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Spatial and Temporal Variation of Dung Beetle Assemblages in a Fragmented Landscape at Eastern Humid Chaco

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Abstract
The aims of this study were to characterize the fauna of dung beetles and analyze their spatial and temporal diversity in a cattle ranch in the province of Chaco. Seven surveys were conducted in three environmental units: a forest fragment, a cattle pasture, and an open grassland. The efficiency of the sampling was assessed with non-parametric richness estimators, and attributes of the assemblage were evaluated. The species composition and the abundance distribution in each of the environmental units studied were compared using rank-abundance curves. The indicator value of each species was measured with the IndVal method. The relationship between richness, abundance, and environmental variables (temperature, precipitation, and relative humidity) was calculated by multivariate multiple regression analysis. A total of 3,356 adult individuals belonging to 29 species of the subfamily Scarabaeinae and to five species of Aphodiinae were captured. *Dichotomius nisus* (Olivier), *Trichillum externepunctatum* (Preudhomme), *Canthon podagricus* (Harold), *Onthophagus hirculus* (Mannerheim), *Pseudocanthon aff. perplexus*, *Ontherus sulcator* (Fabricius), and *Ataenius platensis* (Blanchard) were the most abundant. Diversity, species richness, and abundance were highest in the forest fragment and in spring and summer captures. Between 94% and 97% of the species present in the entire landscape were recorded. According to the analysis of similarity, the composition of the assemblage was different among habitats. *Eurysternus caribaeus* (Herbst), *Eurysternus aeneus* (Génier), and *O. sulcator* were indicators of the forest. In the three units, the coprophagous species represented more than 60% of the total species number. The rainfall regime, the temperature, and the heterogeneous use of the environmental units influenced the structure of dung beetle assemblages.

Introduction

During the twentieth century, Argentina lost two thirds of the surface of native forests and jungles. According to the first forest census carried out in 1914, these environments occupied 105 million hectares. Recorded data by the National Forest Inventory show that the native forest mass reached only 12% of its original extension in 2001.

The level of deforestation in the Chaco province is higher than that in other provinces of Argentina. The Provincial Forest Inventory (2005) stated that this activity has reduced the forested areas to 50% of their original surface. This province is included as one of the ecoregions most affected by anthropic actions; the transformation of the landscape is constant—the forests and savannas are replaced by agricultural fields and cattle ranches. As a result, biological diversity suffers a permanent decrease (Burkart 2006). Programs for the protection of native forests aimed at preserving the floristic composition, mainly of trees of forestry value, have been implemented in recent years. These programs also accidentally benefit other components of the flora and fauna, which provide multiple ecosystem services unknown by farmers and cattle breeders.

The alterations of natural ecosystems in environments modified by different human activities have deep ecological impacts because these practices change the environmental conditions and modify the structure of many insect communities (Samways 1994). It is frequently assumed that these transformed landscapes have low ecological value, and little is known about the importance of the preservation of the forest fragments. However, these remnant patches of forest serve as a refuge and host a sample of the original ecosystem biodiversity (Damborsky *et al* 2008).

Biodiversity studies have proposed different faunal and floristic groups as indicators of the effects of human activities. Dung beetles are extensively used in this type of research because they are vulnerable to habitat alterations; they are well represented in tropical forests and their derived ecotopes. Likewise, they are important components of the soil entomofauna, they are well defined from the taxonomic and functional point of view, and the sampling methods are standardized (Halffter & Arellano 2002, Halffter *et al* 2007, Mc Geoch *et al* 2002, Nichols *et al* 2007, 2008, Navarrete & Halffter 2008). In addition to their usefulness as bioindicators, dung beetles play a fundamental activity linked to the removal and recycling of organic matter in the nutrient cycle. They use both carrion in early or advanced stage of decomposition and the feces of different vertebrates for food and nesting (Halffter & Edmonds 1982). These organisms perform a series of ecological functions in the ecosystem, and habitat disturbance can interrupt many of the functions in which they are involved.

The recognition of the ecological value and the ecosystem services provided by dung beetles contributes to understand the consequences of these insects' diversity loss in natural habitats as well as in landscapes modified by human activities (Nichols *et al* 2008). In the Chaco region of Argentina, the information on the effects of the different land uses on the diversity of this group of indicators is limited.

