J Insect Conserv (2016) 20:447–456
DOI 10.1007/s10841-016-9877-7

ORIGINAL PAPER

Using dung beetles to evaluate the conversion effects from native to introduced pasture in the Brazilian Pantanal

César Murilo de Albuquerque Correa[1] · Anderson Puker[2,3] · Kleyton Rezende Ferreira[4] · Cleilsom Melgarejo Cristaldo[5] · Felipe Nery Freitas Ferreira[6] · Alfredo Raúl Abot[5] · Vanesca Korasaki[7,8]

Received: 20 December 2015 / Accepted: 9 May 2016 / Published online: 20 May 2016

Abstract The Pantanal is the largest Neotropical seasonal freshwater wetland on Earth. Extensive livestock production has been the dominant economic land use activity of the Pantanal, where approximately 80 % of the land is occupied by native and introduced pastures. However, the impact of native pasture conversion into introduced pasture on the biodiversity of this biome is little understood. Here we evaluate the effect of native pasture to introduced pasture conversion on dung beetle communities. We sampled dung beetles in July 2011 (dry season) and January 2012 (rainy season), at four native pasture sites and four introduced pasture sites in Aquidauana, Mato Grosso do Sul, Brazil. The sampling was carried out using pitfall traps baited with three different bait types: carrion, cattle dung, and human feces. We sampled 7086 individuals, belonging to 32 species of 16 genera and six tribes of dung beetles. The abundance was similar among the pasture types. However, a higher species richness was found on the native pasture. Species composition also differed between the two pasture types in each sampling season. Additionally, the dominant functional guilds were different in the two landscapes. The result shows that the conversion of native grasslands into introduced pasture results in a decrease of species number and changes in species composition. These findings highlight the importance on native pasture to the conservation of dung beetle biodiversity in this ecosystem.

Keywords Agro-pastoral landscape · Biodiversity conservation · Grasslands · Land use change · Scarabaeinae · Wetlands ecosystems

✉ César Murilo de Albuquerque Correa
correa.agro7@gmail.com

[1] Programa de Pós-Graduação em Entomologia, Universidade Federal de Lavras, Lavras, MG 37200-000, Brazil

[2] Faculdades Integradas Aparício Carvalho (FIMCA), Porto Velho, RO 76811-678, Brazil

[3] Programa de Pós-Graduação em Entomologia, Universidade Federal de Viçosa, Viçosa, MG 36570-000, Brazil

[4] Programa de Pós-Graduação em Entomologia e Conservação da Biodiversidade, Universidade Federal da Grande Dourados, Dourados, MS 79804-070, Brazil

[5] Universidade Estadual de Mato Grosso do Sul, Aquidauana, MS 79200-000, Brazil

[6] Departamento de Biologia Geral, Universidade Federal de Viçosa, Viçosa, MG 36570-000, Brazil

[7] Universidade do Estado de Minas Gerais, Frutal, MG 38200-000, Brazil

[8] Programa de Pós-Graduação em Ecologia, Universidade Federal de São João del-Rei, São João del-Rei, MG 36307-352, Brazil

Introduction

The Pantanal, a World Heritage Site and Biosphere Reserve, is the largest Neotropical seasonal freshwater wetland on Earth (ca. 160,000 km^2). This extensive wetland is located in Brazil (states of Mato Grosso and Mato Grosso do Sul), Bolivia and Paraguay (Alho et al. 1988). There are at least two well-defined ecohydrology cycles in the Pantanal: dry and rainy. During the dry season, the fields are predominantly covered with native grassland; the surface water becomes scarce, being restricted to the perennial rivers (with defined beds) and large ponds (Girard et al. 2010; Alho and Sabino 2011). Conversely, during the rainy season the rainwater soaks into the soil and marshes, resulting in the overflow of ponds and rivers (Girard et al. 2010; Da Paz et al. 2014).

The Pantanal has a vegetation system arranged in a mosaic. There is a great diversity of forage species, which make up the main food source for large wild herbivores and also for cattle and horses (Seidl et al. 2001; Bergier 2013). The vast expanse of the grassland plains, allied with a favorable climate, promotes the extensive practice of cattle ranching in the Pantanal (Seidl et al. 2001). Over the last two centuries livestock production has been the dominant economic land use activity of the Pantanal (Seidl et al. 2001; Eaton et al. 2011), where approximately 80 % of the lands are used as native and introduced pastures (Eaton et al. 2011).

As a whole, Brazil has an estimated 176 million ha of native and introduced pastures (IBGE 2012). Native pasture contributes approximately 74 million ha, while introduced pastures cover approximately 102 million ha (IBGE 2012). The substitution of native grassland with introduced pastures has been implemented in many regions of Brazil (including the Pantanal) (Seidl et al. 2001; Alho et al. 2011) aiming to improve the technology of livestock production and achieving higher productivity of cattle (Figueiredo et al. 2012). African grasses of the genus *Urochloa* (Poaceae) occupy about 80 % of the cultivated pasture areas in the country (Figueiredo et al. 2012). This grass presented excellent adaptation to the Brazilian climate and due to its good nutritional values became widely cultivated for livestock (Rao et al. 1996).

In open areas of native or introduced pasturelands, dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) bury and utilize the manure deposited by animals for nesting and feeding their offspring, resulting in the cycling of soil nutrients (Slade et al. 2007; Yamada et al. 2007), improved soil fertility (Bang et al. 2005) and aeration (Mittal 1993), reduced fly parasites (Braga et al. 2012) and facilitated growth and development of plants (Nichols et al. 2008). The ecological services and benefit values (Beynon et al. 2015) performed by dung beetles is a practical and natural method of dung removal on pastures (for a review see Nichols et al. 2008), reducing the use of financial resources on the cattle health and on the conservation of pastures (e.g. Lousey and Vaughan 2006).

Many ecological studies have used dung beetles to assess the impacts of land use change on biodiversity (e.g. McGeoch et al. 2002; Nichols et al. 2007; Braga et al. 2013; Korasaki et al. 2013), mainly because dung beetles undergo changes in abundance, species richness and/or composition when subjected to environment changes (Halffter and Favilla 1993; Louzada et al. 2010; Barragán et al. 2011) of anthropogenic or natural origin. For example, the conversion of natural to introduced habitats (Halffter et al. 2007; Navarrete and Halffter 2008; Shahabuddin et al. 2010; Almeida et al. 2011), forest fragmentation and the isolation of forest remnants (Klein 1989; Halffter et al. 1992), and climate change (Larsen 2012). Additionally, they are sensitive, effective and low-cost bioindicators of environmental changes (e.g. Barlow et al. 2007).

