Zoological Studies **50**(5): 546-559 (2011)

Zoological Studies

Dung Beetles (Coleoptera: Scarabaeidae: Scarabaeinae) of Two Non-Native Habitats in Bagé, Rio Grande do Sul, Brazil

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(Accepted March 29, 2011)

Pedro Giovâni da Silva (2011) Dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) of two non-native habitats in Bagé, Rio Grande do Sul, Brazil. *Zoological Studies* **50**(5): 546-559. There are few studies on the fauna of Scarabaeinae in Rio Grande do Sul, Brazil. The aim of this study was to determine species of the Scarabaeinae in areas of *Eragrostis plana* Nees and *Eucalyptus* spp., 2 exotic habitats originally occupied by native grasslands, in the town of Bagé, Rio Grande do Sul, Brazil; and to compare them with the richness found in other ecosystems at the same location. Beetles were collected with the use of pitfall traps with various kinds of bait and without bait, from Sept. to Dec. 2006. In total, 264 beetles belonging to 5 tribes, 7 genera, and 13 species were captured. *Onthophagus* aff. *hirculus* Mannerheim, *Canthon lividus* Blanchard, *C. bispinus* (Germar), and *C. podagricus* Harold were the most abundant species. A comparison of the richness of the studied Scarabaeinae in this region showed that the richness found in the exotic habitats investigated was lower. These habitats seem to have influenced the Scarabaeinae fauna, giving support only to common species native to the region with generalist eating habits. http://zoolstud.sinica.edu.tw/Journals/50.5/546.pdf

Key words: Environmental change, *Eragrostis plana*, *Eucalyptus*, Pampas.

In Brazil, beetles that belong to the Scarabaeinae (Coleoptera: Scarabaeidae) are commonly known as *rola-bostas* (the Portuguese name for dung beetles) mainly because many of its species form small balls with portions of their food resources, which are rolled on the ground and buried to serve as food for larvae (Halffter and Matthews 1966, Hanski and Cambefort 1991). There are about 7000 species of the Scarabaeinae worldwide, and in Brazil, there are approximately 700 species (Vaz-de-Mello 2000).

These beetles mainly eat mammal excrement, carrion, and rotten fruit, removing them from the soil and incorporating these resources in the nutrient cycle. Thus, they contribute to edaphic aeration and hydration, in addition to extending the productive capacity of the soil by building their galleries (Alves and Nakano 1977, Haynes and Williams 1993, Miranda et al. 1998). Furthermore, they help with secondary dispersal of seeds (Shepherd and Chapman 1998) and are useful in forensic entomology (Estrada and Coates-Estrada 1991). Some species are being used in various countries for the biological control of important parasites of livestock (Waterhouse 1974, Fincher et al. 1981, Ridsdill-Smith et al. 1986, Honer et al. 1987, Wardhaugh and Menéndez 1988, Flechtmann et al. 1995, Flechtmann and Rodrigues 1995, Rodrigues and Marchini 1998, Koller et al. 1999 2007, Aidar et al. 2000), because they decrease the availability of sites for reproduction of those parasitic organisms (Ridsdill-Smith and Hayles 1990, Andresen 2002, Boonrotpong et al. 2004).

The effectiveness of these insects in removing organic matter makes them essential components in maintaining and regulating of terrestrial ecosystems in which they live (Halffter

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and Matthews 1966, Hanski and Cambefort 1991), because the group forms a taxonomically and functionally well-defined community (Hanski and Cambefort 1991). For these and other reasons, the Scarabaeinae is an important group of insects which has been used as a bioindicator of fragmentation, disturbance, and diversity in tropical forests and savannas (Halffter and Favila 1993, Favila and Halffter 1997, Spector and Forsyth 1998, Halffter and Arellano 2001, McGeoch et al. 2002, Davis et al. 2004, Spector 2006, Nichols et al. 2007), due to its high interaction with mammals native to those ecosystems (Davis et al. 2002).

Distributions of these beetles are strongly influenced by the vegetative cover, fragmentation, physical structure, and environmental elevation (Nealis 1977, Doube 1983, Lobo and Halffter 2000, Halffter and Arellano 2002, Escobar et al. 2007). These characteristics are important factors that determine the composition, abundance, and richness of their assemblages (Martín-Piera and Lobo 1993, Davis et al. 1999, Escobar et al. 2005, Almeida and Louzada 2009).

Rio Grande do Sul has 2 distinct biomes: the northern part includes Atlantic forest and the southern is represented by the Pampas (Pillar et al. 2006). Some decades ago, natural areas at the latter site were replaced by 2 types of vegetation consisting of exotic plants, especially *Eucalyptus* spp. plantations to produce derivatives (Pillar et al. 2006, SBS 2007, Roesch et al. 2009) and the uncontrolled spread of *Eragrostis plana* Nees (known as *capim annoni*-2), a South African grass brought to Brazil with the accidental penetration of its seeds in sets of seeds of forage species (Reis 1993, Reis and Coelho 2000, Bilenca and Miñarro 2004, Boldrini et al. 2005, Medeiros and Focht 2007); it has now spread through the south-central states of Brazil and into Uruguay (Medeiros and Focht 2007). Due to its rapid growth and adaptations compared to native species, this grass was cultivated and distributed as a forage species. After evidence of its low acceptance by cattle and their low weight gain, besides the damage to the digestive tract of bovines and its rapid dissemination, the use of this grass has been largely avoided, and current research aims at finding ways of fighting against its spread (Reis 1993, Reis and Coelho 2000, Medeiros and Focht 2007).

The transformation of natural grasslands in the southern Rio Grande do Sul may have adverse effects on the fauna and flora native to this ecosystem, such as the loss of the already known diversity and of a still unknown richness. These alterations are intensified by the constant and increasing expansion in area of these exotic plant species and increases in human activities that are degrading this biome (Pillar et al. 2006, Roesch et al. 2009). Studies on dung beetles in Rio Grande do Sul are still very scarce, and there are gaps in our knowledge relative to the diversity of this group in the state (Vaz-de-Mello 2000), as well as the effects of the conversion of natural ecosystems on this fauna. Thus, the objective of this study was to determine species of the Scarabaeinae in habitats of *E. plana* and *Eucalyptus* spp. in Bagé, Rio Grande do Sul, Brazil, and to compare the richness found in other habitats at the same location.

MATERIALS AND METHODS

This study was conducted in experimental areas of Centro de Pesquisa de Pecuária dos Campos Sulbrasileiros (CPPSul, South-Brazilian Research Center on Livestock) belonging to Empresa Brasileira de Pesquisa Agropecuária (Embrapa), called Embrapa Pecuária Sul, a Brazilian research institution of agriculture and livestock, located at km 595 of BR-153 in the municipality of Bagé, Rio Grande do Sul, Brazil.

Bagé is part of the Campanha region of Rio Grande do Sul within the Pampas biome. It has an area of approximately 4096 km^2 (IBGE 2006) and is bounded on the south by Uruguayan territory. The Campanha region includes the southern part of Serra do Sudeste and the western region of Depressão Central of Rio Grande do Sul, including various towns. It is characterized by small topographical ripples with elevations varying 60-300 m, with a large amount of natural pasture and a few places with a significant coverage of native trees, mainly along water courses (Pimentel 1940). According to Köppen's classification, the climate is mesothermal subtropical (Cfa) or temperate. The average annual precipitation is 1350 mm with a variation of 20%, and temperatures range -1-39°C (IBGE 2006).

Two habitats were chosen for this study: a plantation of mature trees (approximately 30 yr old) of *Eucalyptus* spp. (with an approximate total area of 11.5 ha), with a density of 3 × 3 m between individuals (54°00'44"W, 31°21'22"S, 230 m in elevation); and a pasture habitat with the presence of some species of the Poaceae, Fabaceae, caraguatás (*Eryngium* spp.), and coverage of approximately 80% by *E. plana*

(54°00'38"W, 31°20'50"S, 223 m in elevation) (with an approximate total area of 31 ha). The distance between the habitats was approximately 1000 m (Fig. 1), and neither habitat had the presence of bovines.

To sample beetles, 4 pitfall traps were used in each habitat, and for each set of traps, there was a baited trap with human excrement (20 g) for collecting coprophagous species; a rotted chicken liver (20 g) for species attracted to carrion; and another trap with fermented banana (20 g) to attract saprophagous species; the 2 latter baits were allowed to rot in covered plastic pots at ambient temperature for 3 d. Thus, the 3 main eating habits of species of dung beetles were covered (Halffter and Matthews 1966). A 4th trap without bait was used to collect beetles with possible different eating habits from those previously mentioned, possibly attracted to dead insects.