The aims of this study were to characterize the assemblage structure of coprophagous and necrophagous beetles and to assess their temporal variation in a livestock farm of the province of Chaco, Argentina. Moreover, the spatial variation in species richness, abundance, diversity, and species composition of this assemblage was evaluated in three units with different intensities of anthropic disturbance. Since these units exhibit differences in structure and vegetation cover, it is expected that the beetle assemblages' attributes will decrease in the environments where the heterogeneity of the vegetation declines as a result of different land uses and the transformation of the ecosystem.

Material and Methods

Study area

The research was conducted in a livestock farm located at Presidencia de la Plaza, Chaco province, Argentina. The area is located in the Eastern District or Humid Chaco from the Chaco province, included in the Neotropical Region, Chaco Subregion, which covers central and north Argentina, south of Bolivia, west of Paraguay, and southern Brazil (Morrone 2001). This farm was selected for being representative of cattle landscapes of the Eastern Humid Chaco, and even though extensive cattle ranching is the main productive activity, it preserves native forest patches.

Samplings were carried out in a cattle pasture (PI), adjacent grassland (PII), and a forest fragment (B). These environmental units are located between 27°01′32″ S and 27°01′53″ S, and from 59°38′00″ W and 59°38′56″ W. The relief is extremely flat, and the soil is silty clay, features that make drainage difficult.

Characterization of the environmental units

Cattle pasture (PI). It covers an area of 40 ha and hosts 60 heads of cattle. Two well-defined strata are observed: one that reaches about 80 cm in height, where *Sporobolus indicus* and *Schizachyrium microstachyum* are dominant, and small groups of *Senecio bonariensis*, and the other that does not exceed 10 cm in height, with a predominance of *Paspalum notatum* and *Cynodon dactylon*. Among the most common herbaceous plants are *Desmodium canum*, *Oxalis* sp., *Eryngium elegans*, *Cyperus entrerianus*, and *Sisirynchium* sp.

Grassland (PII). It measures 30 ha and was not used for cattle grazing during the sampling period. It is characterized by the almost exclusive domain of "star grass" (*Cynodon plectostachyus*), an implanted species that behaves as invasive. Patches of *Celtis* sp. and isolated tree specimens of *Astronium balansae*, *Prosopis kuntzei*, and *P. affinis* are also scattered in this environment.

Forest fragment (B). It consists of an islet of 10 ha of high mesophilous forest, which had undergone moderate disturbance because of the sylvopastoral management carried out. It includes three strata: the arboreal stratum, with specimens of *Schinopsis balansae*, *Diplokeleba floribunda*, *Handroanthus heptaphylla*, *Ceiba insignis*, *Erythrina dominguenzii*, *Gleditsia amorphoides*, *Cordia americana*, *Maclura tinctoria*, *Hexachlamys edulis*, *Prosopis nigra*, and *Cereus* sp., whose height varies between 7 and 25 m. The arbustive stratum is between 2 and 4 m, which is more or less dense in some sectors of the forest and where the most common and conspicuous specimens include *Brunfelsia australis*, *Allophyllus edulis* and *Eugenia uniflora*. In the herbaceous stratum, where the bromeliacea *Aechmea distichantha* and *Pseudananas sagenarius* are abundant, there are some grasses such as *Oplismenus hirtellus* and *Olyra ciliatifolia*; there are also a few climbing plants and abundant epiphytes such as *Microgramma vacciniifolia* and *Campylocentrum neglectum*.

Field work

Samplings were conducted in October and December 2006 and in February, April, June, October, and December 2007. Five sites were randomly selected in each environmental unit. Two different trap types were placed in each sampling site at a distance of 25 m from each other: one baited with feces of omnivorous mammals (coprotraps) and one with decomposing squid and chicken (necrotraps). A total of 210 traps were placed. Each trap remained active for 72 h on each sampling date.

The specimens captured were fixed in 70% ethanol and placed in labeled polypropylene bags until their transfer and processing in the laboratory.

Temperature and relative humidity data correspond to the average of the sampling dates measured with a weather station Weatherlink - Monitor II - Davis. Monthly precipitation data were also registered. The temperature ranged between 17°C and 37°C and the relative humidity between 50 and 89%. The samplings carried out in October 2006 and June 2007 corresponded to a period of low rainfall, with values of 84 and 18 mm, respectively, while rainfall in December 2006, February, April, October, and December 2007 ranged between 117 and 178 mm.

