

Attractivity of omnivore, carnivore and herbivore mammalian dung to Scarabaeinae (Coleoptera, Scarabaeidae) in a tropical Atlantic rainforest remnant

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ABSTRACT. Attractivity of omnivore, carnivore and herbivore mammalian dung to Scarabaeinae (Coleoptera, Scarabaeidae) in a tropical Atlantic rainforest remnant. In this study, performed in a remnant of Brazilian Atlantic Forest, three types of dung from animals with distinct alimentary habits were utilized, in order to verify possible differences of attractivity of these dungs to the Scarabaeinae and the influence of seasonality in the attractivity. Three habitats were sampled: edge, clearing and forest core, each with 40 pitfall traps. A total of 2,137 beetles were collected from August 2005 to July 2006. *Canthidium* sp. 1 (43%) and *Dichotomius sericeus* (41%) were the most abundant species. From the total number of beetles collected, 80.5% were attracted to human dung, 11% to jaguar dung, 7.8% to waterbuck dung and 0.7% to the control. The species *Canthidium* sp.1, *Canthidium* sp. 2, *Ateuchus* sp., *Canthon nigripennis*, *Canthonella* sp. and *D. sericeus* came to all three bait types. Eight species were found in the baits with human dung, where *Canthidium* sp.1 (49%) and *D. sericeus* (39%) were the most common. A significant difference in attractiveness of the different baits was observed; the highest abundance found in traps baited with human dung ($F = 36.59$; g.l. = 3; $p < 0.0001$). A significant difference in richness was observed between rainy and dry seasons ($F = 12.29$; g.l. = 1; $p < 0.001$), the highest richness found in the dry season.

KEYWORDS. Atlantic forest; bait; dung beetles; seasonality.

RESUMO. Atratividade de Scarabaeinae (Coleoptera: Scarabaeidae) por fezes de mamíferos onívoros, carnívoros e herbívoros em um remanescente de Floresta Tropical Atlântica. Nesse estudo, realizado em um remanescente de Floresta Atlântica Brasileira, três tipos de fezes de animais com distintos hábitos alimentares foram utilizados para verificar possíveis diferenças de atratividade dessas fezes por Scarabaeinae e a influência da sazonalidade nessa atratividade. Três habitats foram amostrados: borda, clareira e núcleo da floresta, cada um com 40 armadilhas de queda ("pitfall"). Um total de 2137 besouros foi coletado de agosto de 2005 a julho de 2006. *Canthidium* sp. 1 (43%) e *Dichotomius sericeus* (41%) foram as espécies mais abundantes. Do número total de besouros coletados, 80,5% foram atraídos para fezes humanas, 11% para fezes de jaguar, 7,8% para fezes de cobo e 0,7% para o controle. As espécies *Canthidium* sp.1, *Canthidium* sp. 2, *Ateuchus* sp., *Canthon nigripennis*, *Canthonella* sp. e *D. sericeus* foram aos três tipos de isca. Oito espécies foram encontradas nas iscas com fezes humanas, onde *Canthidium* sp.1 (49%) e *D. sericeus* (39%) foram as mais abundantes. Diferença significativa de atratividade por diferentes iscas foi observada; a maior abundância foi evidenciada em armadilhas iscadas com fezes humanas ($F = 36.59$; g.l. = 3; $p < 0.0001$). Diferença significativa foi observada na riqueza entre as estações chuvosa e seca ($F = 12.29$; g.l. = 1; $p < 0.001$) sendo a maior riqueza verificada na estação seca.

PALAVRAS-CHAVE. Besouros coprófagos; Floresta Atlântica; isca; sazonalidade.

The beetles of the subfamily Scarabaeinae (Coleoptera, Scarabaeidae) are well represented insects in tropical regions, and recently have been used in monitoring biodiversity studies (Halffter & Favila 1993; Davis *et al.* 2001; Rensburg & Botes 2002). The communities of these beetles are very sensitive to habitat alteration and have distinct organization patterns when studied in tropical forest fragments or in areas which have been deteriorated by human action (Howden & Nealis 1975; Janzen 1983; Klein 1989; Halffter *et al.* 1992; Didham *et al.* 1998; Lobo & Martín-Piera 1999; Gardner *et al.* 2008).