In the Brazilian Pantanal, studies on dung beetle communities are scarce (only Louzada et al. 2007; Rodrigues et al. 2010; Tissiani et al. 2015) and the effect of the substitution of natural to introduced pasture on the dung beetle community was yet to be investigated. Therefore, we sampled dung beetles in native (e.g. *Andropogon* spp. and *Axonopus* spp.) and introduced pastures (*Urochloa* spp.) using pitfall traps baited with carrion, cattle dung, and human feces in the dry and rainy seasons to test the following hypotheses: (1) introduced pastures have lower abundance and species richness; (2) there are differences in dung beetle species composition between pasture systems in each season; and (3) the dominant functional guilds are different in the two landscapes.

Materials and methods

Study sites

This study was conducted in Aquidauana, Mato Grosso do Sul, Brazil (19°54′36″S, 55°47′54″W), at Aquidauana's Pantanal. The climate of the region, according the Köppen classification is *Aw*, i.e. tropical hot-wet, with a rainy summer and a dry winter (Alvares et al. 2014). The average temperature is 26 °C (12–40 °C), with maximum peaks recorded between September and October. Monthly rainfall averages 30 mm during the dry period between the months of May and September, and it increases to an average of 160 mm during the rainy period between October and April.

The study site possesses extensive areas of natural pasture (resistant to the seasonal flooding that occurs in this biome) that are used as grazing for cattle (Santos et al. 2011). The low fertility soil and limitations on quantity and quality of native forage, results in pastures with a low support capacity of around 4 ha per animal unit (Santos et al. 2011). Consequently, farms in the Pantanal are often very extensive (>10,000 ha), and it has been reported that large pastures are important for dung beetle conservation (Buse et al. 2015). In the 1970s African grasses from the genus *Urochloa* were introduced as a strategy to increase the support capacity, and therefore, the stock productivity of pastures in the Pantanal. These grass species were adapted to low soil fertility and resistant to flooding, increasing the support capacity to 1.5 animal unit ha^{-1} (Seidl et al. 2001).

We sampled dung beetles in four areas of native pastures (e.g. *Andropogon* spp. and *Axonopus* spp.) and four of introduced pasture (*Urochloa* spp.). Areas of the same pastures type (e.g. native pastures) were separated by approximately 0.5 km, while areas of different pastures (e.g. native vs. introduced) were separated by approximately 1 km.

Experimental protocol

In each of the eight pasture areas, we installed four linear transects (250 m) located approximately 50 m from the edge habitat and separated from the others by 100 m for the allocation of the traps. The distance (100 m) between transects was used to ensure independence of the samples (Larsen and Forsyth 2005). Therefore, transects were considered as replicates ($n = 16$ transects) for each habitat in each sampling season. In each transect we demarcated six points separated by 50 m. At each point we installed a set of three traps separated from each other by 3 m in a triangular shape; the traps of each set were baited with approximately 40 g of carcass (decaying beef), cattle dung, and human feces. We sampled dung beetles with different baits in order to assure an accurate sampling and also due to their different functional and trophic specializations.

Dung beetle sampling

We sampled dung beetles in July 2011 (dry season) and January 2012 (middle of the rainy season) with traps remaining active for 48 h in each of the eight pasture areas. Dung beetles were sampled using pitfall traps (15 cm diameter; 9 cm depth), installed at ground level. The pitfall traps were covered with plastic lids (15 cm diameter) supported with three wooden sticks (25 cm), so as to reduce desiccation of the baits and avoid possible damage in case of rain. Within each trap 250 ml of a saline solution + neutral detergent (1.5 %) were added. The baits were placed in plastic containers (50 mL) at the center of each trap using a wire as bait holder. Overall, we installed 576 traps per sampling season, with a total sampling effort of 1152 traps during the study. Sampling in both pastures occurred simultaneously.

The dung beetles were sent to the Universidade Federal de Mato Grosso (UFMT; Cuiabá, Mato Grosso, Brazil) where they were identified by Dr. Fernando Zagury Vaz-de-Mello. Voucher specimens were deposited at the Entomology Section of the Zoological Collection of the UFMT and in the Entomology Laboratory at the Universidade Estadual de Mato Grosso do Sul (UEMS; Aquidauana, Mato Grosso do Sul, Brazil).

To determine the size estimates for each species a sample of 20 individuals were measured (from the clypeus to the pygidium) with a digital caliper. If this number of individuals were not available due to the number of individuals collected in the traps, the size was estimated for all the individuals available.

Data analysis

We used individual-based rarefaction analysis to compare patters of species and sample effort in two pasture types. Comparisons between habitats were carried out visually with a 95 % confidence interval (CI) of the rarefaction curves implemented with the EstimateS software (Cowell 2005).

We used generalized linear mixed modelling (GLMMs) to verify differences in dung beetle abundance and species richness between native and introduced pastures. We used pasture types (fixed factor) and seasons (random factor). For this, we used the type of pasture as explanatory variables and the abundance and species richness as response variables. We used “Poisson” errors for the abundance and richness. All GLMMs were subjected to residual analysis for fitting of the distribution of errors (Crawley 2002). We conducted these analyses with the software R (R Development Core Team 2015). We plotted species rank-abundance distributions to visually compare patterns of species dominance in the two pasture types.

We used a non-metric multidimensional scaling (NMDS) to express graphically the changes in dung beetle community composition among the pasture types in each sampling season. To verify these differences we used an analysis of similarity (ANOSIM) (Clarke and Warwick 2001). All data were performed over a Bray–Curtis dissimilarity matrix with standardized and square-root transformed data (Anderson and Willis 2003). These analyses were performed using the software Primer v.6 with PERMANOVA+ (Clarke and Gorley 2006).

We use the Indicator Value analysis (IndVal; Dufrene and Legendre 1997) to identify the species that were significant and reliable indicators of each pasture system. We used 5000 randomizations to determine the statistical significance of the observed indicator value (Monte Carlo test; $p < 0.05$). Species with significant IndVal results above 70 % were regarded as indicator species for a given land use. Species with intermediate IndVal, i.e. 45–70 %, were considered detector species (Verdú et al. 2011).