The pitfall trap consisted of a plastic container 15 cm high and 10 cm in diameter, buried at ground level. It contained a preservative substance and was protected against the rain and sun. To accommodate the bait, smaller containers were used (6 cm high by 5 cm in diameter), pierced at the upper end by a fine metallic wire to give them support, and placed in the larger container in order to stay centered above it. Ceramic tiles (20 × 20 cm) supported by 3 small wooden stakes (15 cm long) were used to keep the bait fresh, avoid evaporation of the preservative substance, and maintain a distance of 10 cm between the edge of the trap and the protection. The substance used to capture the beetles was a mixture of 300 ml water, 5 ml formalin, and a few drops of neutral detergent to break the surface tension of the water.

The traps were set 30 m apart from each other and distributed in a Y-shape (in the center and vertices). The preservative substance was replaced every 2 wk, and the collected insects were placed in properly identified plastic pots and taken to the Entomology Laboratory of Embrapa Pecuária Sul for enumeration and identification. The study was conducted from Sept. to Dec. 2006, with sampling every 2 wk, and the baits were replaced weekly. A similar methodology was used

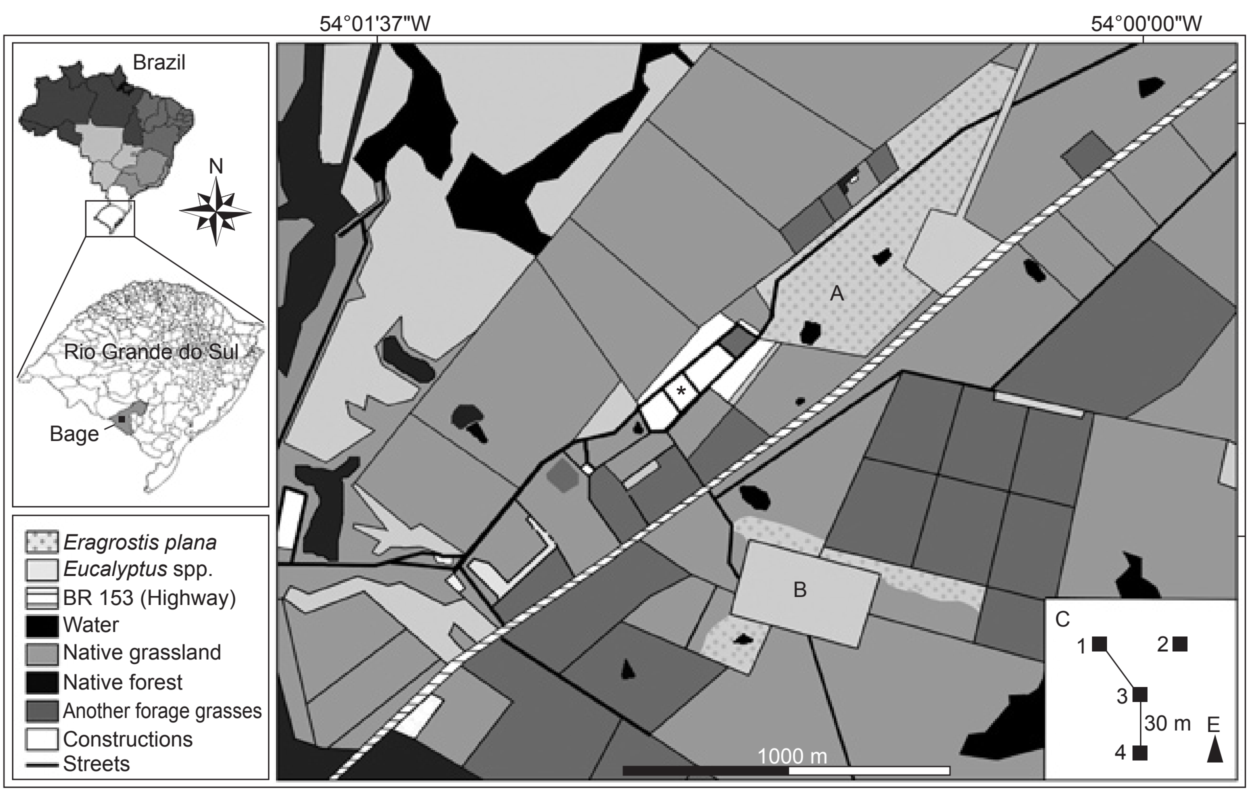

Fig. 1. Location of the 2 sampled habitats for species of the Scarabaeinae through pitfall traps, in Sept.-Dec. 2006 in the municipality of Bagé, Rio Grande do Sul, Brazil. *Embrapa Pecuária Sul. (A) Habitat of *Eragrostis plana* Ness. (B) Habitat of *Eucalyptus* spp. plantation. (C) Arrangement of traps (1, baited with carrion; 2, baited with fermented banana; 3, baited with human excrement; 4, unbaited).

by Schiffler et al. (2003) to survey dung beetles in Linhares, Espírito Santo, Brazil.

Insects were identified through a dichotomous key to genera of the Scarabaeinae (Vaz-de-Mello and Edmonds 2009), by comparing specimens deposited in the laboratory, and by consulting an expert on Brazilian species, Dr. Fernando Z. Vaz de Mello (Univ. Federal de Mato Grosso, Mato Grosso, Brazil). After sorting, the insects were placed in labeled entomological blankets or pinned with entomological pins, which were respectively contained in sealed plastic bags and entomological boxes for better preservation. The beetles were deposited in the Entomology Laboratory of Embrapa Pecuária Sul.

Student's *t*-test was conducted with the software PAST 1.91 (Hammer et al. 2001) to check for possible differences in abundances in each sampled habitat. The food preference of the species was inferred using the criterion of a minimum of 80% falls in a given baited trap (Almeida 2006, Almeida and Louzada 2009). For this purpose, individuals collected in the trap without bait and also singleton and doubleton species, respectively represented by 1 and 2 individuals, were not taken into consideration.

Species were grouped according to their behavior (functional guilds), or the way they use resources for feeding and nesting, into tunnelers (those who bury portions of their food just below the resource), rollers (species that roll small spheres of food on the ground until burying them), and dwellers (a group of species that feed and nest themselves in the food) (Halffter and Matthews 1966, Cambefort and Hanski 1991, Doube 1991, Gill 1991, Hanski and Cambefort 1991).

Simpson and Shannon indices were employed to compare the diversities of the habitats (Baños-Picón et al. 2009). The Pielou evenness index was used to verify the uniformity of the abundances of each habitat and trap (Moreno 2001). These indices were calculated using the software PAST 1.91 (Hammer et al. 2001).

Similarities between the habitats of *E. plana* and *Eucalyptus* spp. were calculated using the binary Jaccard coefficient (Magurran 1988). The 1st-order Jackknife richness estimator was calculated for each trap in each habitat and for the total richness found in this study using the software EstimateS (Colwell 2007), to verify the possibility of finding other species in the studied areas.

Studies conducted at the same location were used as a basis for comparison between the richness and composition of species in the sampled habitats. A cluster analysis with paired groups using the Jaccard similarity coefficient was performed with the software PAST 1.91 (Hammer et al. 2001). An ordination analysis was carried out in order to verify the grouping of species in the sampled habitats. Non-metric multidimensional scaling (NMDS) using Bray-Curtis similarity (qualitative data) was conducted with the Primer 6 program (Clarke and Gorley 2005).

RESULTS

In total, 264 dung beetles were collected, belonging to 5 tribes, 7 genera, and 13 species (Table 1). Both habitats had the same number of species, and the habitat of *E. plana* had almost twice the number of individuals than was collected in the *Eucalyptus* spp. habitat. However, this difference was not statistically significant (t = 1.04, p > 0.05), probably due to the sample size and sampling design used in this study.