Besides function as an information source for inventories, monitoring and about landscape alterations, the Scarabaeinae

have important ecological roles. These roles include efficient and rapid nutrient cycling, with organic matter processing, and the improvement of its availability to the environment (Halffter & Matthews 1966; Bornemissa & Williams 1970; Nealis 1977); secondary seed dispersal of many Neotropical tree species, playing an important role on the natural process of forest regeneration (Estrada & Coates-Estrada 1991), as well as controlling eggs and larvae of parasites which are present on fresh mammal excrement (Bergstrom *et al.* 1976; Flechtmann *et al.* 1995).

Dung, mainly mammalian dung, is one of the resources used by the Scarabaeinae as a food for larvae and adults and

as a substrate for oviposition. Fungi, decomposing vegetables, and carcasses are also used by some species as food resource (Halfpter & Matthews 1966). Such feeding diversification is believed to have occurred in Neotropical Forest due to the extinction of large mammals during the Pleistocene (Halfpter 1991), leading the beetles to use different sources of food other than dung.

The presence of excrement associated with other factor such as climate, mainly temperature and precipitation, in addition to altitude, may affect the spatial and temporal distribution of Scarabaeinae (Fincher 1973; Halfpter & Edmonds 1982; Escobar *et al.* 2006). Dung beetle communities are known to respond to changes in rainfall (Hanski & Cambefort 1991). In general, at the tropical region, their communities show higher abundance and richness during the rainy season (Cambefort 1991; Andresen 2005). Thus, the present study compares the attraction of three different types of excrement: jaguar (carnivorous), waterbuck (herbivorous) and human dung (omnivorous) to Scarabaeinae verifying if there are oscillations on the attractiveness of the dung to Scarabaeinae, associated with seasonality in Atlantic Forest remnant in the northeast of Brazil.

MATERIAL AND METHODS

Study area

The study was conducted at the Parque Estadual de Dois Irmãos, a Brazilian remnant of Atlantic rain forest in the state of Pernambuco, Recife municipality (7°55'–8°09'S, 34°52'–35°00'W). This reserve is a forest fragment with 387.4 ha, isolated in a predominantly urban landscape (Tabarelli 1998).

According with Köppen's climate classification, Recife's climate is As', warm and humid coastal tropical, with an annual average temperature of 23°C. The rain regimen occurs during autumn-winter (March–August), with higher average precipitation during June and July. The annual pluviometric average is 2,460 mm, having a hydric deficiency period from October to January, thus characterizing the dry season (Coutinho *et al.* 1998).

Insect Collection

Sampling was performed monthly from August 2005 to July 2006, using pitfall traps, arranged in three distinct areas of the forest: edge (until 100m of the edge), interior (from 200 m of the edge) and clearings. Transects of 150 m were established in the edge and interior of the forest, however, due to the spatial distribution of the clearings it wasn't possible to establish transects in them. Each area had 10 sets of traps spaced 15 m apart (except in the clearings, where the distance varied), each set comprised four traps set 2 m apart from each other, disposed in a square shape. The trap consisted of a plastic recipient with a 9.5 cm diameter. In each set of traps three types of bait coming from mammals with different eating habits were distributed: omnivorous habit (human excrement); carnivorous habit {jaguar excrement, *Panthera onca* (Linnaeus, 1758)} and herbivorous habit (waterbuck excrement, *Kobus*

ellipsiprymnus Ogilby, 1833). The last two types of excrement were collected in the zoo of Parque Estadual de Dois Irmãos. One of the four traps in each set was not baited serving as a control for the study. Traps were buried on the ground and were protected from rain by a suspended polystyrene disc. The traps stayed in the field for 48h before being collected. The material is deposited at the "Coleção Entomológica da Universidade Federal de Pernambuco".

Data analysis

The attractiveness of each type of bait to Scarabaeinae was verified through the Levins's standardized index (B_A), measuring the niche width of species with $N > 50$. The calculation of Levins index was done with the software Ecological Methodology (Kenny & Krebs 2000). The species which had Levins's (B_A) values equal or lower than 0.5 were considered as specialists and the species with values upper than 0.5 were considered as generalists (Krebs 1999).