To compare the functional guilds (“foraging strategies”), we classified the species sampled as dwellers, rollers, or tunnelers (as proposed by Hanski and Cambefort 1991). We also classified the sampled individuals as small when they were <10 mm in mean length or large when ≥ 10 mm (Arellano et al. 2005). The individuals were then allocated in their respective functional guilds and classified as: small or large dweller, roller, and tunneler beetles.

Results

Abundance and species richness

We collected 7086 individuals belonging to 32 species of 16 genera and six tribes of dung beetles (Table 1). In the native pastures we captured 30 species in the rainy season and 19 species in the dry season, while in the introduced pastures we collected 25 dung beetle species in the rainy season and 14 species in the dry season (Table 1). Of the 32 species sampled, 23 were found in both pastures, whereas five were found exclusively in native pastures and only two in introduced pastures (Table 1).

In the native pastures, four of 30 species were collected in low numbers with just a few individuals (n < 10). From the 3924 individuals sampled, the dominant species were: *O.* aff. *hirculus* (19.9 %), *D. nisus* (15.3 %), *Canthidium* aff. *barbacenicum* (14.6 %), *Canthidium* aff. *pinotoides* (7.3 %), and *Canthon edentulus* Harold (4.5 %) (Fig. 1). In contrast, in the introduced pastures 11 of the 25 species were represented by just a few individuals. From the 3162 individuals sampled in this pasture type, the dominant species were: *Dichotomius nisus* (Olivier) (34.1 %), *Trichillum externepunctatun* Preudhomme de Borre (32.6 %), *Canthon mutabilis* Lucas (7.6 %), *Onthophagus* aff. *hirculus* (5.5 %) and *Dichotomius bos* (Blanchard) (5.4 %) (Fig. 1).

The observed species richness [Sobs (Mao Tau)] in native pasture was higher than that observed in introduced pasture (95 % CI) (Fig. 2). The dung beetles' abundance was similar among the native and introduced pastures ($\chi^2_{(1,60)} = 1.12$, $p = 0.28$) (Fig. 3). Species richness was greater in the native pasture ($\chi^2_{(1,60)} = 10.38$, $p < 0.001$) (Fig. 3).

Of the 32 species analyzed, eight (25 % of the total) were considered indicator or detectors species by classification used by Verdú et al. (2011). Two species were considered indicators and four detector species of native pastures, and two were considered detector species of introduced pastures (Fig. 4).

Species composition

The ordering of sample points produced a pattern consistent with the species composition in both seasons, with a clear difference in species composition between each pasture system forming a distinct cluster on the NMDS plot in the rainy (ANOSIM; R = 0.86, $p = 0.001$) and dry seasons (ANOSIM; R = 0.56, $p = 0.001$) (Fig. 5).

Functional guilds

In native pastures we sampled small (<10 mm) and large (≥10 mm) dung beetles of the three functional guilds (dweller, roller and tunneler), although the proportion of large dwellers was very low. In introduced pastures the guild of the large dweller beetles was absent (Fig. 6). Small tunneler beetles were the most dominant guild on native pastures, whereas large tunneler and small dwellers beetles were the most dominant on the introduced pastures (Fig. 6).

Discussion

Patterns of abundance and species richness

This study presented for the first time the effect of conversion from native pasture to introduced pasture on dung beetle communities in the largest freshwater wetland on Earth. Our results reveal a reduction in dung beetle species richness due to the land use change. The biodiversity loss of dung beetles, beyond being a conservation matter, may also negatively affect ecological services, such as soil revolving, nutrient cycling and pest control (see review of Nichols et al. 2008). Therefore, studies on the response of animal groups that provide important services to the ecosystem, due to anthropic disturbance, are important to supply baselines for conservation policies (Louzada et al. 2010; Correa et al. 2013a; Korasaki et al. 2013), that could help in the overall protection of ecosystems.

Our study of dung beetle communities in native and introduced pastures in the Brazilian Pantanal confirmed the occurrence of common species of open areas such as introduced pastures in the Cerrado-Pantanal ecotone (Aidar et al. 2000; Puker et al. 2014, Correa et al. 2013b, 2016), introduced pastures (Louzada and Carvalho e Silva 2009; Almeida et al. 2011; Abot et al. 2012) and native grasslands in the Cerrado (Brazilian savanna) (Almeida et al. 2011). Additionally, we report for the first time the occurrence of *Coprophanaeus bonariensis* Gory (Phanaeini) for the state of Mato Grosso do Sul (for an annotated checklist see Vaz-de-Mello et al. 2016). It also contributes to the understanding of local diversity of these beetles.

Although dung beetle abundance did not significantly differ between pasture types, species richness did. In this study two species (*D. nisus* and *T. externepunctatum*) contributed more than 60 % of the total of individuals sampled on introduced pasture. In general, introduced pastures are considered simple and homogeneous habitats with low diversity of food resources (Louzada and Carvalho e Silva 2009; Almeida et al. 2011). This habitat simplification and homogenization of food resources may modify the distribution patterns and abundance of species (Quintero and Halffter 2009). Thus, only dung beetle species that can adapt to the microclimatic conditions of these introduced pastures, with high temperature and

Table 1 Biodiversity of dung beetles sampled in native and introduced pastures in the dry and rainy seasons in the Pantanal, Mato Grosso do Sul, Brazil