The most abundant species between the studied habitats were *Onthophagus* aff. *hirculus* Mannerheim, *Canthon lividus* Blanchard, *C. bispinus* (Germar), and *C. podagricus* Harold, with 57 (21.6%), 48 (18.2%), and the 2 latter ones with 46 (17.4%) individuals each. Together, these species represented 74.6% of the total number of individuals captured. *Onthophagus* aff. *hirculus* was captured in both traps baited with human excrement and unbaited traps. It presented similar numbers in the 2 sampled habitats. *Canthon lividus* was captured in greater numbers in traps baited with the carcass, as it has a copro-necrophagous eating habit (Martínez 1959), although it was classified as a necrophagous species according to the criterion used in this study. This species was collected 5-times more often in the *Eucalyptus* spp. than in the *E. plana* habitat. *Canthon bispinus* and *C. podagricus* are necrophagous species (Martínez 1959). In this study, both species were classified as preferably necrophagous generalists. The 1st species occurred almost 3-times more often in the *E. plana* habitat than in the *Eucalyptus* habitat. *Canthon podagricus* was restricted to the *Eucalyptus* habitat. In the *E. plana* habitat, the more abundant species were *C. podagricus* and *C. bispinus* (together representing 46.4% of the total for this habitat), while in the *Eucalyptus* habitat, species with higher numbers of individual were *C. lividus* and *O.* aff. *hirculus* (together representing 73.3% of the total in this place).

The trap with the highest abundance in the 2 habitats was the one baited with carcass (41%), while the one baited with human excrement had greater richness (77%). In the *Eucalyptus* habitat, the most attractive bait was the carcass (46.8%), while human excrement (47%) presented a higher abundance in the *E. plana* habitat (Table 2). Only 2 species, *Canthidium moestum* Harold and *C. podagricus* occurred in 3 types of baited traps. Another 4 species, *C. bispinus*, *C. lividus*, *Deltochilum sculpturatum* Felsche, and *Ontherus sulcator* (Fabricius) occurred in 2 types of baited traps. The other species occurred only in 1 type of baited trap.

In this study, only 61% of the species were classified in food preference categories; 3 were grouped as coprophagous (23%), 1 as necrophagous (8%), and 4 as generalists (31%) and, among them, 3 (23%) were classified as preferably necrophagous and only 1 (8%) as preferably coprophagous. Five species did not have sufficient number of individuals to infer a food preference, with 3 being doubletons and 2 singletons.

According to the classification of species by the way they use food resources for feeding and nesting, 8 captured species (61%) were rollers, 4 species (31%) were tunnelers, and 1 (8%) was dweller. In this region, characterized by open areas, the number of rollers seemed to surpass the number of tunnelers, although they were similar (pers. observ.).

Roller species were exclusively represented by the Deltochilini. Tunnelers were represented by the Ateuchini, Coprini, and Onthophagini. The only tribe of dweller species captured in this study was the Oniticellini. Except for similar features such as how the species use food resources, species of these tribes have eating habits directed toward coprophagy, necrophagy, and saprophagy, but there are also reports of micetophagy, oviphagy, and predation (Halffter 1959, Herter and Colli 1998, Vaz-de-Mello et al. 1998, Villalobos et al. 1998, Vaz-de-Mello 1999). They are widely spread throughout the Neotropical region, with different numbers of genera and species, and new studies are being conducted on the inclusion/exclusion of genera cited for some of these tribes (Vaz-de-Mello 2008), as there are problems with generalizations of behaviors for higher taxa, in addition to exce-

Table 1. List of tribe and species of the Scarabaeinae collected in areas of *Eragrostis plana* and *Eucalyptus* spp. plantations in Sept.-Dec. 2006, in Bagé, Rio Grande do Sul, Brazil, with their respective functional and alimentary guilds

Tribe/species	Functional guild	Alimentary guild[1]	Total
Ateuchini			
Uroxys dilaticollis Blanchard, 1845	Tunneler	Insufficient no. (S)	1
Coprini			
Canthidium moestum Harold, 1867	Tunneler	Generalist (*C)	10
Ontherus sulcator (Fabricius, 1775)	Tunneler	Coprophagous (97%)	36
Deltochilini			
Canthon bispinus (Germar, 1824)	Roller	Generalist (*N)	46
C. curvipes Harold, 1868	Roller	Insufficient no. (D)	2
C. lividus Blanchard, 1845	Roller	Necrophagous (85%)	48
C. mutabilis Lucas, 1857	Roller	Insufficient no. (D)	2
C. ornatus bipunctatus Burmeister, 1873	Roller	Insufficient no. (D)	2
C. podagricus Harold, 1868	Roller	Generalist (*N)	46
C. seminitens Harold, 1867	Roller	Coprophagous (100%)	5
Deltochilum sculpturatum Felsche, 1907	Roller	Generalist (*N)	8
Oniticellini			
Eurysternus aeneus Génier, 2009	Dweller	Insufficient no. (S)	1
Onthophagini			
Onthophagus aff. *hirculus* Mannerheim, 1829	Tunneler	Coprophagous (100%)	57
Total number of individuals			264
Total number of species			13

[1]S, singleton; D, doubleton; C, coprophagous; N, necrophagous; * indicates food preference.

ptions within tribes and genera in terms of eating and nesting habits.

Between the 2 sampled habitats, *E. plana* had higher diversity indices of Shannon and Simpson (1.90 and 0.82, respectively) than the area with *Eucalyptus* spp. trees (Table 2). With almost 1/2 the abundance found in the *Eucalyptus* spp. habitat compared to the other habitat, minor dominance and greater equality contributed to the high diversity estimated for the *E. plana* area, although the 2 places presented the same number of species. This result is commonly found when this situation occurs, because these indices take richness and abundance as predictors of the diversity found in a given place (Magurran 1988, Moreno 2001).

The estimated richness by Jackknife's method was higher for the *Eucalyptus* habitat. There was a greater chance of finding other species here than in the other area because of the low abundance and richness compared to *E. plana*. Jaccard's coefficient of similarity between the same habitats was 0.538, showing a low similarity in species compositions between the 2 areas (Magurran 1988, Moreno 2001). For this study, the increase in terms of estimated richness was 38%. Therefore, there is a need for further studies in these habitats for better knowledge of their actual richness.

Pielou's evenness index presented higher values for the *E. plana* habitat (0.82), and demonstrated a better distribution of individuals per species in that location. The dominance of the Simpson index presented lower values for the same habitat (0.18). These results demonstrate that despite the fact that it had almost twice the number of individuals in relation to the other habitat, the abundance of the *E. plana* habitat was more equally distributed among species. These results were influenced by the higher number of singletons present in the *Eucalyptus* habitat.

Evenness values among traps were higher for those baited with banana in the *E. plana* habitat, and for those baited with human excrement in the *Eucalyptus* spp. habitat. In the 1st case, the number of species was very low, and in the 2nd case, despite the higher number of species, this bait had a lower abundance than the carcass, but numbers of individuals were more evenly distributed.

Table 2. Distribution of Scarabaeinae species by baited traps in the area of grass with *Eragrostis plana* and *Eucalyptus* spp. in Bagé, Rio Grande do Sul, Brazil, from Sept. to Dec. 2006, with their estimators and diversity indexes. Pitfall traps: NB, no bait; HE, human excrement; BA, fermented banana; CA, rotten chicken livers

Species	*Eragrostis plana*				Total	*Eucalyptus* spp.				Total	Overall total
	NB	HE	BA	CA		NB	HE	BA	CA		
Canthidium moestum	0	4	4	1	9	0	1	0	0	1	10
Canthon bispinus	2	3	0	28	33	0	7	0	6	13	46
C. curvipes	0	0	0	0	0	0	0	0	2	2	2
C. lividus	0	2	0	6	8	0	5	0	35	40	48
C. mutabilis	0	0	0	2	2	0	0	0	0	0	2
C. ornatus bipunctatus	0	2	0	0	2	0	0	0	0	0	2
C. podagricus	12	4	8	22	46	0	0	0	0	0	46
C. seminitens	0	4	0	0	4	1	0	0	0	1	5
Deltochilum sculpturatum	0	2	0	5	7	0	0	0	1	1	8
Eurysterus aeneus	0	0	0	0	0	1	0	0	0	1	1
Ontherus sulcator	0	31	0	0	31	0	4	1	0	5	36
Onthophagus aff. *hirculus*	0	28	0	0	28	25	4	0	0	29	57
Uroxys dilaticollis	0	0	0	0	0	0	1	0	0	1	1
Abundance	14	80	12	64	170	27	22	1	44	94	264
Richness	2	9	2	6	10	3	6	1	4	10	13
Estimated richness	2.0	11.6	2.0	6.7	12.6	4.5	7.1	1.0	5.5	15.0	18.1
Diversity - Shannon	0.41	1.58	0.63	1.32	1.90	0.31	1.60	0	0.68	1.48	1.98
Diversity - Simpson	0.25	0.72	0.45	0.68	0.82	0.13	0.77	0	0.34	0.70	0.84
Dominance	0.75	0.28	0.55	0.32	0.18	0.87	0.23	1	0.66	0.30	0.16
Evenness	0.59	0.72	0.91	0.73	0.82	0.28	0.89	1	0.49	0.64	0.77

The number of species shared between habitats was 7, and represents approximately 54% of the captured assemblage. In this study, 6 species (46%) were restricted to a particular habitat. In the *E. plana habitat*, *C. mutabilis* Lucas, *C. ornatus bipunctatus* Burmeister, and *C. podagricus* were restricted to this location, while *C. curvipes* Harold, *Eurysternus aeneus* Génier, and *Uroxys dilaticollis* Blanchard were restricted to the *Eucalyptus* habitat. These results influenced the low similarity found between the 2 habitats.