Multivariate analyses were performed aiming to discriminate possible spatial-temporal differences in the Scarabaeinae communities in terms of consistent abundance changes. For that purpose the types of bait were compared, using non-metric multidimensional scaling (NMDS) from Primer program (Clarke and Gorley 2001). This analysis was implemented over a similarity matrix (Bray–Curtis Similarity) constructed over an abundance data by species matrix, for each type of bait used throughout the period of study. The bi dimensional configuration of the similarities trustworthiness was evaluated by the measure of STRESS, which varies on an increasing scale from 0 to 1. The relationship of bait type to the similarity between traps during 12 months was analyzed using ANOSIM tests (Clarke and Gorley 2001).

Pearson (r^2) coefficient of correlation was used to verify the relation of Scarabaeinae abundance and richness with pluviometry and temperature. Richness data were transformed by adding their square roots to 0.5 of their initial value.

To evaluate the distinction of Scarabaeinae mean abundances and richness by trap during the dry season and the rainy season, an ANOVA Two Way test was performed using the software Statistica 6.0 (Statsoft, Inc. 2004). In order to homogenize the variances and normalize the residues, both the abundance and richness were transformed by adding their square roots to 0.5 of their initial value.

Meteorological data

Data referring to temperature and precipitation from August 2005 to July 2006 were provided by INMET (National Meteorology Institute). The base for data collection of INMET covers a radius of 10 km from the metropolitan area of Recife. The Parque Estadual de Dois Irmãos is inserted in that radius specified.

RESULTS

Richness and abundance of species

A total of 2,137 beetles from 11 species were collected



Fig. 1. NMDS showing the grouping of Scarabaeinae according to each type of bait (omnivorous, herbivorous and carnivorous) from August 2005 to July 2006, using Bray-Curtis similarity.

during the study. Two species were particularly abundant: *Canthidium* sp.1 (43% of the total) and *Dichotomius sericeus* (Harold, 1867) (41%). ANOSIM analysis revealed significant distinctions between bait type and the abundance of Scarabaeinae by trap during 12 months ($R = 0.545$, $P = 0.001$).

Bait attractiveness

From the total of the collected beetles, 80.5% were attracted to human dung, 11% were attracted to jaguar dung, 7.8% were attracted to waterbuck dung and 0.7% was found in the control traps. In traps baited with human dung individuals from eight species were collected, with *Canthidium* sp. 1 (49%) and *D. sericeus* (39%) being the most common species. In traps baited with jaguar dung, nine species were found, *D. sericeus* (69.5%) and *Canthon nigripennis* Lansberge, 1874 (12.5%) were the most representative. In traps baited with waterbuck dung seven species were notified, with *Ateuchus* sp. (45.5%), *Canthidium* sp.1 (23%) and *D. sericeus* (22%) were the dominant species. The species *Canthidium* sp.1, *Canthidium* sp.2, *Ateuchus* sp., *Canthon nigripennis*, *Canthonella* sp. and *D. sericeus* were attracted to the three types of baits (Table I). *Canthidium* sp.1 ($B_A = 0.06$), *Canthidium* sp.2 ($B_A = 0.11$) and *D. sericeus* ($B_A = 0.30$) were considered specialists for human dung. Whereas, *Ateuchus* sp. ($B_A = 0.70$) was a generalist species, with no preference for a determined type of bait. The two-dimensional configuration formed by the NMDS, with a STRESS of 0.11, showed distinct clusters for each type of bait during the period studied (Fig. 1).

Seasonal influence on the attractiveness of baits

The Scarabaeinae appeared in every month of the collection, with the period among August (14% of total individuals), September (12% of total individuals), October (17% of total individuals), November (14% of total individuals), and December (13% of total individuals) having the highest proportions of individuals in respect to the total of individuals collected. In these months, Scarabaeinae were better

represented when human dung was used as bait. The beetles captured using waterbuck excrement as bait occurred more frequently during September (1.5%) and August (1.0%), while the species collected using jaguar excrement as bait had higher abundance in January (2.5%) and June (1.5%) (Fig. 2). January had the lowest precipitation (12.3 mm). Possibly, all these results were due to dominant species.

The highest peaks of precipitation and temperature, during the period of the study, were, respectively, 432 mm (June) and 27.7°C (February) (Fig. 3). Temperature ($r^2 = 0.1$, $P = 0.32$) as much as precipitation ($r^2 = 0.08$, $P = 0.40$) were not effectively correlated with the abundance of the Scarabaeinae.