Data analysis

The beetles were identified, and the abundance and richness in each environmental unit and on each sampling date and the density and number of species per trap were recorded. The sampling efficiency was assessed for each environmental unit and for the entire landscape with the non-parametric richness estimators ICE and Jackknife of first order, which are considered more accurate, but the Michaelis-Menten equation was also used as it is adequate to assess inventories with a small number of samples (Colwell & Coddington 1994). Expected species accumulation curves for each environmental unit were generated with the program EstimateS v. 8.2 (Colwell 2009).

Alpha diversity was estimated by calculating species richness (*S*), Shannon-Wiener (*H*′), Pielou's evenness (*J*′), and Simpson's dominance index (*D*) with the program PAST (Hammer *et al* 2001).

An analysis of similarity was made to examine whether there were differences in species composition between units through the ANOSIM procedure of the program PRIMER, version 5.0 (Clarke & Gorley 2001).

Composition patterns and distribution of species abundance for each of the habitats were contrasted with rank-abundance curves (Feinsinger 2001). These curves represent the values of abundance of each species at a logarithmic scale (log 10).

Variations in richness and abundance between environmental units, sampling date, and trap types were analyzed using permutational multivariate analysis (PERMANOVA) in a model of multivariate analysis of covariance (MANCOVA), adding temperature, humidity, and precipitation as covariables (Anderson 2001).

Species were classified as specialists when more than 80% of individuals were collected in either necrotraps or coprotraps and as generalists when less than 80% of the beetles were collected in one of the two types of traps (Halffter & Favila 1993).

Species from forest fragment, grassland, or cattle pasture were grouped when at least 75% of the individuals were recorded in one or another habitat and were considered generalists when less than 75% of the individuals were recorded in one of the units according to the criterion proposed by Arellano *et al* (2008).

Furthermore, the association of beetle species with a particular environmental unit was evaluated with the indicator value method (IndVal) proposed by Dufrene & Legendre (1997), which combines measures of species specificity and fidelity to a type of habitat. The calculation was carried out with the program PC-Ord 6.0 (Mc Cune & Mefford 2011). The statistical confidence (α =0.05) of the IndVal values was calculated with a Monte Carlo randomization test (10,000 permutations). A species was considered a habitat indicator with an IndVal value greater than 70% and p<0.05, whereas a species with values between 50% and 70% was classified as a detector species (Mc Geoch *et al* 2002).

Temporal β-diversity was assessed for each pair of successive months sampled with the complementarity index (Colwell & Coddington 1994).

The relationship between abundance and species richness and environmental variables (temperature, precipitation, and relative humidity) was studied by multivariate multiple regression analysis calculated with DISTLM program (Anderson 2003), using the Bray Curtis measure distance, with a significance level of α =0.05.

Food and habitat preference and the indicator value were evaluated for species whose abundance was higher than ten individuals.

Results

A total of 3356 adult beetles belonging to 18 genera and 34 species, 29 of which corresponded to the subfamily Scarabaeinae and five to Aphodiinae, were collected (Table 1). About 41% (S=14) of the species were captured in the three environments. Nearly 97% (S=33) of the species identified were collected in the forest, and 44% (S=15) of them were exclusive of this environmental unit. Among the most numerous species were *Onthophagus hirculus* (Mannerheim), *Pseudocanthon aff. perplexus*, *Ontherus sulcator* (Fabricius), *Canthon podagricus* (Harold), and *Canthidium* aff. *cupreum*, which constituted 52% of the relative abundance in the forest fragment. In the cattle pasture, *Trichillum externepunctatum* (Preudhomme) and *Dichotomius nisus* (Olivier) represented 63.05% of the relative abundance, and two species dominated the grassland area, *D. nisus* and *C. podagricus* accounted for 58% of the abundance.

The minimum number of estimated species was 35.1 (ICE), whereas the maximum was 35.9 (Jackknife 1). The values obtained by the various estimators suggest that the invested effort allowed registering between 94% and 97% of the species present in the landscape. Moreover, the efficiency of the sampling in each environment was almost 90% (ICE), although lower in the grassland, where 84% (17/20) of the species present were captured according to Michaelis-Menten estimator (Table 2). The species accumulation curve shows that an asymptote was reached in the three habitats, with a richness loss of 50% in the pasture and grassland as compared to the forest (Fig 1).

The forest fragment showed higher values of diversity, species richness, and abundance, whereas the pasture and grassland showed high values of dominance (Table 3). Significant differences were found in the abundance and richness between environmental units (Table 4).