Taxon	Native			Introduced			Body	Functional	Total
	Rainy	Dry	Total	Rainy	Dry	Total	Size	Guild	
Ateuchini									
Ateuchus sp.	176	62	238	104	48	152	Small	Tunneler	390
Genieridium bidens (Balthasar)		40	40	3		3	Small	Dweller	43
Trichillum externepunctatum Preudhomme de Borre	78	54	132	954	14	968	Small	Dweller	1100
Uroxys sp.	23	29	52	6	7	13	Small	Unknown	65
Coprini									
Canthidium sp.	26	14	40	2	8	10	Small	Tunneler	50
Canthidium aff. *barbacenicum*	320	253	573	18		18	Small	Tunneler	591
Canthidium aff. *pinotoides*	289		289	115		115	Small	Tunneler	404
Dichotomius bos (Blanchard)	82	37	119	139	33	172	Large	Tunneler	291
Dichotomius glaucus (Harold)	18		18	2		2	Large	Tunneler	20
Dichotomius nisus (Olivier)	79	522	601	252	827	1079	Large	Tunneler	1680
Dichotomius opacipennis (Luederwaldt)	59		59	1		1	Large	Tunneler	60
Ontherus appendiculatus (Manerrheim)	20	67	87	15	40	55	Large	Tunneler	142
Ontherus sulcator (Fabricius)				1		1	Large	Tunneler	1
Deltochilini									
Canthon edentulus Harold	157	22	179	5	1	6	Small	Roller	185
Canthon histrio (Lepelletier and Serville)	81	9	90	2		2	Small	Roller	92
Canthon mutabilis Lucas	133	44	177	227	15	242	Small	Roller	419
Canthon ornatus Redtenbacher	2	13	15	3		3	Small	Roller	18
Canthon substriatus Harold	15		15	4		4	Small	Roller	19
Canthon aff. *curvodilatatus*	6		6	3	1	4	Small	Roller	10
Canthon aff. *virens*	8		8				Small	Roller	8
Deltochilum aff. *komareki*	13		13				Large	Roller	13
Deltochilum pseudoicarus Balthasar	41		41	6		6	Large	Roller	47
Malagoniella astyanax (Olivier)	30		30				Large	Roller	30
Malagoniella puncticollis (Blanchard)	122	32	154	21	19	40	Large	Roller	194
Oniticellini									
Eurysternus caribaeus (Herbst)	9	6	15				Large	Dweller	15
Eurysternus nigrovirens Génier	5	6	11				Small	Dweller	11
Onthophagini									
Digitonthophagus gazella (Fabricius)	51	37	88	39	12	51	Small	Tunneler	139
Onthophagus aff. *hirculus*	470	312	782	73	103	176	Small	Tunneler	958
Phanaeini									
Coprophanaeus bonariensis Gory	3		3				Large	Tunneler	3
Coprophanaeus ensifer (Germar)	1		1				Large	Tunneler	1
Coprophanaeus milon (Blanchard)				2		2	Large	Tunneler	2
Gromphas inermis Harold	3	45	48	18	19	37	Large	Tunneler	85
Number of individuals	2320	1604	3924	2015	1147	3162			7086
Number of species	29	19		25	14				

intense solar exposure (e.g. Navarrete and Halffter 2008), and use cattle dung as a food and nesting resource (Louzada and Carvalho e Silva 2009; Correa et al. 2016) can maintain and/or increase their populations. The dominance of a few dung beetle species with a high abundance rate observed in this study reflects a pattern very well documented in the introduced pastures of Brazil (e.g. Aidar et al. 2000; Koller et al. 1999, 2007; Louzada and Carvalho e Silva 2009; Almeida et al. 2011; Abot et al. 2012; Correa et al. 2013b, 2016).

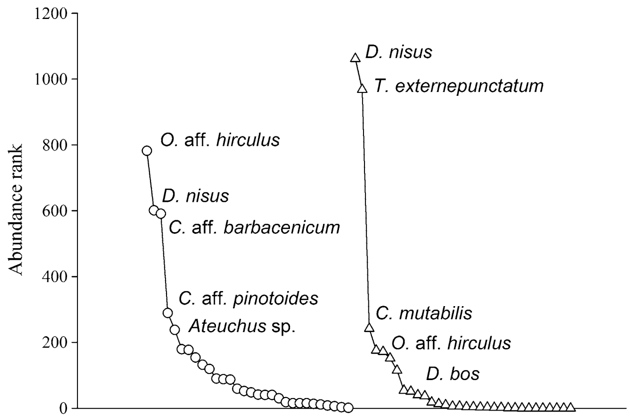


Fig. 1 Rank-abundance distribution of dung beetle species in native (*circle*) and introduced pastures (*triangle*)

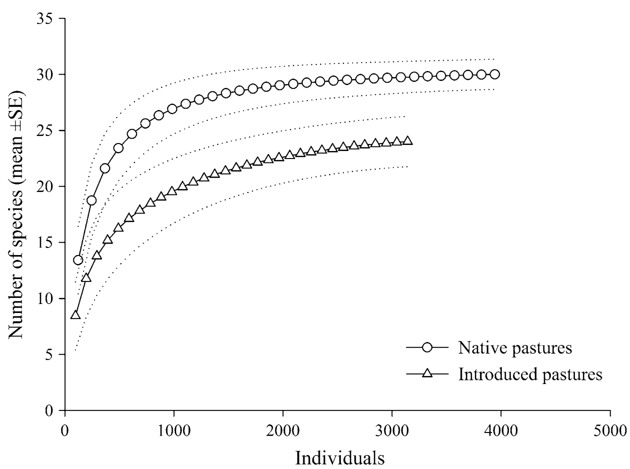


Fig. 2 Individual-based species accumulation curves for dung beetles sampled in native and introduced pastures. The *dotted lines* are 95 % CI, illustrating that there was significant difference among pasture types

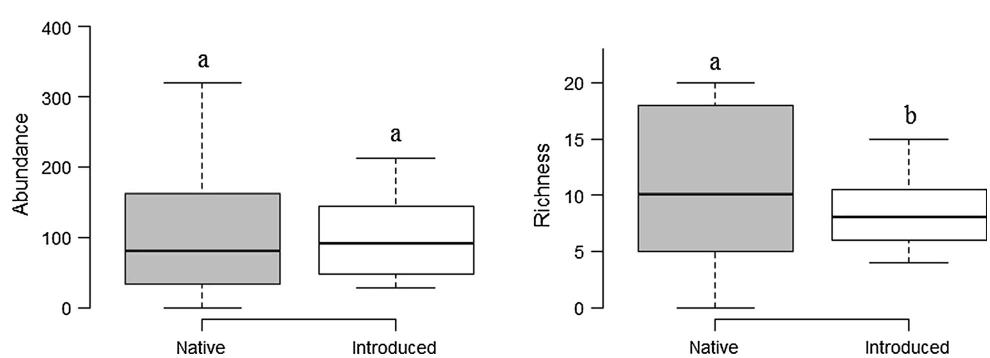
The substitution of native pastures for introduced pastures has been implemented in many regions of Brazil (Seidl et al. 2001; Alho et al. 2011), with the aim of improving the technology of livestock production and achieving higher productivity of cattle (Figueiredo et al. 2012). Information on the effects of substituting native pastures for introduced pastures on the assembly of dung beetles in the Brazilian Pantanal does not yet exist, and given the increasing substitution of native pastures for introduced pastures in this ecosystem, our results demonstrate that native grasslands are important for conservation of dung beetle biodiversity, as already documented for native pastures in the Cerrado (Brazilian savanna) (Almeida et al. 2011). Of the 32 species sampled, 23 were found in both pastures, with five occurring exclusively in native pastures. These findings suggest that the conservation of native pastures may be a source of biodiversity for dung beetles that could potentially colonize introduced pastures in the Pantanal, and thus provide ecological services and benefit values (Beynon et al. 2015) in this agroecosystem.