When the abundance of Scarabaeinae within the different treatments (baits and control) was tested between the two seasons, there was no interaction of the factors among the parameters ($F = 2.52$; d.f. = 3; 472; $p = 0.06$). There was significant difference between the seasons ($F = 6.40$; d.f. = 1; 472; $p = 0.01$). It is important to highlight that only the Scarabaeinae attracted to human dung differed in abundance between seasons (Fig. 4a). A significant difference of attractiveness to different baits was observed too with the higher abundance found in traps baited with human dung ($F = 180.81$; d.f. = 3; 472; $p < 0.0001$). This result was influenced by the abundance of the Scarabaeinae attracted to human dung (Fig. 4a).

Temperature ($r^2 = 0.03$, $P = 0.60$) as much as precipitation ($r^2 = 0.08$, $P = 0.36$) were not correlated with Scarabaeinae richness. When the richness of Scarabaeinae within treatments (baits and control) was tested between the two seasons, there was interaction of the factors among the parameters ($F = 2.63$; d.f. = 3; $p = 0.05$). A significant difference was observed between rainy and dry seasons ($F = 4.26$; d.f. = 1; $p = 0.04$), with the higher richness found in the dry season. This result was, nevertheless, influenced by the richness of the Scarabaeinae attracted to human dung (Fig. 4b). There was also a significant difference among baits ($F = 147.09$; d.f. = 3; p

Table I. Total number of Scarabaeinae attracted to excrements of omnivorous (human), carnivorous (jaguar) and herbivorous (waterbuck) mammals plus the control traps, from August 2005 to July 2006, in Parque Estadual de Dois Irmãos, Pernambuco, Brazil.

Species	Omnivorous	Carnivorous	Herbivorous	Control	Total
<i>Ateuchus</i> sp.	72	17	76	3	168
<i>Canthidium</i> sp.1	856	15	38	4	913
<i>Canthidium</i> sp. 2	99	1	10	2	112
<i>Canthidium</i> sp. 3	0	1	0	0	1
<i>Canthon nigripennis</i>	12	30	3	0	45
<i>Canthonella</i> sp.	5	5	2	0	12
<i>Coprophanaeus jasius</i>	0	0	1	0	1
<i>Deltotilum morbillosum</i>	0	2	0	0	2
<i>Dichotomius bicuspis</i>	1	2	0	0	3
<i>Dichotomius sericeus</i>	671	166	37	5	879
<i>Onthophagus</i> sp.	1	0	0	0	1
Total number of individuals	1717	239	167	14	2137
Total number of species	8	9	7	4	11

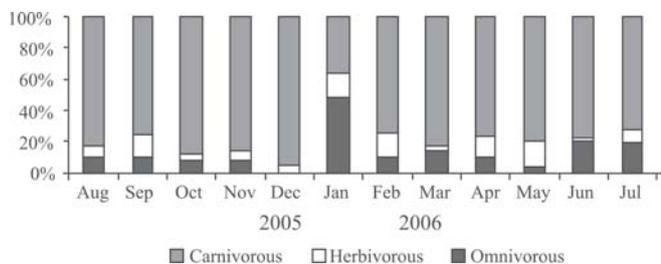


Fig. 2. Proportion of individuals of Scarabaeinae distributed monthly from August 2005 to July 2006 for each type of bait that was used: human (omnivorous), jaguar (carnivorous) and waterbuck (herbivorous) excrement.

< 0.0001). The species *Canthonella* sp., *Onthophagus* sp., *Deltochilum morbillosum* Burmeister, 1848, *Coprophanæus jasius* (Olivier, 1789) and *Canthidium* sp. 3 were found only during this dry season. The *Dichotomius bicuspis* (Germar, 1824) species had only three specimens recorded and were restricted to the rainy season (Table II).

The dry season had higher Scarabaeinae richness with the species *Canthonella* sp., *Onthophagus* sp., *Deltochilum morbillosum*, *Coprophanæus jasius* and *Canthidium* sp. 3 found only during this season. The *D. bicuspis* species had only three specimens reported and were restricted to the rainy season.

DISCUSSION

In this study there was a distinction of attractiveness of different types of dung to Scarabaeinae, which was higher in human dung, and that there was a seasonal component to the number of beetles captured.