The minimum number of species per trap was S=2. The maximum number of species per trap in B was 15 ($\overline{X}$ = 4.52), in PII was 13 ($\overline{X}$ = 2.24), and in PI was 7 ($\overline{X}$ = 2.34). Evenness was higher in the forest fragment, a fact reflected in the rank-abundance curve with five dominant species that constituted 51% of the abundance and several species with moderately high abundance. The beetle assemblages of PI and PII showed a similar distribution, with steep slopes, although the hierarchical order of the species was different. One species, *D. nisus*, was dominant in both units, and few species showed moderate abundance (Fig 2). These curves also evidenced the differential composition of the assemblages.

According to the analysis of similarity, there was a difference in the assemblage between habitats (R=0.81; p=0.001), which was significant between B and PI and between B and PII (p<0.05).

Habitat preference

Eleven species showed preference for the forest fragment, two species showed preference for the cattle pasture, and ten were categorized as generalists (Table 1). Seven of the 23 species evaluated showed significant indicator values (p<0.05): three were indicators of forest fragment: *Eurysternus caribaeus* (Herbst), (IndVal=71.4%; p=0.002), *Eurysternus aeneus* (Génier) (IndVal=71.4%; p=0.004), and *O. sulcator* (IndVal=73.5; p=0.05); three were qualified as detectors of forest: *Anisocanthon villosus* Harold (IndVal=60.6), *O. hirculus* (IndVal=61.6), and *P. aff. perplexus* (IndVal=57.1); and one was qualified as detector of PI: *Gromphas inermis* (Harold) (Ind Val=59.0).

Food preference

In the forest fragment, 67% (12/18) of the species were coprophagous, while four showed necrophagous habits (*Canthon bispinus* Germar, *C. podagricus*, *Canthon quinquemaculatus* Castelnau, and *Deltochilum elongatum* Felsche) and two (*A. villosus* and *E. caribaeus*) showed generalist food preference habits. In the cattle pasture, only one species (*C. podagricus*) showed preference for carrion, as long as in the grassland no strictly necrophagous species were detected. As in forest patch, in PI and PII, most species (>60%) showed coprophagous habits. The number of species captured in coprotraps was higher than that in necrotraps. In addition, the number of individuals captured in excrement traps was three times higher than that captured in carrion traps; these differences were significant (Table 4).

Temporal variation

Species richness ranged between 6 and 24 from October 2006 to December 2007 and both the number of species and of individuals showed a seasonal pattern (Table 3). The largest number of beetles was caught in October and February 2007, and the greatest diversity and richness were verified in the samplings of December 2006 and October and December 2007. The lowest evenness in February and October 2007 was due to the high number of *D. nisus* and *T. externepunctatum*, respectively.

Abundance and richness varied between samplings carried out in the different months (Table 4). In addition, the interactions between different factors (environmental units, months, and traps) were significant.

Species replacement was high between April and June 2007, a period during which 92% of species were lost. Between June and October 2007, species entered the landscape, and no losses were recorded. October and December 2007 were the most similar, with a low value (0.38) of complementarity index.

Table 1 Species abundance and habitat preference of dung beetles in each environmental unit.

Taxa	Number of specimens				Habitat	Code
	B	PI	PII	Total	preference	
Aphodiinae						
Eupariini						
Ataenius platensis (Blanchard, 1846)	45	88	31	164	G	p
Ataenius picinus Harold, 1867	6	2	9	17	G	v
Aidophus flaveolus (Harold, 1867)	2	33	19	54	G	aa
Ataenius sp.	8	0	0	8		t
Cartwrightia cartwrighti Cartwright, 1967	24	0	0	24	B	r
Scarabaeinae						
Ateuchini						
Eutrichillum sp.	59	0	0	59	B	i
Trichillum externepunctatum Preudhomme, 1889	53	304	32	389	PI	l
Coprini						
Canthidium aff cupreum (Blanchard, 1843)	85	0	0	85	B	e
Dichotomius carbonarius Mannerheim, 1829	59	3	30	92	G	h
Dichotomius nisus (Olivier, 1789)	28	329	395	752	G	q
Dichotomius nobilis (Waterhouse, 1891)	4	4	4	12	G	y
Dichotomius sp. 2	0	1	1	2		ah
Ontherus sulcator (Fabricius, 1775)	162	14	13	189	B	c
Deltochilini						
Anisocanthon villosus Harold, 1868	67	0	12	79	B	g
Canthon quinquemaculatus Castelnau, 1840	46	0	56	102	B	o
Canthon septemmaculatus (Latreille, 1811)	8	0	0	8		u
Canthon aff mutabilis Lucas, 1857	4	30	26	60	G	x
Canthon bispinus (Germar, 1824)	56	16	15	87	G	j
Canthon lituratus (Germar, 1813)	51	0	0	51	B	m
Canthon podagricus Harold, 1868	126	51	99	276	G	d
Canthon sp. 1	1	0	0	1		ae
Canthon sp. 2	9	0	0	9		s
Canthon sp. 4	2	0	0	2		ab
Deltochilum elongatum Felsche, 1907	54	20	91	165	G	k
Malagoniella astyanax punctatostriata (Blanchard, 1843)	5	0	0	5		w
Pseudocanthon aff. perplexus (LeConte, 1847)	199	0	0	199	B	b
Phanaeini						
Coprophanaeus cyanescens Olsoufieff, 1924	2	2	0	4		ac
Coprophanaeus ensifer Germar, 1821	1	0	0	1		af
Coprophanaeus sp.	2	1		3		ad
Gromphas inermis Harold, 1869	1	82	13	96	PI	ag
Oniticellini						
Eurysternus caribaeus (Herbst, 1789)	48	0	0	48	B	n
Eurysternus aeneus Génier, 2009	77	0	0	77	B	f
Onthophagini						
Onthophagus hirculus Mannerheim,1829	201	24	8	233	B	a
Onthophagus sp.	3	0	0	3		z
Total	1498	1004	854	3356		

