examined using distance-based linear models (DISTLM) (Legendre and Anderson, 1999) by setting up "binary codes" for each of the categorical factors: the "purpose of production" (cutting, milk or mixed) and "type of management" (extensive, semi-intensive or semi-confinement). The variables "purpose of production", type of management and buffer were identified with the help of the indicator. We performed a correlation analysis between the variables, and the urban infrastructure variable was removed from the model. The continuous variables were also included in the analysis (penetration resistance, area size and herd number). We use a step-wise selection procedure and adjusted R² as a selection criterion. The DistLM was illustrated using distance-based redundancy analysis (dbRDA). These analyses were performed using the Primer v.6 software with PERMANOVA+ (ANDERSON; GORLEY; CLARKE, 2008).

2.3 Results

2.3.1 Patterns of species richness, abundance and biomass

We collected 11049 individuals of 83 dung beetle species, with 1055 individuals of 52 species in BZ1, 790 individuals of 39 species in BZ2, 2025 individuals of 39 species in BZ3 and 7179 individuals of 52 species in BZ4 (Table S1). In the savanna areas, abundance (F= 2.5046; p= 0.0884; Figure 2A), species richness (F=2.0694 p=0.1365; Figure 2B) and biomass

(F=2.9288; p= 0.05869; Figure 2C) did not show differences among zonas bioclimatic zones. However, exotic pastures showed significant differences in the abundance (F=26.251, p<0.0001; Figure 2D), species richness (F=13.548 p=0.00131; Figure 2E) and biomass (F=23.895; p<0.0001; Figura 2F) among bioclimatic zones. Both abundance and biomass were higher in the BZ4 when contrasted to all other bioclimatic zones (Figure 2D and 2F). Species richness was higher in the BZ3 and BZ4 than those found in the ZB1 and ZB2 (Figure 2E). Exotic pasture areas were predominantly composed of *Urochloa* spp.

2.3.2 Species composition and environmental variables

The effect of bioclimatic zone and land use systems was significant in explaining the dung beetle species composition, the interaction between bioclimatic zone and land use systems was also statistically significant (Figure 3; PERMANOVA - Table 1).

The dbRDA performed for dung beetle composition and environmental variables shows a precise selection of the four bioclimatic zones, with BZ1 and BZ3 with a positive correlation with axis 1, BZ2 with negative correlation with axis 2 and BZ 4 with positive correlation with axis 2 (Figure 5). The great importance of variable buffer shows that the axis represented by the percentage of native vegetation has a positive correlation with axis 2 (Figure 4). We used a distance-based linear model (DISTLM) to find out the relationship between the composition of dung beetles and environmental variables. In the marginal test, the bioclimatic zone and buffer showed a significant relationship with the species-derived multivariate data cloud when considered alone and ignoring all the other variables (Tabela 2). Bioclimatic zone alone explained about 54% of the variability, while buffer and density explained 50% and 7.5%, respectively (Table 2). However, the density shows p with marginal significance (p = 0.088). In the sequential test, the bioclimatic zone to be taken first. Next to this, the variable that increased the R2 criterion the most was the buffer. Together they explained about 78% of the variability in the data cloud. The best solution suggested that all the six variables (bioclimatic zone, buffer, area size, the purpose of production, type of management and resistance of soil penetration) combinedly explained about 91% of the total variability.

2.4 Discussion

This study evaluated, for the first time, the dung beetle community response in different bioclimatic regions to two land-use systems. We found that the components of the structure of the dung beetle community in the savanna areas show little variation between bioclimatic

regions. However, when land-use change occurs for exotic pasture, the community shows more considerable variation between bioclimatic zones. The main variables affecting the exotic species community were the bioclimatic zone and the landscape.

2.4.1 Patterns of species richness, abundance and biomass

The species richness, abundance and biomass of the dung beetles showed no difference among the different bioclimatic zone. However, the three parameters differed among the bioclimatic zones for the exotic pasture system. Human activities are responsible for additional local heating (Lim et al. 2005), which the replacement of native vegetation by pasture can heat the local climate by approximately 1.5°C (Loarie et al. 2011). Microclimate conditions and vegetation structure influence the dung beetle community (Hanski, 1983), and the forest conversion leads to environmental changes that negatively affect the dung beetle community (Nichols et al. 2013). Thus, the low canopy cover and simplification of herbaceous complexity in exotic pasture probably restricts the establishment of Cerrado dung beetle species (Macedo et al. 2020) in exotic pasture areas.