Despite the native and introduced pastures being relatively very similar (Almeida et al. 2011), indicator species (*Canthidium* aff. *barbacenicum* and *Onthophagus* aff. *hirculus*) were only found in native pasture. Species considered indicators are highly specific to a certain environment (McGeoch et al. 2002), therefore they are more susceptible to changes in habitat. These two species can be important as study tools and monitoring of native pastures. Detector species found in both pasture types possess a moderate specificity, with different degrees of preference among various ecological states (McGeoch et al. 2002). Their requirements are less rigorous regarding the structure of the environment, when compared to indicator species, making adaptation to new habitat conditions more rapidly, since they can move further into adjacent habitats (Verdú et al. 2011).

Species composition

The dung beetle species composition differed between native and introduced pastures in each sampling season. Generally, in dung beetle communities the number of individuals within populations reduces or species are lost when they are unable to adapt to new environmental

Fig. 3 Mean abundance and species richness of dung beetles sampled in native and introduced pastures in the Pantanal. *Different letters* above the *bars* indicate statistically significant differences among pasture types ($p < 0.01$). *Error bars* represent SE



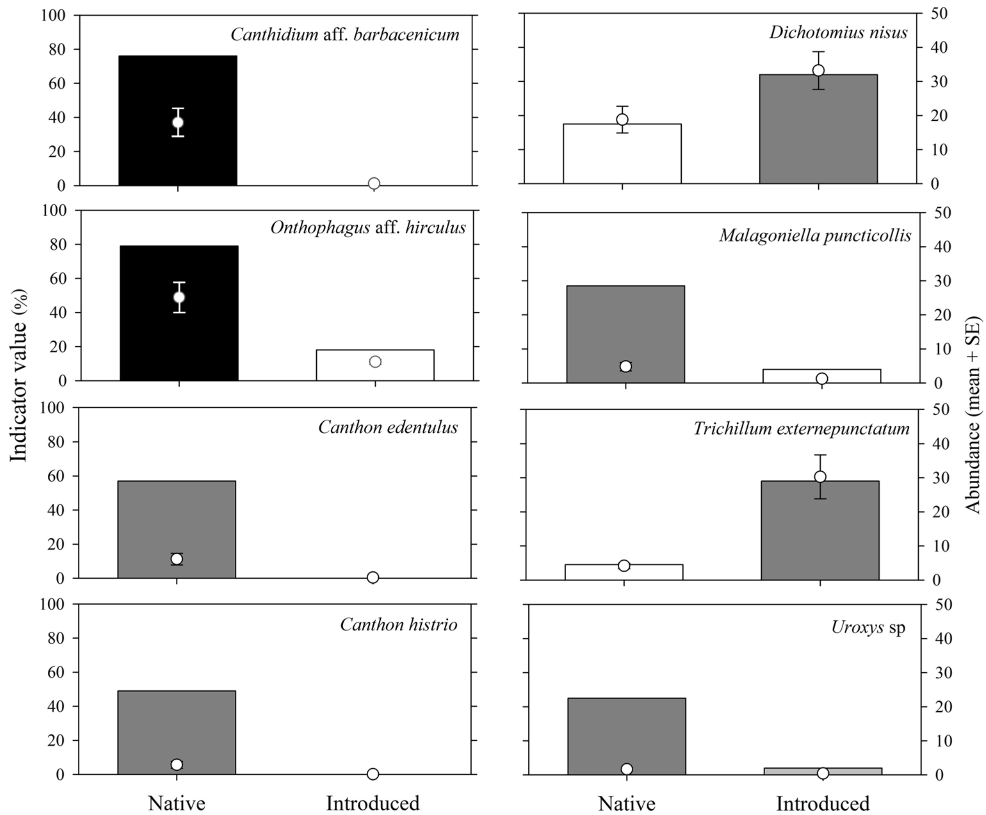


Fig. 4 Indicator values (IV) and abundances of indicator species (IV > 75 %) and detector species (IV: 45–75 %). *Bars* indicate IV. *Dot with error bars* indicates mean abundances ±SE

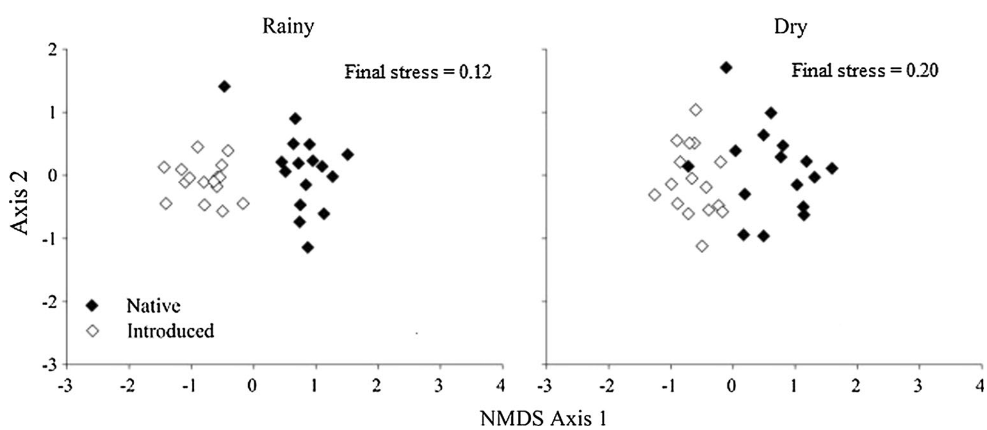


Fig. 5 Non-metric multidimensional scaling results (NMDS), constructed from Bray–Curtis matrices, for dung beetle communities in native and introduced pastures in the rainy and dry sampling seasons

conditions (Navarrete and Halffter 2008; Shahabuddin et al. 2010; Almeida et al. 2011). Moreover, despite pastures with introduced grasses being relatively similar to native pastures (Almeida et al. 2011), this change in the vegetation structure may influence the spread of odor from the food source (Correa et al. 2016), favoring species with high dispersal ability (e.g. Hanski and Cambefort 1991). Changes in vegetation structure directly influence the composition of the local fauna of dung beetles (Louzada et al. 2010; Almeida et al. 2011). This can be due to changing environmental factors that directly affect the biology of the species, such as luminosity, temperature and humidity, which provide support for reproduction, nesting, foraging and development of dung beetles (e.g. Halffter and Edmonds 1982; Hanski and Cambefort 1991).