G generalists, *B* forest, *PI* cattle pasture, *PII* grassland.

Table 2 Species richness obtained with non-parametric estimators in different environmental units.

	Observed richness	Jack 1	Estimated richness %	ICE	Estimated richness %	Michaelis-Menten	Estimated richness %
Forest fragment	33	35.9	92.6	34.9	89.3	36.6	90.1
Cattle pasture	17	17.9	94.4	17.2	95.2	19.1	88.9
Grassland	17	19.9	85.2	18.9	89.9	20.2	84.2
Total	34	35.9	94.0	35.1	97.0	35.6	94.6

Six species were the most numerous in the three environments studied, of which *D. nisus*, *O. hirculus*, and *O. sulcator* were captured in all of the sampled months (Fig 3). *Canthon podagricus* presented two peaks of abundance: one in spring (October 2006, a month with low rainfall) and one at the end of summer (February 2007). About 64% of the specimens of *D. nisus* were collected in February 2007, 76% of *O. sulcator* in December 2006, and *O. hirculus* in December 2006 (36%) and December 2007 (31%). The greatest abundance of *P. aff. perplexus* (n=150) and *T. externepunctatum* (n=335) was found in October 2007.

The environmental variables that most influenced the abundance and richness were the temperature (F=8.41; p=0.002) and the rainfall (F=24.48; p=0.0002). The latter indicates in a greater proportion the observed variability.

Discussion

In the forest fragment where the study was performed, the richness reached 28 species if only Scarabaeinae was considered. These values are similar to those reported by numerous authors in the Neotropics (Halffter *et al* 1992, Barbosa-Silva *et al* 2007, Escobar *et al* 2007, Martínez *et al* 2009). In the PI and PII, species loss was significant; the species richness of Scarabeinae in the cattle pasture (S=14) was similar to that in livestock fields in Mexico (Halffter & Arellano 2002, Navarrete & Halffter 2008) and Rio Grande do Sul, Brazil (Silva *et al* 2009).

The sampling effort was satisfactory according to the non-parametric estimators, the richness observed was similar to that estimated, and a large proportion of species (>90%) was captured, although this proportion was lower in the grassland.

During the sampling period, cattle had no access to the grassland. The number of species in this habitat and that in the cattle pasture were the same but were lower than that in the forest fragment (B). In the forest fragment studied, twice the number of species persisted than in the most disturbed environments (PI and PII). Although the food supply (cow feces) was high in the adjacent cattle pasture, the species richness difference between environments should be considered independent of the existence of abundant food resource in PI. As the landscape studied is a plain without relief changes, it was the vegetation cover that determined this difference in the assemblage.