Therefore, we believe that natural areas provide milder climatic conditions, especially lower temperatures, greater vegetation complexity, higher humidity and less soil compaction, leading to more favourable conditions for the dung beetle community (Guerra-Alonso et al. 2019).

The bioclimatic zone did not influence the community in natural systems. However, in exotic pastures, the dung beetle community is more simplified and therefore, more susceptible to changes in the community (Louzada and Carvalho e Silva 2009), due to the hot climate, leading to a reduction in abundance, species richness and biomass in hot bioclimatic zones when compared to the meso-thermal bioclimatic zone. Menéndez and Gutiérrez et al. (2004) suggests that habitat associations are sensitive to microclimatic conditions, and climate change could be a significant factor influencing habitat selection in dung beetles. Guerra Alonso (2020) found that dung beetle responses to livestock management cannot be generalized for all biomes. In our work, we demonstrated that the dung beetle responses are different between two land-use systems between bioclimatic zones, indicating that the effect of land-use change in the dung beetle community can be an intensifying factor in climate changes.

2.4.2 Patterns of composition

The difference in the composition of the dung beetle community was detected between land-use systems and between bioclimatic zones. In addition, the interaction between the two factors was also significant. Our result corroborates with other studies, strengthening the idea that changes in land use, even though subtle as Cerrado for exotic pastures, affect the dung beetle community (Almeida et al. 2011; Macedo et al. 2020). This change leads to alters in the associated ecological functions, such as dung removal, soil bioturbation and parasite control (Losey and Vaugh, 2006; Braga et al. 2012, 2013; Alvarado et al. 2019). The significant interaction is another indication that the bioclimatic zone acts differently on the dung beetle community in native and exotic areas.

2.4.3 Exotic pastures and environmental variables

Bioclimatic zone and buffer showed a significant relationship with the species-derived multivariate data cloud when considered alone and ignoring all the other variables on exotic pasture, indicating that landscape influences the dung beetle community (e.g. Louzada et al., 2010; Imura et al. 2014; Lascaleia et al. 2018). The structural complexity of vegetation may be more important than habitat or livestock intensification to influence the species richness and composition of dung beetles (Numa et al., 2009; Alvarado et al. 2018). The increase in landscape heterogeneity leads to an increase in the dung beetle diversity but also of other groups, such as plants and vertebrates (Imura et al. 2011; Fahrig et al 2015). In addition to the complexity, the forest cover amount in the landscape has been related to the composition of dung beetles (Halffter & Arellano, 2002; Alvarado et al. 2017), therefore surrounding land-use influences the species richness of dung beetles (Imura et al. 2011).

In our study, the herd and pasture size, as well as the management and herd purpose, when considered alone, did not influence the composition of the dung beetle community. However, the diversity of arthropods can decrease with increasing intensity of management, and also with an alteration of the landscape structure (Hendrickx et al. 2007). Other factors have also been related to changes in the dung beetle community, such as grazing time, cattle grazing removal, vegetation height, use of parasiticides, management intensity, soil density (Geiger et al. 2010; Imura et al. 2014; Alvarado et al. 2018; Correa et al. 2020), overgrazing (Negro et al. 2011). However, in our study, the soil density did not influence the composition of dung beetle community.

2.4.4 Implications for conservation of dung beetles in agrospasturis landscapes

The livestock sector contributes about 40% of the world Gross Domestic Product (GDP), occupying a large part of the globe, either through grazing areas or for the cultivation of the grains for animal feed (Herrero et al. 2013). However, among the anthropic activities, the cattle farming areas are the most representative, occupying around 30% of the ice-free areas (Herrero et al. 2013), is a threat to biodiversity (Korasaki et al. 2013; Macedo et al. 2020), can lead to contamination and degradation of soil and water (Herrero et al. 2013) and release of greenhouse gases (Hagemann et al., 2011; Weiss and Leip, 2012; Ghosh et al. 2020).