A higher density of cattle on introduced pastures may also play a fundamental role on the construction of local structural heterogeneity on the dung beetle assemblages, altering the vegetal succession by exerting a control in the development of foraging plants (Olff and Ritchie 1998; Adler et al. 2001). The changes in structural heterogeneity caused by intense grazing imply an alteration of habitat diversity, bringing consequences such as a more homogenous environment and transformations in local biodiversity

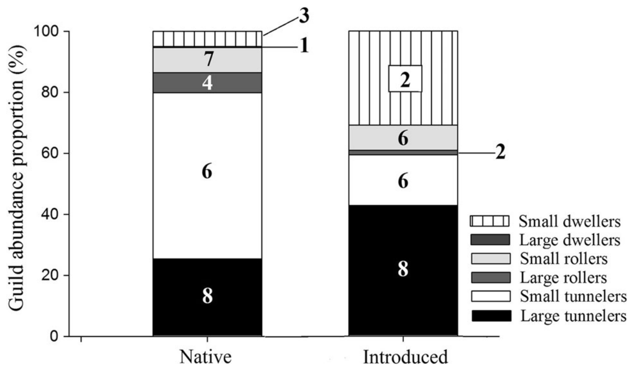


Fig. 6 Proportional change in functional dung beetle guild sampled in native and introduced pastures. *Numbers* inside the figure represent the species numbers in each functional group

(Wallis-de-Vries et al. 2007). In contrast, structural heterogeneity increases the quantity of ecological niches to species adapted to high or low vegetation (Debano 2006), a characteristic of native pastures in the Pantanal (Santos et al. 2011). Additionally, an increase in cattle density may reduce vegetal coverage, while also compacting the soil surface (Vzzoto et al. 2000), having a negative effect, especially on dung beetle species that build their nests below ground (Bang et al. 2005).

Functional guilds

Small tunneler beetles were dominant in native pastures. We believe that these beetles are dominant in native pastures because their size may permit a greater number of individuals and species to share the same resource (Correa et al. 2013b). In contrast, the large tunneler and small dweller beetles were dominant in the introduced pastures. We believe that the predominance of large tunneler beetles in introduced pastures may in the first instance be associated with higher availability of food recourses. Moreover their large size permits individuals of this guild to use a greater quantity of dung pad (e.g. Louzada and Carvalho e Silva 2009; Correa et al. 2013b, 2016), making it less available to other beetle guilds such as dwellers and rollers. The domain of small and large tunneler beetles in native and introduced pastures, respectively, may also be related to adaptation of these species to open habitats, such as pasturelands.

In summary, we assert that subtle changes in vegetation structure in open areas, beyond altering the composition and the richness of dung beetle species as reported by Almeida et al. (2011) in the Cerrado, also affects the functional guilds of dung beetles.

Conservation of dung beetles in the native pastures

In recent decades (<40 years), cattle production has been considered the main source of land use change in the Pantanal (Seidl et al. 2001; Alho et al. 2011; Silva et al. 2011). Approximately 45 % of the Pantanal has been affected by human activities, including alteration and loss of natural habitats, and if the current rate of degradation continues (2.3 % per year), natural habitats of the Pantanal will be destroyed in approximately 50 years (Silva et al. 2011). The greater dung beetle species richness in native pastures highlights the importance of these ecosystems for the conservation of dung beetle biodiversity. The Pantanal is one of the least known ecosystems in terms of biodiversity of Brazil, and it is known that invertebrates play an important functional role in its conservation (Lewinsohn et al. 2005). Thus, it is necessary to develop a management plan for livestock production in native and introduced pastures in the Pantanal that may encourage the use of native pastures, including agricultural techniques such as rotational management for more efficient use of native pastures (Eaton et al. 2011) and consequently the conservation of dung beetle biodiversity and their ecological services.

Acknowledgments We thank father of the first author, Agenor Martinho Correa, for the encouragement and logistical support. We also thank Cristiano Lopes-Andrade and José H. Schoereder (UFV) for supply of equipment at their labs for screening of the dung beetles, Fernando Z. Vaz-de-Mello (UFMT) for identification of the dung beetle species, Natalie Swan (University of Lancaster, Lancaster, UK) for reviewing the English of this article, Adilson Areco, Flávia Torres, and Vagner dos Santos for the field support, and Mrs. Odilon Ribeiro and Zelito Ribeiro for access to their properties. CMAC received a MSc scholarship from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) (134418/2013-1) from the Agronomy Graduate Program, Universidade Estadual de Mato Grosso do Sul.

Compliance with ethical standards

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

References

Abot AR, Puker A, Taira TL, Rodrigues SR, Korasaki V, Oliveira HN (2012) Abundance and diversity of coprophagous beetles (Coleoptera: Scarabaeidae) caught with a light trap in a pasture area of the Brazilian Cerrado. Stud Neotrop Fauna Environ 47:53–60

Adler PB, Raff DA, Lauenroth WK (2001) The effect of grazing on the spatial heterogeneity of vegetation. Oecologia 128:465–479

Aidar T, Koller W, Rodrigues SR, Correa AM, Silva JCC, Balta ODS, Oliveira JM, Oliveira VL (2000) Besouros coprófagos (Coleoptera: Scarabaeidae) coletados em Aquidauana, MS, Brasil. An Soc Entomol Bras 29:817–820

Alho CJR, Sabino J (2011) A conservation agenda for the Pantanal's biodiversity. Braz J Biol 71:327–335

Alho CJR, Lacher TE, Gonçalves HC (1988) Environmental degradation in the Pantanal ecosystem. Bioscience 38:164–171