A greater richness of beetles has often been reported in places with larger forest cover (Halffter *et al* 1992, Escobar *et al* 2007, Andresen 2008). By comparing undisturbed forests versus forests with some level of disturbance, the communities of beetles were shown to be very similar as long as they maintain complex vegetation structure (Arellano *et al*

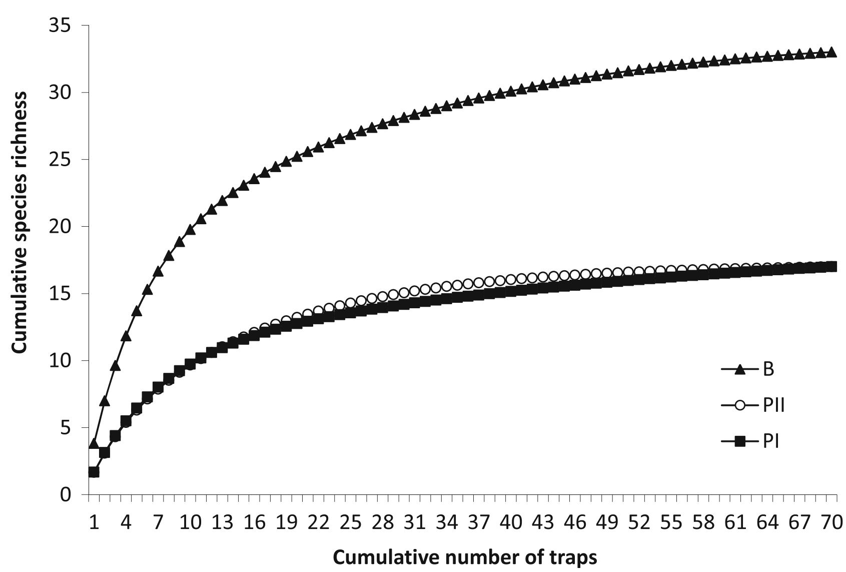

Fig 1 Species accumulation *curves* for each environmental unit; sampling effort represented by number of traps (*B* forest, *PI* cattle pasture, *PII* grassland).

Table 3 Spatial and temporal variation of the dung beetles assemblage attributes in the environmental units and sampled months.

	Species richness (*S*)	Abundance (*N*)	Shannon Index (*H*′)	Equitability Index (*J*′)	Dominance Index (*d*)
Units					
Forest	33	1498	2.86	0.82	0.13
Cattle pasture	17	1004	1.88	0.66	0.33
Grassland	17	854	1.96	0.69	0.46
Sampled month					
October-06	16	334	1.77	0.64	0.40
December-06	24	475	2.27	0.71	0.30
February-07	22	950	1.93	0.63	0.50
April-07	16	65	2.44	0.88	0.18
June-07	6	41	1.49	0.83	0.39
October-07	24	912	2.00	0.63	0.37
December-07	23	579	2.62	0.83	0.18

2005, Scheffler 2005). Presumably, the higher diversity of Scarabaeidae in tropical forests results from the greater richness of ecological niches in these ecosystems (Halffter 1991).

Dominance-diversity curves evidenced differences in abundance in which each species contributed to the assemblage structure and a more even distribution in the forest fragment. The curves of the more disturbed environments, which in this study corresponded to those of the cattle pasture and grassland, matched the sites where the native vegetation had been replaced by grassland. Moreover, the forest fragment presented a curve similar to that found in sites with better preserved vegetation (Trevilla-Rebollar *et al* 2010).

Although Andresen (2008) argued that the dominance pattern is not by itself indicative of habitat disturbance, in an early study, Nichols *et al* (2007) reported high values of dominance associated with an increase in anthropic disturbance. In the searched area, this attribute was higher in the two environmental units more intensively used by ranching activities.

The highest proportion of coprophagous species in this research was closely related to the available food supply (cow feces), which was much higher than the decaying organic matter. The larger number of coprophagous species in relation to the necrophagous ones has also been previously demonstrated in areas that were transformed into areas for cattle ranching (Halffter *et al* 1992, Silva *et al* 2012).

The lowest richness and diversity were recorded during low rainfall months (October 2006 and June 2007). Only *C. podagricus* showed a high population size in October 2006. The highest activity, expressed as the largest number of species and individuals, was restricted to months with favorable environmental conditions, i.e., the warmer and rainier seasons of spring and summer. This positive correlation between precipitation and the attributes of dung beetle assemblage has been already reported before (Barbosa Silva *et al* 2007, Silva *et al* 2009, Trevilla-Rebollar *et al* 2010). In Uruguay prairies, Morelli *et al* (2002) proved the abundance, density, and richness of beetles to be directly correlated with temperature.

The seasonality of necrophagous and coprophagous beetles has also been observed in humid tropical forests of Mexico (Halffter *et al* 1992, Halffter & Arellano 2002). Arellano *et al* (2005) also reported higher values of biomass in months following heavy rains but found no correlation between these variables.