In Brazil, all regions have pastures with some level of degradation (Dias Filho, 2014). The replacement of degraded pastures by managed and integrated agroforestry systems reduces the carbon footprint of the meat, due to improved pasture, increasing livestock production (Figueiredo et al. 2016). This technique acts as a potential sink for C in the soil, offsetting the GEEs from livestock (Figueiredo et al. 2016). However, Piccini et al. (2019) found that local "farmers" decisions can be crucial in shaping local habitats and dung beetle communities and their associated ecological functions, rather than the system adopted (organic or conventional). Therefore, manure from conventional livestock farms sustains 35% fewer insects than manure from organic farms (Geiger et al 2010).

The dung beetle community, beneficial to pasture systems for promoting various ecological services in this agroecosystem (Nichols et al. 2008), is influenced by several factors, such as the use of parasiticides (Verdú et al. 2018), but also the landscape structure (Alvarado et al. 2018). Therefore, the management conservation of this habitat requires the consideration of several spatial scales. Land management is generally carried out on a fine scale (the farm level), but for better results, it is necessary to manage on a spatial scale beyond the farm (Gabriel et al., 2010). Thus, the more heterogeneous the landscape, the higher the diversity (Fahrig et al. 2015), Also, Negro et al. (2011) indicate that the maintenance of traditional pastoral activities can mean helping to preserve the habitat heterogeneity and, consequently, the dung beetle diversity. However, some ranchers end up deforesting and increase the pressure for small farmers to sell their land (Redo et al. 2013), leading to a landscape with less heterogeneity.