Alho CJR, Mamede S, Bitencourt K, Benites M (2011) Introduced species in Pantanal: implications for conservation. Braz J Biol 71:321–325

Almeida S, Louzada J, Sperber C, Barlow J (2011) Subtle-use change and tropical biodiversity: dung beetle communities in Cerrado grasslands and exotic pastures. Biotropica 43:704–710

Alvares CA, Stape JL, Sentelhas PC, Goncalves JLM, Sparovek G (2014) Köppen's climate classification map for Brazil. Meteorol Z 22:711–728

Anderson MJ, Willis TJ (2003) Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. Ecology 84:511–525

Arellano L, Favila ME, Huerta C (2005) Diversity of dung and carrion beetles in a disturbed Mexican Tropical Montane cloud forest and on shade coffee plantations. Biodivers Conserv 14:601–615

Bang HS, Lee JH, Kwon OS, Na YE, Jang YS, Kim WH (2005) Effects of paracoprid dung beetles (Coleoptera: Scarabaeidae) on the growth of pasture herbage and on the underlying soil. Appl Soil Ecol 29:165–171

Barlow J, Gardner TA, Araujo IS et al (2007) Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. PNAS 104:18555–18560

Barragán F, Moreno CE, Escobar F, Halffter G, Navarrete D (2011) Negative impacts of human land use on dung beetle functional diversity. PLoS One 6:e17976

Bergier I (2013) Effects of highland land-use lowlands of Brazilian Pantanal. Sci Total Environ 463–464:1060–1066

Beynon S, Wainwright WA, Christie M (2015) The application of an ecosystem services framework to estimate the economic value of dung beetles to the UK cattle industry. Ecol Entomol 40:124–135

Braga RF, Korasaki V, Audino LD, Louzada J (2012) Are dung beetles driving dung-fly abundance in traditional agricultural areas in the Amazon? Ecosystems 15:1173–1181

Braga RF, Korasaki V, Andresen E, Louzada J (2013) Dung beetle community and functions along a habitat-disturbance gradient in the Amazon: a rapid assessment of ecological functions associated to biodiversity. PLoS One 8:e57786

Buse J, Slachta M, Sladecek FXJ, Pung M, Wagner T, Entling MH (2015) Relative importance of pasture size and grazing continuity for the long-term conservation of European dung beetles. Biol Conserv 187:112–119

Clarke KR, Gorley RN (2006) Primer v6 Permanova+. Primer-E Ltd., Plymouth

Clarke KR, Warwick RM (2001) Changes in marines communities: an approach to statistical analysis and interpretation, 2nd edn. Primer-E Ltd., Plymouth

Correa CMA, Puker A, Korasaki V, Ferreira KR (2013a) *Omorgus suberosus* and *Polynoncus bifurcatus* (Coleoptera: Scarabaeoidea: Trogidae) in exotic and native environments of Brazil. Zoologia 30:238–241

Correa CMA, Puker A, Korasaki V, Oliveira NG (2013b) Dung beetles (Coleoptera, Scarabaeinae) attracted to sheep dung in exotic pastures. Rev Bras Entomol 57:113–116

Correa CMA, Puker A, Korasaki V, Ferreira KR, Abot AR (2016) The attractiveness of baits to dung beetles in Brazilian Cerrado and exotic pasturelands. Entomol Sci 19:112–123

Cowell RK (2005) EstimateS: statistical estimation of species richness and shared species from samples, version 7.5. http://viceroy.eeb.uconn.edu/estimates. Accessed 2 April 2015

Crawley MJ (2002) Statistical computing—an introduction to data analysis using S-Plus. Wiley, London

Da Paz AR, Collischonn W, Bravo JM, Bates PD, Baugh C (2014) The influence of vertical water balance on modeling Pantanal (Brazil) spatio-temporal inundation dynamics. Hydrol Process 28:3539–3553

Debano SJ (2006) Effects livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona. Biodivers Conserv 15:2547–2564

Dufrene M, Legendre P (1997) Species assemblages and indicators species: the need for a flexible asymmetrical approach. Ecol Monogr 67:345–366

Eaton DP, Santos SA, Santos MCA, Lima JVB, Keuroghlian A (2011) Rotational grazing of native pasturelands in the Pantanal: an effective conservation tool. Trop Conserv Sci 4:39–52

Figueiredo UJ, Nunes JAR, Valle CB (2012) Estimation of genetic parameters and selection of *Brachiaria humidicola* progenies using a selection index. Cropp Breed Appl Biotech 12:237–244

Girard P, Fantin-Cruz I, Oliveira SML, Hamilton SK (2010) Small-scale spatial variation of inundation dynamics in a floodplain of the Pantanal (Brazil). Hidrobiologia 638:223–233

Halffter G, Edmonds WD (1982) the nesting behavior of dung beetles (Scarabaeinae)—an ecological and evolutive approach. Instituto de Ecología, Xalapa

Halffter G, Favilla ME (1993) The Scarabaeinae (Insecta, Coleoptera), an animal group for analyzing, inventorying, and monitoring biodiversity in tropical rain forest and modified landscapes. Biol Int 27:15–21

Halffter G, Favila ME, Halffter V (1992) A comparative study of the structure of the scarab guild in Mexican tropical rain forest and derived ecosystem. Folia Entomol Mex 84:131–156

Halffter G, Pineda E, Arellano L, Escobar F (2007) Instability of copronecrophagous beetle assemblages (Coleoptera: Scarabaeinae) in a mountainous tropical landscape of Mexico. Environ Entomol 36:1397–1407

Hanski I, Cambefort Y (1991) Dung beetle ecology. Princeton University Press, Princeton

IBGE (Instituto Brasileiro de Geografia e Estatística) (2012) Censo Agropecuário 2006: Brasil, Grandes Regiões e Unidades da Federação – Segunda Apuração. Rio de Janeiro, Brazil. http://www.ibge.gov.br. Accessed 10 July 2015

Klein BC (1989) Effects of forest fragmentation on dung and carrion beetle communities in Central Amazonia. Ecology 70: 1715–1725

Koller WW, Gomes A, Rodrigues SR, Alves RGO (1999) Besouros coprófagos (Coleoptera: Scarabaeidae) coletados em Campo Grande, MS, Brasil. An Soc Entomol Bras 28:403–412