The cluster (Jaccard coefficient of similarity) and ordination (Bray-Curtis coefficient of similarity) analyses showed the formation of different groups, according to each study conducted in the town and their respective habitats (Figs. 2, 3).

The ecosystems of forest, edge, and grassland (named “grassland 1”) studied by Silva et al. (2008) formed a distinct group with approximately 55% similarity. These results were expected since sampling in these ecosystems was to investigate an ecotone of forest and grassland. However, Silva et al. (2008) found, even at the local level,

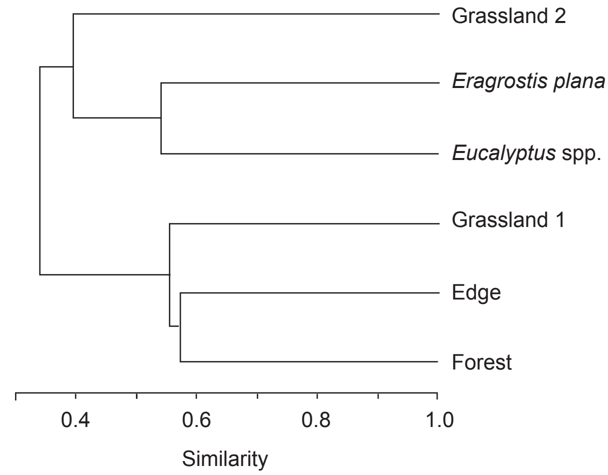

Fig. 2. Dendrogram of Jaccard similarity values between habitats in relation to the composition of captured species of the Scarabaeinae in Bagé, Rio Grande do Sul, Brazil. Data compiled by Silva et al. (2008): forest, edge, and grassland 1; Silva et al. (2009): grassland 2; present study: *Eragrostis plana* and *Eucalyptus* spp.

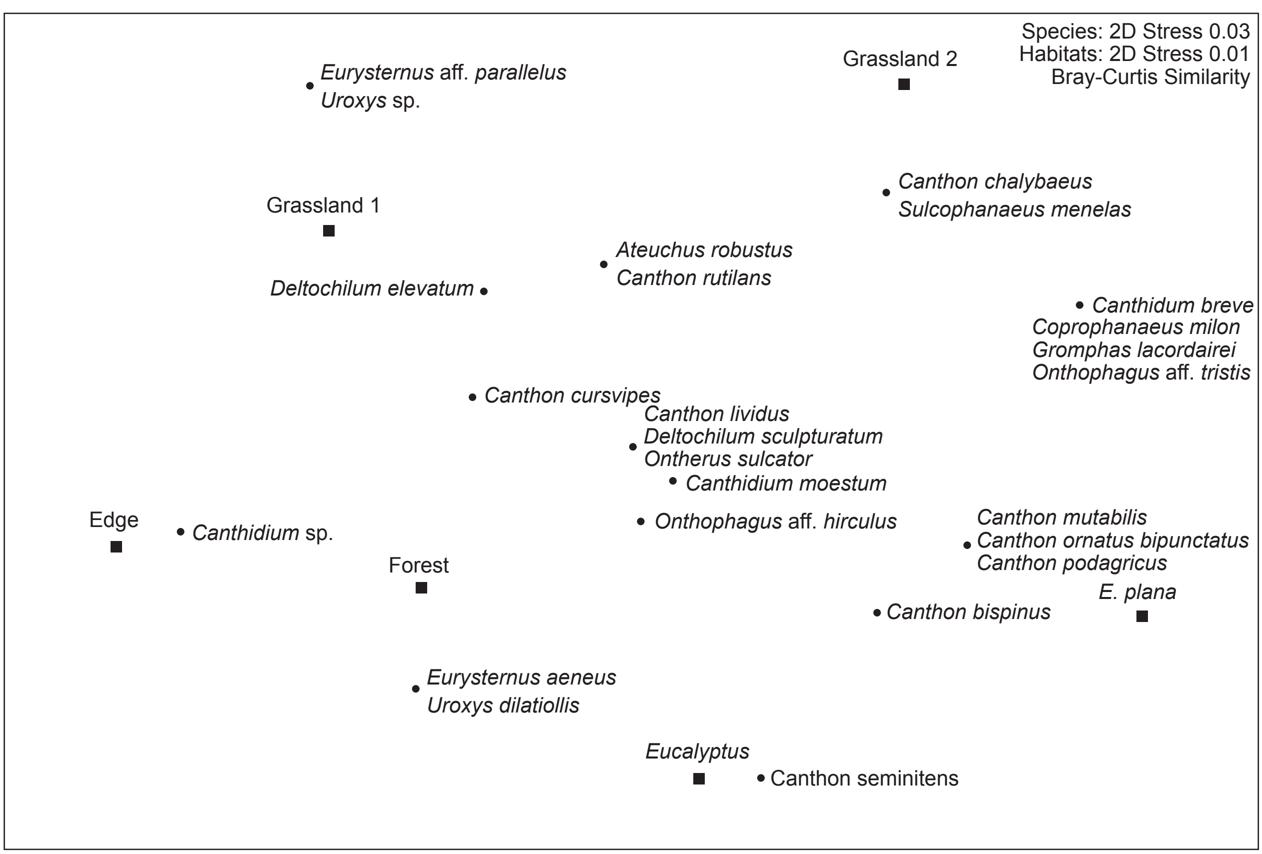

Fig. 3. Non-metric multidimensional scaling (NMDS) showing the grouping of Scarabaeinae species according to each type of habitat and the grouping of habitats based on the species distribution in Bagé, Rio Grande do Sul, Brazil.

different compositions of species of dung beetles in the forest, edge, and grassland, showing spatial variations of species distributions in different environments (Durães et al. 2005), as found in the current comparison of locations.

The habitats sampled in this study formed a group with the grassland area studied by Silva et al. (2009) (named "grassland 2"). This area is located close to the 2 locations investigated in the current study, although they were sampled at different times. Despite the low similarity (~40%), the composition of species shared by these 3 habitats contributed to their grouping (Table 3).

The ordination graph showed a distribution similar to the cluster graph. But this graph showed a better distribution of habitats in relation to species distribution. In this case, "grassland 2" was separated from the other habitats because the number of species (17) existing in this location was greater than those in other nearby habitats.