3 Acknowledgments

4 Figures and tables
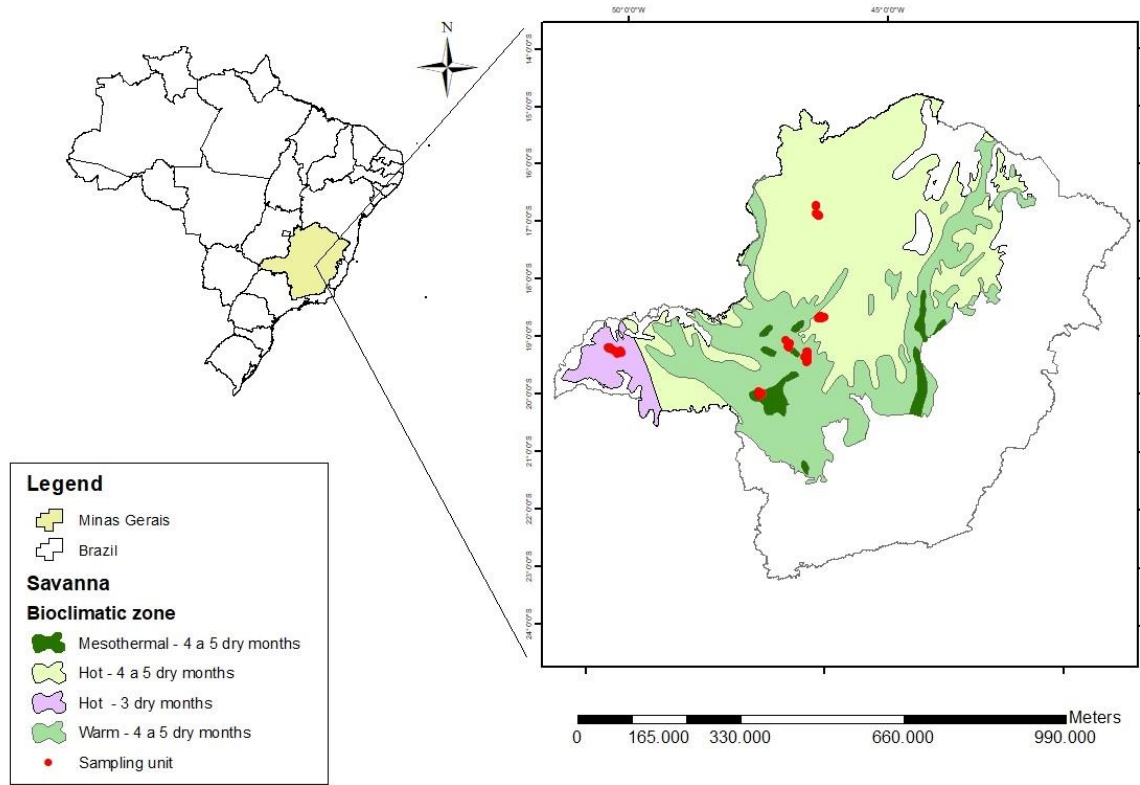
Fig. 1. Map of the study region, showing the location of the sampling sites in different bioclimatic zones.
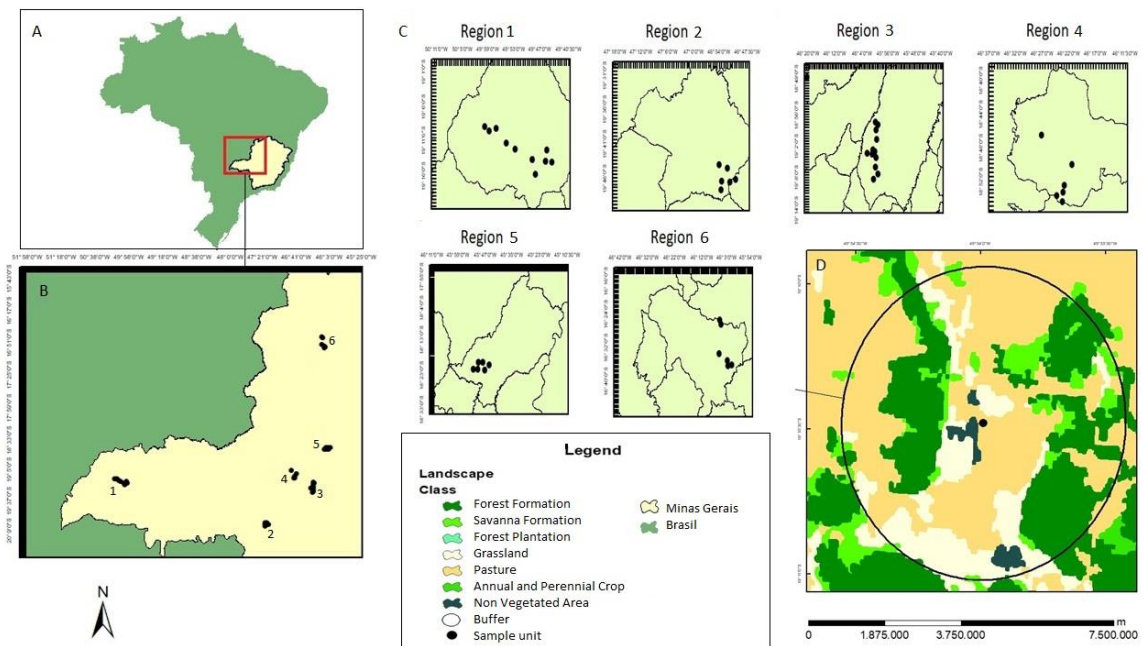
Fig. 2. Map of the study region, showing the location of the sampling sites. A. Brazil, B. Sampling points along study area, C. Detail of each