The low level of species exchange between December 2006 and February, October and December 2007 indicates

Table 4 Permanova analysis of richness and abundance of dung beetles between environmental units, months, and bait type.

	F	*P* (perm)
Abundance		
Units	4.19	0.002
Months	2.01	0.002
Bait types	5.07	0.002
Units × months	1.84	0.002
Units × baits	4.67	0.002
Months × baits	4.55	0.001
Units × months × baits	2.38	0.001
Richness		
Units	5.43	0.002
Months	2.44	0.006
Bait types	3.71	0.044
Units × months	1.67	0.027
Units × baits	4.52	0.011
Months × baits	4.95	0.001
Units × months × baits	2.72	0.001

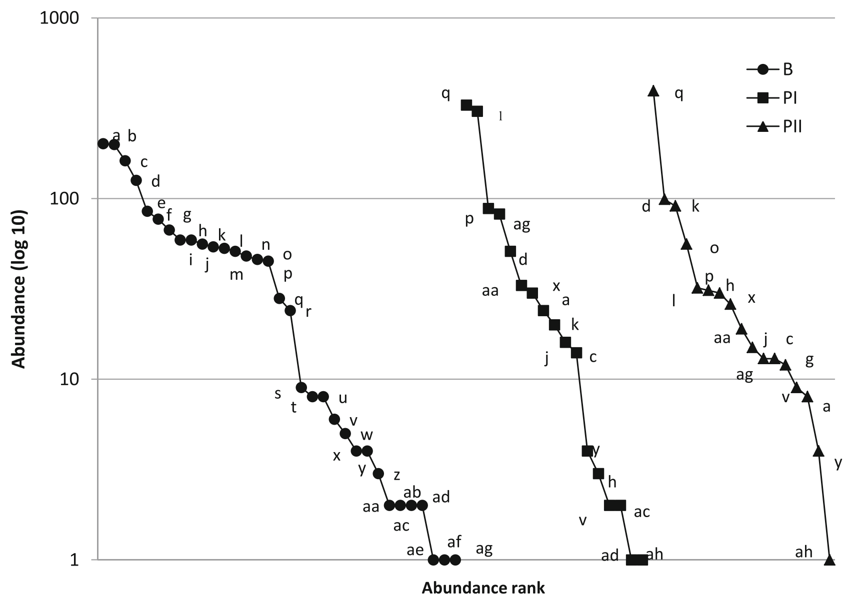

Fig 2 *Curves* of Whittaker of rank-abundance (dominance-diversity) for three habitats. Each *point* in the *curve* represents a beetle species identified by an *alphabetic code* (see Table 1 for full species name).

that these months share numerous species. Meanwhile, the values of the complementarity index between June (winter in the southern hemisphere), a month of low rainfall, and October (spring), when greater rainfalls begins, explain the high rate of temporary replacement of species.

Livestock activity not only requires the deforestation of forested areas but also leads to the accumulation of dung, which causes a significant loss of the grazing area (Bornemissza 1960). On the other hand, a rich fimicola fauna, noted for their veterinary interest, develops in the cattle feces (Koller *et al* 2007). Among them are Muscidae larvae, particularly the horn flies *Haematobia irritans* (L.) and infective stages of gastrointestinal parasitic nematodes, which find dung pads as a favorable environment to complete their life cycle.

Because of their eating and nesting habits, dung beetles disintegrate feces and incorporate organic matter and nutrients into the soil. In this way, they also contribute to the destruction of muscids and helminths eggs that affect cattle productivity, acting as biological controllers (Koller *et al* 2007). The composition of an assemblage of beetles is for that reason of particular interest, taking into account aspects such as the direct relationship between the size of a beetle and its potential in the excrement degradation process. Flechtmann *et al* (1995) also mentioned food preference as a feature for which a coprophagous species is positioned as