There was a particular distribution of species, showing the formation of various sets of species. The groups formed were: *Canthidium breve* (Germar), *Coprophanaeus milon* (Blanchard), *Gromphas lacordairei* Brullé, and *Onthophagus* aff. *tristis* Harold, which were restricted to "grassland 2"; *C. mutabilis*, *C. ornatus bipunctatus*, and *C. podagricus* which were restricted to "grassland 2" and *E. plana*; *C. lividus*, *D. sculpturatum*, and *O. sulcator* which occurred in all habitats; *C. chalybaeus* Blanchard and *Sulcophanaeus menelas* (Castelnau) which were restricted to habitats of native pasture (grasslands 1 and 2); *Ateuchus robustus* (Harold) and *C. rutilans* Castelnau which were restricted to native habitats (forest, edge, and grasslands 1 and 2); *Eurysternus* aff. *parallelus* (Castelnau) and *Uroxys* sp. which were restricted to the forest

Table 3. Qualitative listing of species of the Scarabaeinae captured in different studies in Bagé, Rio Grande do Sul, used in a cluster analysis of ecosystems where they were found. Ecosystems: native forest (FO), edge (ED), and native grassland 1 (G1), data compiled by Silva et al. (2008); native grassland 2 (G2), data compiled by Silva et al. (2009); present study: *Eragrostis plana* (EP) and *Eucalyptus* spp. (EU)

Species	Ecosystems					
	FO	ED	G1	G2	EP	EU
Ateuchus robustus (Harold, 1868)	1	1	1	1	0	0
Canthidium breve (Germar, 1824)	0	0	0	1	0	0
Canthidium moestum	1	0	1	1	1	1
Canthidium sp.	1	0	0	0	0	0
Canthon bispinus	0	0	0	1	1	1
C. chalybaeus Blanchard, 1845	0	0	1	1	0	0
C. curvipes	1	1	1	0	0	1
C. lividus	1	1	1	1	1	1
C. mutabilis	0	0	0	1	1	0
C. ornatus bipunctatus	0	0	0	1	1	0
C. podagricus	0	0	0	1	1	0
C. rutilans Castelnau, 1840	1	1	1	1	0	0
C. seminitens	0	0	0	0	1	1
Coprophanaeus milon (Blanchard, 1845)	0	0	0	1	0	0
Deltochilum elevatum (Castelnau, 1840)	1	1	1	0	0	0
D. sculpturatum	1	1	1	1	1	1
Eurysternus aeneus	1	0	0	0	0	1
Eurysternus aff. *parallelus* (Castelnau, 1840)	0	1	0	0	0	0
Gromphas lacordairei Brullé, 1834	0	0	0	1	0	0
Ontherus sulcator	1	1	1	1	1	1
Onthophagus aff. *hirculus*	1	1	0	1	1	1
O. aff. *tristis* Harold, 1873	0	0	0	1	0	0
Sulcophanaeus menelas (Castelnau, 1840)	0	0	1	1	0	0
Uroxys dilaticollis	1	0	0	0	0	1
Uroxys sp.	0	1	0	0	0	0
Total no. of species	12	10	10	17	10	10

edge and grassland habitats (grassland 1); and *E. aeneus* and *U. dilaticollis* which occurred only in the native forest. The other species presented different distributions. *Canthidium moestum* did not only occur at the edge of the forest or native grasslands. *Canthidium* sp. was restricted to native forest. *Canthon bispinus* occurred only in the exotic habitats and in grassland 2. *Canthon curvipes* did not occur in *E. plana* or grassland 2. *Canthon seminitens* Harold was present only in the 2 exotic habitats. *Deltochilum elevatum* (Castelnau) was restricted to the set of forest, edge, and grassland, and *O.* aff. *hirculus* was not present only in grassland 1.

DISCUSSION

Most of the collected species (69%) are common and were distributed in the south-central region of Brazil and Argentina (Martínez 1959), such as *Canthidium moestum*, *C. bispinus*, *C. curvipes*, *C. lividus*, *C. ornatus bipunctatus*, *C. podagricus*, *C. seminitens*, *D. sculpturatum*, and *U. dilaticollis*, comprising both forest ecosystems along the Atlantic coast of Brazil (Atlantic forest) and grasslands typical of the southern region of Rio Grande do Sul, Uruguay and southeastern Argentina (Pampas). The other captured species were widely distributed over Brazil and other South American countries (Martínez 1959, Vulcano and Pereira 1964). The total group of sampled species was often captured in other studies (Silva et al. 2008 2009), but did not represent 1/2 of all species already found in the region (pers. observ.).

Numbers of specialist and generalist species were the same in the present study. However, many specialists were also sampled in other kinds of baited traps, increasing the number of species that may use more than 1 type of food resource. This pattern, in which there was a greater number of generalist species in relation to specialists, is common in assemblages of the Scarabaeinae in Neotropical forests (Halffter and Matthews 1966), but little is known about the fauna of dung beetles of subtropical ecosystems in the same region. In pastures, the Scarabaeinae fauna associated with the excrement of herbivorous mammals may be large (Halffter and Matthews 1966). This could explain the greater number of specialist species (coprophagous) in relation to generalists, as occurs on African savannas (Halffter and Matthews 1966, Hanski and Cambefort 1991). As the sampled habitats might not offer available food for herbivorous mammals, the Scarabaeinae fauna associated with these habitats may be mainly those with less-specific eating habits.

In the tropics of the Neotropical region, the occurrence of dung beetle communities in forested areas is generally more diverse than in other areas such as open grasslands (Klein 1989, Halffter 1991, Davis et al. 2001, Scheffler 2005). This occurs because of the higher availability of food resources provided by mammals native to these locations, in addition to climatic factors which tend to be more aggressive in open areas than in forested areas. In this study, the forested area is an exotic monoculture that does not offer resources compatible with the fauna of native mammals which would influence distributions of dung beetles. Beyond the sampling design, this may explain the low abundance found in the *Eucalyptus* habitat, because the captured species were adapted to open areas.

However, in South American subtropical regions where grasslands are the predominant vegetation, the fauna of dung beetles is mainly adapted to eating excrement of ruminant mammals' which inhabit these pastures, similar to African savannas (Davis et al. 2002). The assemblage of dung beetles of this subtropical ecosystem type is not well known in terms of their habitat preferences, although it shows a tendency similar to species found in the tropical zone, because the connection with forests is as strong as that with mammals in the Neotropical region (Halffter 1959 1991, Gill 1991, Silva and Di Mare 2010). For example, Silva et al. (2008) found greater richness and abundance of dung beetles in the forest ecosystem than in other grassland habitats sampled in Bagé, in the south of Rio Grande do Sul.

Also, species found in habitats sampled in this study are likely to be "tourists" (Halffter and Moreno 2005), just passing through the area, perhaps looking for food, because they do not normally feed or nest in these places, and were attracted only by the offer of food available because of the development of this study. These places act as "islands", because they are usually surrounded by native pastures where species of the Scarabaeinae occur, and may serve as a temporary refuge or as a place to be explored if necessary. Although one of the species collected here (*C. seminitens*) was reported only in the 2 sampled exotic habitats in relation to the other compared ecosystems (Table 3), it should be emphasized that the species also frequents grassland areas and is rare in surveys in the region (pers. observ.).

Most of the captured species were represented by rollers. These data differ from those of Halffter et al. (1992), Louzada and Lopes (1997), and Almeida and Louzada (2009), in which those authors found a greater number of species belonging to the tunneler guild in tropical forests and savannas. These data may probably have been influenced by the negative effect of exotic vegetation on the native and exotic fauna of mammals, because there was a large decrease in the heterogeneity of food resources for such organisms (Medeiros and Focht 2007), which causes a direct effect upon the fauna of dung beetles. The rollers were represented by the Deltochilini, a group adapted to flying and rolling the resource over long distances, and which presents a great diversity in number of genera and species (Halffter and Matthews 1966, Hanski and Cambefort 1991). This tribe includes *Canthon* Hoffmannsegg, one of the largest genera of the Neotropical region, comprising about 190 species. This genus and *Deltochilum* Eschscholtz are comprised of copro-necrophagous species and represent almost 70% of the American species of the Deltochilini tribe (Halffter and Matthews 1966). This may explain the greater representation of rollers captured in this study. However, the proportions of rollers and tunnelers here sampled were similar to those found by Silva et al. (2009), whose work was carried out in subtropical native grasslands, where there are frequent accumulations of dung by bovines which inhabit these areas, different from the circumstances of this study.

Thus, the presence of food resources in the area seemed more important than the vegetation for the richness and abundance of dung beetles at this location, although Halffter and Arellano (2002) said that the vegetation coverage is more important for this group than food availability in grasslands with cattle. In this study; however, the influence of exotic vegetation may have contributed to these factors, through a decrease in food resources, and, as a result, very few mammal species occupy the area.

The richness found in this study was one of the smallest among works which were already developed in the municipality of Bagé, Rio Grande do Sul. Silva et al. (2008) collected 16 species in a natural forest-grassland ecotone, with 10 in the grassland, 10 in the edge, and 12 in the forest. Silva et al. (2009) captured 17 species in another area of native grassland. Notably, the number of sampled species reflects the increase in the number of pitfall traps and baited types used in those studies, and not necessarily the duration of their realization, because Silva et al. (2008) made collections during 2 wk in Oct. 2007, and this may indicate the low richness found at each investigated location, although similar to those found here.