region, D. Buffers used to measure surrounding land use.
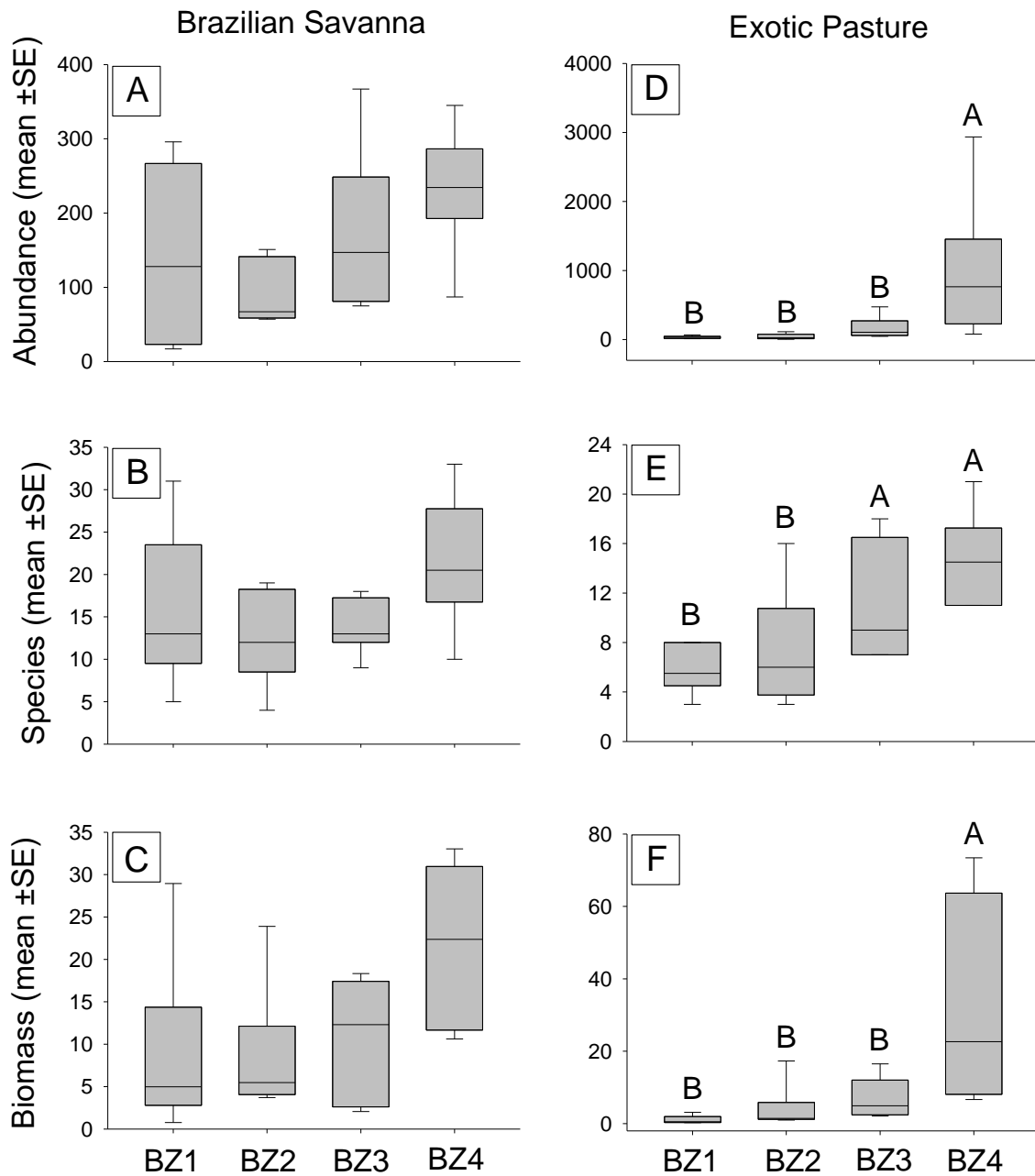
Fig. 3. Mean value of dung beetle abundance, species and biomass on Brazilian savanna and exotic pasture. Different letters above bars indicate statistically significant differences (p< 0.05) among land use systems. Error bars represent ±SE.
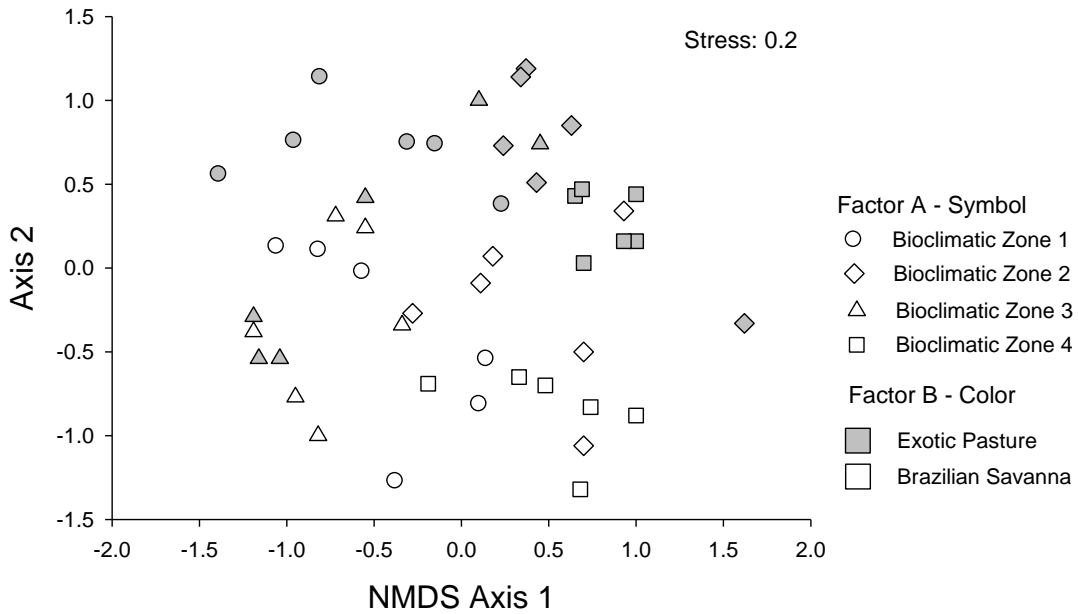