The proportion of individuals collected at each type of bait differed in its distribution pattern during the months sampled, corroborating with the results obtained by Estrada *et al.* (1993), which showed discrepancies in Scarabaeinae distribution during dry and rainy seasons. Nevertheless, the higher abundance reported during the dry season, does not support Halffter & Matthews (1966), Janzen (1983) and Stumpf's (1986) proposals, according to which, in tropical humid forests abundance rise after the beginning of the rainy season. From August to December, the low-precipitation period, omnivorous dung bait (human dung) and herbivorous dung bait (waterbuck dung) presented a pattern with the highest percentage values in terms of individuals. The carnivore dung bait (jaguar dung) did not correspond to this pattern, as it had higher percentages in number of individuals on the months of January and July. Such differences, in terms of seasonal distribution pattern are in accord with Halffter & Edmonds' (1982) proposal, which affirms, generally, that temperature and precipitation are the climatic factors that most affect spatial and temporal distribution of Scarabaeinae.

Many small and medium-sized forest fragments (<500 ha) are not capable of sustaining large herbivorous vertebrate populations, top predators, and frugivorous primates and

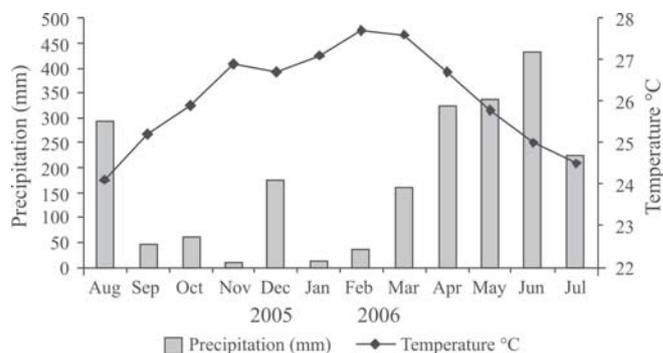


Fig. 3. Mean monthly rainfall and temperatures from August 2005 to July 2006 in Parque Estadual de Dois Irmãos, Pernambuco, Brazil.

birds (Lovejoy *et al.* 1984, 1986; Arango-Vélez & Kattan 1997). Possibly, the limited amount of food in terms of excrement, in Parque Estadual de Dois Irmãos, may explain the predominance of just a few species, in this case *Canthidium* sp. 1 and *D. sericeus*, over the others species. Together these two species represented 84% of the total number of the beetles collected. When little food is available, intense competition results in strict specialization on a particular resource (Cambefort & Hanski 1991; Hanski 1989, 1991). So, the most abundant species were not sensitive to a specialization of the diet, because the majority of the beetles in the genus *Canthidium* Erichson (1847) and *Dichotomius* Hope, 1838 are often associated with habitat modification, where there are abundant resources for these species (Andresen 2005; Silva *et al.* 2007).

Concerning the feeding habits, three species were considered specialists and one species, generalist (through the Levins's standardized index – BA). This result differs from the findings of Silva *et al.* (2007), in a fragment of a Tropical altitudinal Rainforest, in the Pernambuco, Brazil ("Brejos de Altitude"), in which the majority of species was generalist. It also goes against the hypothesis of Halffter & Matthews (1966), which assumes that diet generalization is a characteristic of all Neotropical Scarabaeinae communities. Probably this was the

Table II. Total number of Scarabaeinae attracted to excrements of omnivorous, carnivorous and herbivorous mammals plus the control traps, through rainy and dry season, in Parque Estadual de Dois Irmãos, Pernambuco, Brazil.

Species	Rainy season	Dry season
<i>Ateuchus</i> sp.	51	117
<i>Canthidium</i> sp. 1	298	615
<i>Canthidium</i> sp. 2	31	81
<i>Canthidium</i> sp. 3	0	1
<i>Canthon nigripennis</i>	9	36
<i>Canthonella</i> sp.	0	12
<i>Coprophanæus jasius</i>	0	1
<i>Deltochilum morbillosum</i>	0	2
<i>Dichotomius bicuspis</i>	3	0
<i>Dichotomius sericeus</i>	315	564
<i>Onthophagus</i> sp.	0	1
Total	707	1430