When comparing these samples in terms of the composition of species existing in each habitat, a distinguishable separation was obtained in which each study (or habitat of each study) formed a distinct clade or group, as shown in figures 2 and 3. The present study results were positioned in the clade comprising the 2 habitats investigated herein and also the area of grassland (named grassland 2) sampled by Silva et al. (2009). The greater similarity of species composition (about of 40%) between these habitats in relation to others may be related to the proximity between the investigated areas (approximately 1 km) (pers. observ.). This set is located about 6.5 km from the ecotone studied by Silva et al. (2007), the other clade formed in the cluster analysis. The habitat type and distance may explain differences in the species composition, which manifested the low similarity found between the groups. The division of species into groups formed by their presence in the different analyzed habitats shows the influence (direct and indirect) of the type of vegetation on the Scarabaeinae fauna; because many species, so far, are restricted to certain types of habitats, which have specific characteristics such as microclimatic factors or higher or lower food availability for dung beetle species.

Comparing the richness found in the exotic habitats sampled in this study to other work developed outside Rio Grande do Sul, it was observed that the fauna of dung beetles sampled here was species-poor. For instance, Aidar et al. (2000) collected 20 species in Aquidauana, Mato Grosso do Sul, west-central Brazil, in exotic pastures of *Brachiaria decumbens* Stapf (Poaceae); Koller et al. (1999) also sampled this habitat and found 23 species of dung beetles in Campo Grande, Mato Grosso do Sul. Recently, Koller et al. (2007) listed 40 species in the same habitat. Vaz-de-Mello (1999) captured 36 species in Amazonian secondary forest at Rio Branco, Acre, northwestern Brazil. Durães et al. (2005) sampled a forest-cerrado ecotone and collected 22 species in the 2 habitats, at Belo Horizonte, Minas Gerais, southeastern Brazil. Schiffler et al. (2003) collected 23 species in a restinga area of Espirito Santo, southeastern Brazil. Scheffler (2005) collected 60 species in tropical rainforest at Pará, northern Brazil. Milhomem et al. (2003) sampled different habitats and collected a total of 102 species of dung beetles in Distrito Federal, central Brazil. In the region of Lavras, state of Minas Gerais, Vaz-de-Mello et al. (2001) recorded 18 species in pastures of the region. Almeida and Louzada (2009) recorded 52 species in 4 types of ecosystems in Carrancas, Minas Gerais. Silva et al. (2007) captured 28 species of dung beetles in Caruaru, Pernambuco, northeastern Brazil. Morelli et al. (2002) found 9 species of the Scarabaeinae in Cerro Largo, central Uruguay, as did González-Vainer and Morelli (2008) in a southeastern part of the same country.

The simple arithmetic average of the richness found in those studies is about 3-times higher than the total amount found in the exotic habitats sampled herein. However, due to the sample design, this result needs confirmation, but provides an important setting in which a decline in the diversity of the Scarabaeinae seems to occur, and non-natural ecosystems do not appear to contribute to the maintenance of the total richness of this important fauna (Gardner et al. 2008).

According to what was stated above, ecosystems do seem to influence the distribution of the dung beetle fauna which inhabits these areas. Even if not directly, the ecosystems may influence the mammals and, consequently, the availability of food resources that exist in these environments. The Scarabaeinae fauna of exotic habitats sampled in the present study appeared to have been influenced by the exotic vegetation in this region, and these habitats often only seem to support common species with generalist eating habits. Future studies should be developed to investigate microclimatic factors in each of these habitats which influence the dynamics of this fauna, in order to achieve a better understanding of the fauna which inhabits these locations, and to confirm or refute the results presented in this study.

Acknowledgments: I thank F.Z. Vaz de Mello for assistance with identification of the beetles, S. Saldanha for improving the English version of the manuscript, L.D. Audino for assistance during fieldwork, and Franciéle Garcês (for all). Thanks go to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) for the scholarship, and to PPG Biodiversidade Animal (UFSM), especially to R.A. Di Mare. Thanks are also due to the reviewers for their valuable suggestions and comments.

REFERENCES

Aidar T, WW Koller, SR Rodrigues, AM Corrêa, JCC Silva, OS Balta et al. 2000. Besouros coprófagos (Coleoptera: Scarabaeidae) coletados em Aquidauana, MS, Brasil. Ann. Soc. Entomol. Bras. **29:** 817-820. (in Portuguese with English summary)

Almeida SPA. 2006. Distribuição da diversidade de Scarabaeidae s. str. detritívoros (Coleoptera) entre diferentes fitofisionomias da Chapada das Perdizes, Carrancas – MG. MSc thesis, Univ. Federal de Lavras, Lavras, Brazil, 48 pp. (in Portuguese with English summary)

Almeida SPA, JNC Louzada. 2009. Estrutura da comunidade de Scarabaeinae (Scarabaeidae: Coleoptera) em fitofisionomias do Cerrado e sua importância para a conservação. Neotrop. Entomol. **38:** 32-43. (in Portuguese with English summary)

Alves SB, O Nakano. 1977. Influência do *Dichotomius anaglypticus* (Mannerheim, 1829) (Coleoptera: Scarabaeidae) no crescimento de plantas de Napier. Ecossistema **2:** 31-37. (in Portuguese with English summary)

Andresen E. 2002. Dung beetles in a Central Amazonian rainforest and their ecological role as secondary seed dispersers. Ecol. Entomol. **27:** 257-270.

Baños-Picón L, JD Asis, SF Gayubo, J Tormos. 2009. Analyzing insect community structure through the application of taxonomic distinctness measures. Zool. Stud. **48:** 298-314.

Bilenca D, F Miñarro. 2004. Identificación de áreas valiosas de pastizal en las pampas y campos de Argentina, Uruguay y sur de Brasil (AVPs). Buenos Aires: Fundación Vida Silvestre Argentina, 307 pp. (in Spanish)

Boldrini II, HM Longhi-Wagner, SD Boechat. 2005. Morfologia e taxonomia de gramíneas Sul-RioGrandenses. Porto Alegre, Brazil: Univ. Federal do Rio Grande do Sul, 96 pp. (in Portuguese)

Boonrotpong S, S Sotthibandhu, C Pholpunthin. 2004. Species composition of dung beetles in the primary and secondary forests at Ton Nga Chang Wildlife Sanctuary. Sci. Asia **30:** 59-65.

Clarke, KR, RN Gorley. 2005. Primer: getting started with v6. Plymouth, UK: Primer-E, 12 pp.

Cambefort Y, I Hanski. 1991. Dung beetle population biology. *In* I Hanski, Y Cambefort, eds. Dung beetle ecology. Princeton, NJ: Princeton Univ. Press, pp. 36-50.

Colwell RK. 2007. EstimateS: statistical estimation species richness and shared species from samples. Vers. 8.0. Available at http://viceroy.eeb.uconn.edu/estimates Accessed 15 Dec. 2007.

Davis AJ, JD Holloway, H Huijbregts, J Krikken, AH Kirk-Spriggs, SL Sutton. 2001. Dung beetles as indicator of change in the forests of northern Borneo. J. Appl. Ecol. **38:** 593-616.

Davis AL, CH Scholtz, P Dooley, N Bham, U Kryger. 2004. Scarabaeine dung beetles as indicators of biodiversity, habitat transformation and pest control chemicals in agro-ecosystems. S. Afr. J. Sci. **100:** 415-424.

Davis ALV, CH Scholtz, SL Chown. 1999. Species turnover, community boundaries and biogeographical composition of dung beetle assemblages across an altitudinal gradient in South Africa. J. Biogeogr. **26:** 1039-1055.

Davis ALV, CH Scholtz, TK Philips. 2002. Historical biogeography of scarabaeine dung beetles. J. Biogeogr. **29:** 1217-1256.

Doube BM. 1983. The habitat preference of some bovine dung beetles (Coleoptera: Scarabaeidae) in Hluhluwe Game Reserve, South Africa. Bull. Entomol. Res. **73:** 357-371.

Doube BM. 1991. Dung beetle of southern Africa. *In* I Hanski, Y Cambefort, eds. Dung beetle ecology. Princeton, NJ: Princeton Univ. Press, pp. 133-155.

Durães R, WP Martins, FZ Vaz-de-Mello. 2005. Dung beetle (Coleoptera: Scarabaeidae) assemblages across a natural forest-cerrado ecotone in Minas Gerais, Brazil. Neotrop. Entomol. **34:** 721-731.