Fig. 4. Non-metric mutldimensional scaling (NMDS) constructed from Bray-Curtis matrices of two land use system and four bioclimatic zones.
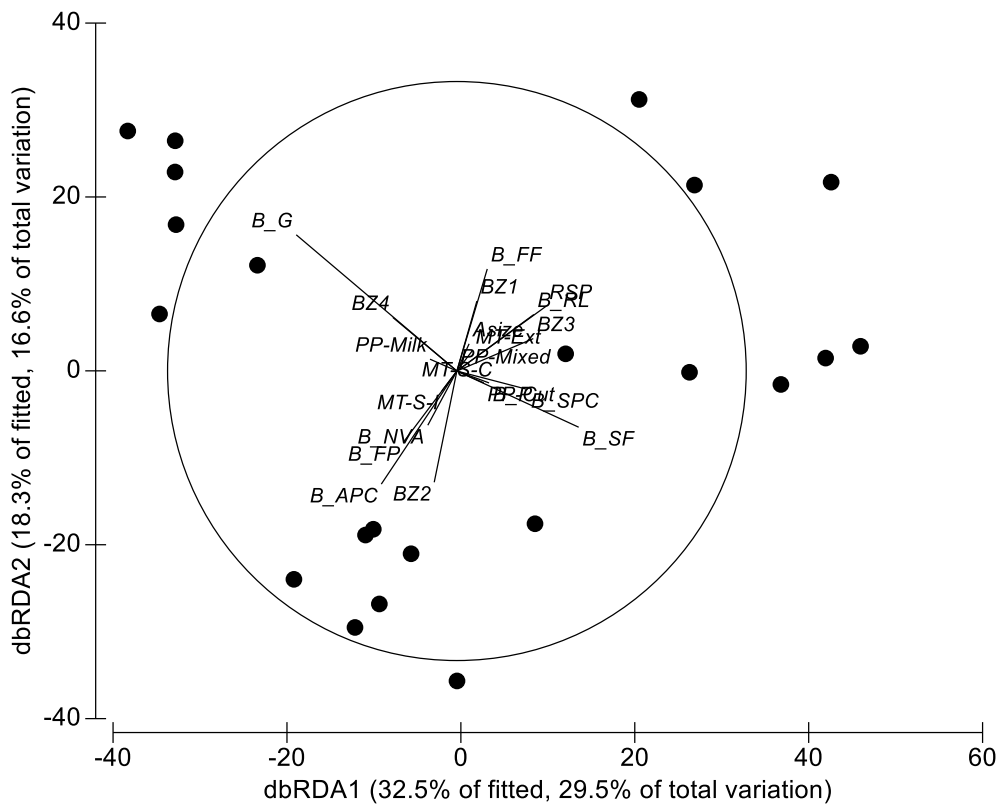
Fig 5. Distance-based redundancy analysis (dbRDA). Relationships between the ordination of the samples based on dung beetle composition and and environmental variables. Resistance to