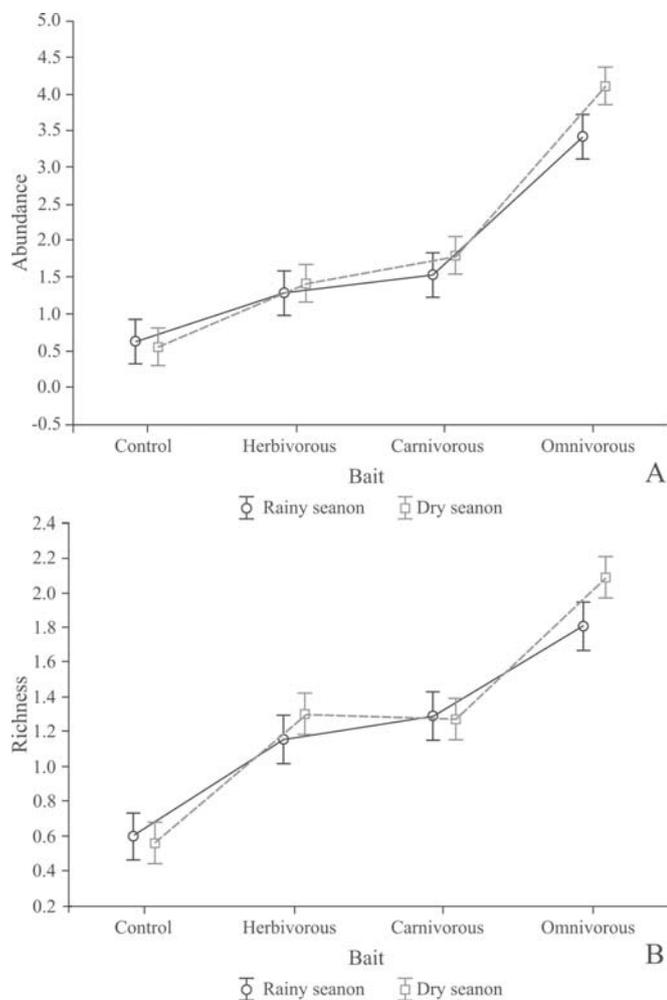


Fig. 4. ANOVA Two-Way analysis characterizing the difference between Scarabaeinae abundances and richness throughout the dry season and the rainy season, for each type of bait that was used: human (omnivorous), jaguar (carnivorous) and waterbuck (herbivorous) excrement in Parque Estadual de Dois Irmãos, Pernambuco, Brazil. (Mean \pm SD).

cause for such results. Besides, not all species sampled by Silva *et al.* (2007) were found in the Parque Estadual de Dois Irmãos. Only *Canthidium* species were considered by both as specialists.

The species *Canthidium* sp.3 and *Deltochilum morbillosum* were only found at the carnivorous dung bait, while *Coprophanæus jasius* occurred in the herbivorous dung bait and *Onthophagus* sp. in the omnivorous dung bait. These species had lower representation in terms of abundance. In this case, the stenophagy hypothesis is discarded. The fact that such species present a lower abundance can be associated with their higher vulnerability due to diet specialization (Halffter & Matthews 1966). One species from the genus *Coprophanæus* d'Olsoufieff, 1924 was reported at the herbivorous dung bait, a genus predominantly necrophagous (Endres *et al.* 2005). The absence or presence of an abundant excrement resource is one of the factors that may determine Scarabaeinae occurrence and distribution in certain biomes.

Considering Scarabaeinae as a whole, the main food resource used by the majority of the species, larvae and adults, is large mammals' excrement. In Parque Estadual de Dois Irmãos, the largest number of beetles (85%) was captured by traps containing human excrement, showing the fact that this type of bait is especially attractive in forests. However, even in pasture, human dung is rapidly attacked by a variety of Scarabaeinae species (Halffter & Matthews 1966).

The results obtained in Parque Estadual de Dois Irmãos are in accordance with Fincher *et al.* (1970), who verified attractiveness of various types of excrement to Scarabaeinae, in the state of Georgia, USA, where the dung of omnivorous animals had the largest number of coprophagous beetles captured. This same premise was attested by Estrada *et al.* (1993) who compared attractiveness of the dung of herbivorous animal [*Alouatta palliata* (Gray, 1849)] excrement and omnivorous animal [*Nasua narica* (Linnaeus, 1766)] excrement to Scarabaeinae in a tropical forest of Mexico, and found that the excrement from the omnivorous animal had a higher abundance of beetles than other types. As the lowest values of abundance were found in the control traps, that is, with no bait, we conclude that there is attractiveness of excrement from animals with distinct feeding habits to Scarabaeinae, with the excrements of omnivorous animals the ones which are most attractive.

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