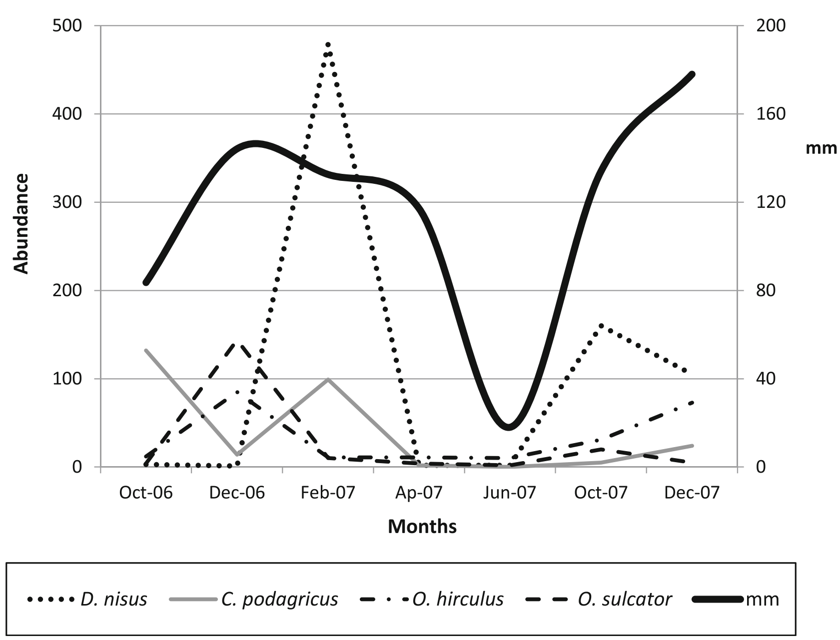

Fig 3 Patterns of abundance of the most numerous dung beetle species during the sampling period for the entire landscape.

more appropriate in biological control programs than necrophagous or generalist ones. According to this criterion, *Dichotomius* and *Ontherus*, among others, are considered by these authors as more efficient in removing livestock feces.

In this study, two species of the above-mentioned genera, *D. nisus* and *O. sulcator*, stood out for their abundance, as well as *O. hirculus*, *P. aff. perplexus*, and *T. externepunctatum*; all had coprophagous habits.

Dichotomius nisus and *T. externepunctatum* were more numerous in the more severely disturbed environments, exposed to desiccation and higher solar radiation. These heliophilous species, which are classified as tolerant and adapted to disturbances, colonize areas that lack dense tree vegetation (Scheffler 2005).

Although *E. caribaeus* was not one of the most abundant species, according to its indicator value (IndVal), it is qualified as a forest species indicator, as well as *O. sulcator*. The species of the genus *Eurysternus* showed no ability to colonize open areas. Scheffler (2005) identified *E. caribaeus* as a species sensitive to moderate disturbances and vulnerable to the destruction of the forest environment. Given these characteristics, *E. caribaeus* could be used in conservation programs to monitor environmental conditions.

Cabrera Walsh & Cordo (1997) reported the efficiency of *O. sulcator*, *G. lacordarei*, *A. picinus*, and *A. platensis* as agents of biological control in Argentina. All of these species were collected in the research units. Mariategui *et al* (2001) verify the effect of the activity of *O. sulcator* in dung removal and the subsequent incorporation of organic matter into the soil, hence the importance of this species in farms where livestock pasturing is practiced. Based on this result, they proposed the use of this species in integral parasite control programs. Although *O. sulcator* was captured in the three research environments, more specimens were detected in the forest (n=162), suggesting that even though it characterizes cattle landscapes of central Argentina (Cabrera Walsh & Gandolfo 1996), in this region it is more vulnerable to climatic conditions and depends on the forest fragment to consolidate its cycle. By analyzing this species in particular, it could be considered that its habitat preference varies not only with altitude (Halffter *et al* 1995, Escobar *et al* 2007) but also with latitude and is related in both cases to climatic requirements.

Based on abundance, richness, and diversity values and rank-abundance curves, beetle assemblage was more diverse in the forest fragment. The remnant patch of native forest where this study was conducted was found to be an adequate beetle fauna refuge.

The reduction in abundance and diversity along with fewer species presence during the coldest and drier sampled months and in those habitats with lack of arboreal stratum provides enough evidence that the rainfall regime, the temperature, and the heterogeneous use of the sampled environmental units influenced the structure of the assemblage of dung beetles in Los Alisos farm.

This study revealed not just a spatial but also a temporal pattern in the structure of the assemblage. The results highlight the importance acquired by forest fragments. It is necessary not only to preserve these kinds of units but also to promote connectivity between patches, forming corridors that contribute to the preservation of the diversity of different communities in order to achieve a balance between production and conservation. Our data also provide further evidence to the approach formulated by Cingolani *et al* (2008) on the compatibility of extensive livestock ranching and conservation of biodiversity.

Two species were of particular interest in this research: *E. caribaeus* because of its indicator value and sensitivity to disturbances and *O. sulcator* because of its abundance and valuable reported biological traits, such as its efficiency in the breaking down of fecal matter and its potential as a biocontrol agent.

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