soil penetration (RSP), area size (Asize), herd size (HerdS), bioclimatic zone (BZ1-BZ4), buffer - forest formation (B_FF), savana formation (B_SF), forest plantation (B_FP), grassland (B_G), pasture (B_P), annual and perennial crop (B_APC), semi-perennial crop (B_SPC), non vegetated área (B_NVA), river, lake (B_RL), purpose of production – Cutting (PP_Cut), Milk (PP_Milk), Mixed (PP_Mixed), type of management – extensive (MT_Ext), semi-intensive (MT_S-I), semi-confinement (MT_S-C).

Table 1. Pseudo-F values of two-way crossed PERMANOVA analyses performed, indicating the pseudo-F values for the differences in assemblage similarity in the composition of dung beetle according to the two considered factors (bioclimatic zone and land use system) as well as their interaction. All tests were statistically significant with P <0.001.

Source	df	SS	MS	Pseudo-F	P
Bioclimatic Zone	3	34250	11417	6.3608	0.0001
Land Use System	1	15935	15935	8.8783	0.0001
Bioclimatic Zone X Land Use System	3	11601	3867	2.1545	0.0001

Table 2. Results of Distance-based linear modeling (DistLM) testing for relationships between, resistance to soil penetration (RSP), area size, herd size, bioclimatic zone (biolclimatic zone 1-4, buffer (forest formation, savana formation, forest plantation, grassland, pasture, annual and perennial crop, semi-perennial crop, non-vegetated area, river, lake), purpose of production (cutting, milk or mixed), type of management (extensive, semi-intensive or semi-confinement) and dung beetles composition in marginal tests (variation explained by single variables) and in sequential tests (variation explained by adding new variable each time to get the optimum fit criterion) using the stepwise selection procedure: on the basis of the adjusted R² selection criterion (significant *P* values in bold italic)

Results of marginal tests of DISTLM				
Variable	SS (trace)	Pseudo-F	P	Proportion
RSP	4206.3	1.6363	0.088	7.5628E-2
Area size	2602.9	0.98194	0.437	4.6799E-2
Herd size	1294.3	0.47649	0.913	2.327E-2

Purpose of production	2492.5	0.93833	0.46	4.4814E-2
Type of management	1688.1	0.62603	0.84	3.0351E-2
Bioclimatic Zone	27824	4.2545	**0.001**	0.50027
Buffer	30117	1.5747	**0.021**	0.54149

Results of sequential tests of DISTLM

Variable	R^2	SS (trace)	Pseudo-F	P	Proportion	Cumul. P
Bioclimatic Zone	0.38268	27824	4.2545	**0.001**	0.50027	0.50027
Buffer	0.41201	15336	1.0942	0.347	0.27574	0.77601
Purpose of production	0.45123	2284.3	1.5717	0.174	4.1072E-2	0.81708
RSP	0.48503	1990.5	1.4594	0.222	3.5788E-2	0.85286
Area size	0.50417	1617.4	1.2317	0.305	2.9081E-2	0.88195
Type of management	0.51464	1424.1	1.1079	0.373	2.5606E-2	0.90755

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5 Supplementary material

Table 1. Biodiversity of dung beetles sampled in Brazilian savanna and introduce pastures in

Taxon	BZ 1	BZ 2	BZ 3	BZ 4	Total
ATEUCHINI					
Ateuchus aff romani	1	0	0	0	1

Ateuchus carbonarius (Harold, 1868)	0	0	0	7	7
*Ateuchus pauperatus (G*ermar, 1824)	0	0	0	2	2
Ateuchus puncticollis (Harold, 1867)	0	0	50	0	50
Ateuchus striatulus (Preudhomme de Borre, 1886)	0	1	2	2	5
Ateuchus subquadratus (Harold, 1868)	0	0	1	0	1
Ateuchus vividus Germar, 1824	0	0	3	6	9
Besourenga sp1	1	0	0	0	1
Canthidium aff *pilluliformes*	339	21	329	64	753
Canthidium aff *viride*	0	12	0	248	260
Canthidium decoratum (Perty, 1830)	21	12	60	3	96
Canthidium barbacenicum Preudhomme de Borre, 1886	41	50	19	158	268
Canthidium impressum Boucomont, 1928	2	1	0	0	3
Canthidium marseuli Harold, 1867	0	1	0	0	1
Canthidium multipunctatum Balthasar, 1939	3	3	0	11	17
Canthidium sp1	5	0	4	0	9
Canthidium sp2	7	4	0	0	11
Canthidium sp3	0	3	0	0	3
Canthidium sp4	0	0	0	2	2
Eutrichillum hirsutum (Boucomont, 1928)	1	0	0	0	1
Generidium bidens (Balthasar, 1938)	0	1	1	2407	2409
Generidium cryptops (Arrow, 1913)	1	2	6	2	11
Trichillum adjunctum Martínez, 1969	0	0	103	0	103
Trichillum extenepuctatum Preudhomme de Borre, 1886	140	218	242	1376	1976
Trichillum heydeni Harold, 1868	0	0	19	0	19
Uroxys aff thorocalis	0	0	0	88	88
Uroxys sp1	0	0	0	43	43
CANTHONINI					
Agamopus unguicularis (Harold, 1883)	3	0	0	1	4
Agamopus viridis Boucomont, 1928	2	10	0	7	19
Canthonella sp.	0	0	1	0	1