Escobar F, G Halffter, L Arellano. 2007. From forest to pasture: an evaluation of the influence of environment and biogeography on the structure of dung beetle (Scarabaeinae) assemblages along three altitudinal gradients in the Neotropical region. Ecography **30:** 193-208.

Escobar F, JM Lobo, G Halffter. 2005. Altitudinal variation of dung beetle (Scarabaeidae: Scarabaeinae) assemblages in the Colombian Andes. Global Ecol. Biogeogr. **14:** 327-337.

Estrada A, R Coates-Estrada. 1991. Howling monkeys (*Alouatta palliata*), dung beetles (Scarabaeidae) and seed dispersal: ecological interactions in the tropical rain forest of Los Tuxtlas, Veracruz, Mexico. J. Trop. Ecol. **7:** 459-474.

Favila ME, G Halffter. 1997. The use of indicator groups for measuring biodiversity as related to community structure and function. Acta Zool. Mex. **72:** 1-25.

Fincher G, W Monson, G Burton. 1981. Effects of cattle feces rapidly buried by dung beetle on yield and quality of coastal Bermuda grass. Agron. J. **75:** 775-779.

Flechtmann CAH, SR Rodrigues. 1995. Insetos fimícolas associados à fezes bovinas em Jaraguá do Sul/SC. 1. Besouros coprófagos (Coleoptera: Scarabaeidae). Rev. Bras. Entomol. **39:** 303-309. (in Portuguese with English summary)

Flechtmann CAH, SR Rodrigues, HTZ Couto. 1995. Controle biológico da mosca-dos-chifres (*Haematobia irritans irritans*) em Selvíria, Mato Grosso do Sul. 4. Comparação entre métodos de coleta de besouros coprófagos (Scarabaeidae). Rev. Bras. Entomol. **39:** 259-276. (in Portuguese with English summary)

Gardner TA, MIM Hernández, J Barlow, CA Peres. 2008. Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for Neotropical dung beetles. J. Appl. Ecol. **45:** 883-893.

Gill BD. 1991. Dung beetles in tropical American forest. *In* I Hanski, Y Cambefort, eds. Dung beetle ecology. Princeton, NJ: Princeton Univ. Press, pp. 211-229.

González-Vainer P, E Morelli. 2008. Relevamiento de los coleópteros coprofilos e necrófilos de Sierra de Minas, Uruguay (Insecta: Coleoptera). Bol. Soc. Zool. Uruguay **17:** 20-33. (in Spanish with English summary)

Halffter G. 1959. Etología y Paleontología de Scarabaeidae. Ciencia **19:** 156-178. (in Spanish with English summary)

Halffter G. 1991. Historical and ecological factors determining the geographical distribution of beetles (Coleoptera: Scarabaeidae: Scarabaeinae). Fol. Entomol. Mex. **82:** 195-238.

Halffter G, L Arellano. 2001. Variación de la diversidad en especies de Scarabaeinae (Coleoptera: Scarabaeidae) como respuesta a la antropización de un paisaje tropical. *In* JL Navarrete-Heredia, HE Fierros-López, A Burgos-Solorio, eds. Tópicos sobre Coleoptera de México. Guadalajara, Mexico: Univ. de Guadalajara, pp. 35-53. (in Spanish with English summary)

Halffter G, L Arellano. 2002. Response of dung beetle diversity to human-induced changes in a tropical landscape. Biotropica **34:** 144-154.

Halffter G, ME Favila. 1993. The Scarabaeinae (Insecta: Coleoptera) an animal group for analysing, inventorying and monitoring biodiversity in tropical rainforest and modified landscapes. Biol. Int. **27:** 15-21.

Halffter G, ME Favila, V Halffter. 1992. A comparative study of the structure of the scarab guild in Mexican tropical rain forests and derived ecosystems. Fol. Entomol. Mex. **84:** 131-156.

Halffter G, EG Matthews. 1966. The natural history of dung beetles of the subfamily Scarabaeinae (Coleoptera: Scarabaeidae). Fol. Entomol. Mex. **12:** 1-312.

Halffter G, CE Moreno. 2005. Significado biológico de las diversidades alfa, beta y gamma. *In* G Halffter, J Soberón, P Koleff, A Melic, eds. Sobre diversidad biológica: el significado de las diversidades alfa, beta y gamma. Vol. 4. Zaragoza, Spain: Sociedad Entomológica Aragonesa, pp. 5-18. (in Spanish with English summary)

Hammer O, DAT Harper, PD Ryan. 2001. PAST: Paleontological Statistics software package for education and data analysis. Palae. Elect. **4:** 9 pp.

Hanski I, Y Cambefort. 1991. Competition in dung beetles. *In* I Hanski, Y Cambefort, eds. Dung beetle ecology. Princeton, NJ: Princeton Univ. Press, pp. 305-329.

Haynes RJ, PH Williams. 1993. Nutrient cycling and soil fertility in the grazed pasture ecosystem. Adv. Agric. **49:** 119-199.

Herter F, G Colli. 1998. The use of leaf-cutter ants, *Atta laevigata* (Smith) (Hymenoptera: Formicidae), as substrate of oviposition by the dung beetle *Canthon virens* Mannerheim in Central Brazil. Coleopt. Bull. **52:** 105-108.

Honer MR, I Bianchin, A Gomes. 1987. Desenvolvimento de um programa de controle de nematódeos e a mosca-dos-chifres na região dos cerrados: Fase 1. Pesquisa em Andamento. Vol. 36. Campo Grande, Brazil: Embrapa - CNPGC, 4 pp. (in Portuguese)

IBGE (Instituto Brasileiro de Geografia e Estatística). 2006. Bagé - RS. Available at http://www.ibge.gov.br Accessed 12 Apr. 2006. (in Portuguese)

Klein BC. 1989. Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. Ecology **70:** 1715-1725.

Koller WW, A Gomes, SR Rodrigues, RGO Alves. 1999. Besouros coprófagos (Coleoptera: Scarabaeidae) coletados em Campo Grande, MS, Brasil. Ann. Soc. Entomol. Bras. **28:** 403-412. (in Portuguese with English summary)

Koller WW, A Gomes, SR Rodrigues, PFI Goiozo. 2007. Scarabaeidae e Aphodiidae coprófagos em pastagens cultivadas em área do cerrado sul-mato-grossense. Rev. Bras. Zooc. **9:** 81-93. (in Portuguese with English summary)

Lobo JM, G Halffter. 2000. Biogeographical and ecological factors affecting the altitudinal variation of mountainous communities of coprophagous beetles (Coleoptera: Scarabaeoidea): a comparative study. Ann. Entomol. Soc. Am. **93:** 115-126.

Louzada JNC, FS Lopes. 1997. A comunidade de Scarabaeidae corpo-necrófagos (Coleoptera) de um fragmento de Mata Atlântica. Rev. Bras. Entomol. **41:** 117-121. (in Portuguese with English summary)

Magurran AE. 1988. Ecological diversity and its measurement. Princeton, NJ: Princeton Univ. Press, 179 pp.

Martínez A. 1959. Catalogo de los Scarabaeidae Argentinos (Coleoptera). Rev. Mus. Arg. Cien. Nat. Bern. Riv. **5:** 1-126. (in Spanish)

Martín-Piera F, JM Lobo. 1993. Altitudinal distribution patterns of copro-necrophage Scarabaeoidea (Coleoptera) in Veracruz, Mexico. Coleopt. Bull. **47:** 321-334.

McGeoch MA, BJV Rensburg, A Botes. 2002. The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. J. Appl. Ecol. **39:** 661-672.

Medeiros RB, T Focht. 2007. Invasão, prevenção, controle e utilização do capim-annoni-2 (*Eragrostis plana* Ness) no Rio Grande do Sul, Brasil. Rev. Agrop. Gaúcha **13:** 1-28. (in Portuguese with English summary)

Milhomem MS, FZ Vaz-de-Mello, IR Diniz. 2003. Técnicas de coleta de besouros copronecrófagos no Cerrado. Pesq. Agrop. Bras. **38:** 1249-1256. (in Portuguese with English summary)

Miranda CHB, JCC Santos, I Bianchin. 1998. Contribuição de *Onthophagus gazella* à melhoria da fertilidade do solo pelo enterrio de massa fecal bovina fresca. Rev. Bras. Zootec. **27:** 681-685. (in Portuguese with English summary)

Morelli E, P Gonzalez-Vainer, A Baz. 2002. Coprophagous beteles (Coleoptera: Scarabaeoidea) in Uruguayan prairies: abundance, diversity and seasonal occurrence. Stud. Neotrop. Fauna Environ. **37:** 53-57.