Koller WW, Gomes A, Rodrigues SR, Goiozo PFI (2007) Scarabaeidae e Aphodiidae coprófagos em pastagens cultivadas em área do Cerrado Sul-Mato-Grossense. R Bras Zoocienc 9:81–93

Korasaki V, Braga RF, Zanetti R, Moreira FMS, Vaz-de-Mello FZ, Louzada J (2013) Conservation value of alternative land-use systems for dung beetles in Amazon: valuing traditional farming practices. Biodivers Conserv 22:1485–1499

Larsen TH (2012) Upslope range shifts of Andean dung beetles in response to deforestation: compounding and confounding effects of microclimatic change. Biotropica 44:82–89

Larsen TH, Forsyth A (2005) Trap spacing and transect design for dung beetle biodiversity studies. Biotropica 37:322–325

Lewinsohn TM, Freitas AVL, Prado PI (2005) Conservation of terrestrial invertebrates and their habitats in Brazil. Conserv Biol 19:640–645

Lousey JE, Vaughan M (2006) The economic value of ecological services provided by insects. Bioscience 56:311–323

Louzada JNC, Carvalho e Silva PR (2009) Utilisation of introduced Brazilian pastures ecosystems by native dung beetles: diversity patterns and resource use. Insect Conserv Divers 2:45–52

Louzada JNC, Lopes FS, Vaz-de-Mello FZ (2007) Structure and composition of a dung beetle community (Coleoptera, Scarabaeinae) in a small forest patch from Brazilian Pantanal. Rev Bras Zoocienc 9:199–203

Louzada J, Gardner T, Peres C, Barlow J (2010) A multi-taxa assessment of nestedness patterns across a multiple-use Amazonian forest landscape. Biol Conserv 143:1102–1109

McGeoch MA, van Rensburg BJ, Botes A (2002) The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. J Appl Ecol 39:661–672

Mittal IC (1993) Natural manuring and soil conditioning by dung beetles. Trop Ecol 34:150–159

Navarrete D, Halffter G (2008) Dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) diversity in continuous forest, forest fragments and cattle pastures in a landscape of Chiapas, Mexico: the effects of anthropogenic changes. Biodivers Conserv 17: 2869–2898

Nichols E, Larsen T, Spector S, Davis AL, Escobar F, Favila M, Vulinec K (2007) Global dung beetle response to tropical forest modification and fragmentation: a quantitative literature review and meta-analysis. Biol Conserv 137:1–19

Nichols E, Spector S, Louzada JNC, Larsen TH, Favila M, The Scarabaeinae Research Network (2008) Ecological functions and services provided by Scarabaeinae dung beetles. Biol Conserv 141:1461–1474

Olff H, Ritchie ME (1998) Effects of herbivores on grassland plant diversity. Trends Ecol Evol 13:261–265

Puker A, Correa CMA, Korasaki V (2014) Deltochilini and Phanaeini dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in introduced and native ecosystems of Brazil. J Nat Hist 48:2105–2116

Quintero I, Halffter G (2009) Temporal changes in a community of dung beetles (Insecta: Coleoptera: Scarabaeidae) resulting from the modification and fragmentation of tropical rain forest. Acta Zool Mex 25:625–649

R Development Core Team (2015) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. http://www.R-project.org. Accessed 18 Jan 2015

Rao IM, Kerridge PC, Macedo MCM (1996) Nutritional requirements of *Brachiaria* and adaptation to acid soils. In: Miles JW, Maass BL, Valle CB (eds) *Brachiaria*: biology, agronomy, and improvement. Centro Internacional de Agricultura Tropical, Empresa Brasileira de Pesquisa Agropecuária-Centro Nacional de Pesquisa de Gado de Corte, Cali, Campo Grande, pp 53–71

Rodrigues SR, Barros ATM, Puker A, Taira TL (2010) Diversidade de besouros coprófagos (Coleoptera, Scarabaeidae) coletados com armadilha de interceptação de voo no Pantanal Sul-Mato-Grossense, Brasil. Biota Neotrop 10:123–127

Santos SA, Souza GS, Costa C, Abreu UGP, Alves FV, Ítavo LCV (2011) Growth curve of Nellore calves reared on natural pasture in Pantanal. R Bras Zootec 40:2947–2953

Seidl AF, Silva JFV, Moraes AS (2001) Cattle ranching and deforestation in the Brazilian Pantanal. Ecol Econ 36:413–425

Shahabuddin PH, Manuwoto S, Noerdjito WA, Tscharntke T, Schulze CH (2010) Diversity and body size of dung beetles attracted to different dung types along a tropical land-use gradient in Sulawesi, Indonesia. J Trop Ecol 26:53–65

Silva JSV, Abdon MM, Silva SMA, Moraes JA (2011) Evolution of deforestation in the Brazilian Pantanal and surroundings in the timeframe 1976–2008. Geografia 36:35–55

Slade EM, Mann DJ, Villanueva JF, Lewis OT (2007) Experimental evidence for the effects of dung beetle functional group richness and composition on ecosystem function in a tropical forest. J Anim Ecol 76:1094–1104

Tissiani ASO, Sousa WO, Santos GB, Ide S, Battirola L, Marques MI (2015) Environmental influence on coprophagous Scarabaeidae (Insecta, Coleoptera) assemblages in the Pantanal of Mato Grosso. Braz J Biol 75:136–142

Vaz-de-Mello FZ, Bavutti LLO, Flechtmann CAH, Puker A, Correa CMA (2016) Lista de espécies dos Scarabaeinae (Coleoptera, Scarabaeidae) do estado de Mato Grosso do Sul, Brasil. Ilheringia Ser Zool 105 (in press)

Verdú J, Numa C, Hernández-Cuba O (2011) The influence of landscape structure on ants and dung beetles diversity in a Mediterranean savanna—forest ecosystem. Ecol Indic 11:831–839

Vzzoto VR, Marchezan E, Segabinazzi T (2000) Efeito do pisoteio em algumas propriedades físicas do solo de várzea. Cienc Rural 30:965–969

Wallis-de-Vries MF, Parkinson AE, Dulphy JP, Sayer M, Diana E (2007) Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 4. Effects on animal diversity. Grass Forage Sci 62:185–197

Yamada D, Imura O, Shi K, Shibuya T (2007) Effect of tunneler dung beetles on cattle dung decomposition, soil nutrients and herbage growth. Grassl Sci 53:121–129