COPRINI

Dichotomius bicuspis (Germar, 1824)	0	1	5	0	6
Dichotomius bos (Blanchard, 1846)	19	17	53	163	252
Dichotomius carbonarius Mannerhein, 1829	3	0	1	0	4
Dichotomius cuprinus (Felsche, 1901)	1	0	1	3	5
Dichotomius glaucus (Harold, 1869)	11	0	9	0	20
Dichotomius lycas (Felsche, 1901)	46	17	45	12	120
Dichotomius nisus (Olivier, 1789)	15	14	130	197	356
Dichotomius quadraticeps Felsche, 1901	1	0	0	2	3
Dichotomius semiaenius (Germar, 1824)	1	0	5	1	7
Digitonthophagus gazella (Fabricius, 1787)	7	1	1	10	19
Isocopris hypocrita (Lucas 1857)	1	0	0	0	1
Isocopris inhiatus (Germar, 1824)	0	14	0	0	14
Ontherus appendiculatus (Mannerheim, 1829)	60	75	4	1434	1573

DELTOCHILINI

Anomiopus sp1	1	0	0	0	1
Anomiopus sp2	0	1	0	0	1
Canthon aff *laminatus*	0	0	0	1	1
Canthon conformis Harold, 1868	0	2	0	43	45
Canthon corpulentus Harold, 1868	0	0	120	0	120
Canthon curvodilatatus Schmidt, 1920	33	0	2	33	68
Canthon dives Harold, 1868	0	0	0	57	57
Canthon histrio (Lepeletier de Saint-Fargeau & Audinet-Serville, 1828)	66	13	32	34	145
Canthon lituratus (Germar, 1824)	0	21	8	48	77
Canthon octodentatus Schmidt, 1920	2	6	0	0	8
Canthon pauxillus (Harold, 1883)	0	0	18	2	20
Canthon tristes Harold, 1862	43	0	0	1	44
Canthon unicolor Blanchard, 1843	1	0	3	0	4
Canthon virens Mannerheim, 1829	2	40	7	1	50
Pseudocanthon sp.	2	9	0	13	24

PHANAEINI

Coprophanaeus acrisius (MacLeay, 1819)	1	6	0	0	7
Coprophanaeus cyanescens (d'Olsoufieff, 1924)	1	0	0	2	3
Coprophanaeus ensifer (Germar, 1821)	1	0	0	8	9
Coprophanaeus spitzi (Pessôa, 1934)	1	3	0	36	40
Deltochilum elevatum (Castelnau, 1840)	0	0	6	0	6
Deltochilum enceladus Kolbe, 1893	0	0	0	6	6
Deltochilum pseudoicarus Balthasar, 1939	3	0	0	23	26
Deltochilum sp1	63	1	15	57	136
Dendropaemon denticollis Felsche, 1909	1	0	0	0	1
Dendropaemon nitidicollis Olsoufieff 1924	0	1	0	1	2
Diabroctis mimas (Linnaeus, 1758)	2	0	0	0	2
Diabroctis mirabilis (Harold, 1877)	0	3	5	6	14
ONITICELLINI					
Eurysternus caribaeus (Herbst, 1789)	1	0	0	0	1
Eurysternus nigrovirens Génier, 2009	20	1	0	19	40
ONTHOPHAGINI					
Onthophagus buculus Mannerheim, 1829	10	22	461	10	503
Onthophagus hircus Mannerheim, 1829	2	24	200	95	321
Onthophagus ptox Erichson, 1842	28	0	0	184	212
Onthophagus sp1	1	0	0	0	1
Onthophagus sp7	1	0	0	3	4
PHANAEINI					
Malagoniella aeneicollis (Waterhouse, 1890)	0	0	0	7	7
Malagoniella astyanax (Olivier, 1789)	1	0	0	0	1
Oxysternon palaemon (Castelnau, 1840)	28	104	36	109	277
Phanaeus kirbyi Vigors, 1825	3	2	0	0	5
Phanaeus palaeno Blanchard in Blanchard & Brullé, 1845	4	53	4	131	192
Sulcophanaeus menelas (Castelnau, 1840)	0	0	14	0	14
Abundance	**1054**	**790**	**2025**	**7179**	**11048**
Richness	**52**	**39**	**39**	**51**	**83**