Moreno CF. 2001. Métodos para medir la biodiversidad. M&T-Manuales & Tesis SEA. Vol. 1. Zaragoza, Spain: Gorfi, 84 pp. (in Spanish with English summary)

Nealis VG. 1977. Habitat associations and community analysis of south Texas dung beetles (Coleoptera, Scarabaeinae). Can. J. Zool. **55:** 138-147.

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

Pillar VD, II Boldrini, H Hasenack, AVA Jacques, R Both, S Müller et al. 2006. Workshop: Espaço atual e desafios para a conservação dos campos. Available at http://www.natbrasil.org.br/Docs/monoculturas/workshop_ufrgs_campos_2006.pdf Accessed 22 Nov. 2006. (in Portuguese)

Pimentel F. 1940. Aspectos gerais de Bagé. Porto Alegre, Brazil: Gundlach, 135 pp. (in Portuguese)

Reis JCL. 1993. Capim annoni-2: origem, morfologia, características, disseminação. *In* Anais da Reunião Regional de Avaliação de Pesquisa com annoni-2. Documentos. Vol. 7. Bagé, Brazil: Embrapa Pecuária Sul, pp. 5-24. (in Portuguese)

Reis JCL, RW Coelho. 2000. Controle do capim annoni-2 em campos naturais e pastagens. Circular Técnica. Vol. 22. Pelotas, Brazil: Embrapa Clima Temperado, 21 pp. (in Portuguese)

Ridsdill-Smith TJ, L Hayles. 1990. Stages of bush fly, *Musca vetustissima* (Diptera: Muscidae), killed by Scarabaeinae dung beetles (Coleoptera: Scarabaeidae) in unfavourable cattle dung. Bull. Entomol. Res. **80:** 473-478.

Ridsdill-Smith TJ, L Hayles, MJ Palmer. 1986. Competition between the bush fly and a dung beetles in dung of differing characteristics. Entomol. Exp. Appl. **41:** 83-90.

Rodrigues SR, LC Marchini. 1998. Besouros coprófagos (Coleoptera: Scarabaeidae) coletados em Piracicaba, SP. Sci. Agric. **55:** 53-58. (in Portuguese with English summary)

Roesch LFW, FCB Vieira, VA Pereira, AL Schünemann, IF Teixeira, AJT Senna, VM Stefenon. 2009. The Brazilian Pampa: a fragile biome. Diversity **2009:** 182-198.

SBS (Sociedade Brasileira de Silvicultura). 2007. Fatos e números do Brasil florestal. Available at http://www.sbs.org.br/FatoseNumerosdoBrasilFlorestal.pdf Accessed 19 Oct. 2007. (in Portuguese)

Scheffler PY. 2005. Dung beetle (Coleoptera: Scarabaeidae) diversity and community structure across three disturbance regimes in eastern Amazonia. J. Trop. Ecol. **21:** 9-19.

Schiffler G, FZ Vaz-de-Mello, CO Azevedo. 2003. Scarabaeidae s. str. (Coleoptera) do Delta do Rio Doce e Vale do Suruaca no município de Linhares, Estado do Espírito Santo, Brasil. Rev. Bras. Zoociên. **5:** 205-211. (in Portuguese with English summary)

Shepherd VE, CA Chapman. 1998. Dung beetles as secondary seed dispersers: impact on seed predation and germination. Trop. Ecol. **14:** 199-215.

Silva FAB, MIM Hernández, S Ide, RC Moura. 2007. Comunidade de escarabeíneos (Coleoptera, Scarabaeidae) copro-necrófagos da região de Brejo Novo, Caruaru, Pernambuco, Brasil. Rev. Bras. Entomol. **51:** 228-233. (in Portuguese with English summary)

Silva PG, MAR Garcia, B Vidal. 2008. Besouros copronecrófagos (Coleoptera: Scarabaeidae sensu stricto) coletados em ecótono natural de campo e mata em Bagé, RS. Ciên. Nat. **30:** 71-91. (in Portuguese with English summary)

Silva PG, MAR Garcia, MB Vidal. 2009. Besouros copronecrófagos (Coleoptera: Scarabaeidae sensu stricto) do município de Bagé, RS (Bioma Campos Sulinos). Biociências **17:** 33-43. (in Portuguese with English summary)

Silva PG, RA Di Mare. 2010. Biogeografia de Scarabaeinae (Coleoptera, Scarabaeoidea, Scarabaeidae) no Brasil. *In* Resumos do XXVIII Congresso Brasileiro de Zoologia. Pará, Brazil: Sociedade Brasileira de Zoologia, pp. 605. (in Portuguese)

Spector S. 2006. Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): an invertebrate focal taxon for biodiversity research and conservation. Coleopt. Bull. **5:** 71-83.

Spector S, AB Forsyth. 1998. Indicator taxa for biodiversity assessment in the vanishing tropics. *In* GM Mace, A Balmford, JR Ginsberg, eds. Conservation in a changing world. Cambridge, UK: Cambridge Univ. Press, pp. 181-209.

Vaz-de-Mello FZ. 1999. Scarabaeidae s. str. (Coleoptera: Scarabaeoidea) de um Fragmento de Floresta Amazônica no Estado do Acre, Brasil. 1. Taxocenose. An. Soc. Entomol. Bras. **28:** 447-453. (in Portuguese with English summary)

Vaz-de-Mello FZ. 2000. Estado de conhecimento dos Scarabaeidae s. str. (Coleoptera: Scarabaeoidea) do Brasil. *In* F Martín-Piera, JJ Morrone, A Melic, eds. Hacia un Proyecto Cyted para el Inventario y Estimación de la Diversidad Entomológica en Iberoamérica. Zaragoza, Spain: Sociedad Entomológica Aragonesa, pp. 181-195. (in Portuguese with English summary)

Vaz-de-Mello FZ. 2008. Análise filogenética da tribo Ateuchini (Insecta, Coleoptera, Scarabaeidae, Scarabaeinae) e taxonomia supragenérica dos gêneros nela incluídos. *In* Resumos do XXVII Congresso Brasileiro de Zoologia. Curitiba, Brazil: Sociedade Brasileira de Zoologia, O-579, p. 1. (in Portuguese)

Vaz-de-Mello FZ, WD Edmonds. 2009. Gêneros e subgêneros da subfamília Scarabaeinae (Coleoptera: Scarabaeidae) das Américas. Available at http://www.scribd.com/doc/36887087/chaveportugues2-0 Accessed 11 Dec. 2009. (in Portuguese with available English version)

Vaz-de-Mello FZ, JNC Louzada, JH Schoereder. 1998. New data and comments on Scarabaeidae (Coleoptera: Scarabaeoidea) associated with Attini (Hymenoptera: Formicidae). Coleopt. Bull. **52:** 209-216.

Vaz-de-Mello FZ, S Reis, JNC Louzada. 2001. Levantamento preliminar das espécies de Scarabaeidae (Insecta: Coleoptera) fimícolas das pastagens da região de Lavras. *In* Anais do X Congresso da Pós-Graduação da Univ. Federal de Lavras. Lavras, Brazil: APG/UFLA, ENT 008, pp. 1-7. (in Portuguese with English summary)

Villalobos FJ, A Diaz, MH Favila. 1998. Two species of *Canthon* Hoffmannsegg feed on dead and live invertebrates. Coleopt. Bull. **52:** 101-104.

Vulcano MA, FS Pereira. 1964. Catalogue of the Canthonini (Col. Scarab.) inhabiting the Western Hemisphere. Entomol. Arb. Mus. G. Frey **15:** 570-685.

Wardhaugh K, NR Menéndez. 1988. The effects of the antiparasitic drug, ivermectin, on the development and survival of the dung breeding fly, *Orthelia cornicina* (F.), and the scarabaeine dung beetles, *Copris hispanus* (L.), *Bubas bubalus* (O.), and *Onitis belial* (F.). J. Appl. Entomol. **106:** 381-389.

Waterhouse DF. 1974. The biological control of dung. Sci. Am. **230:** 100-109.