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Dung beetle assemblages (Coleoptera, Scarabaeinae) in Atlantic forest fragments in southern Brazil

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ABSTRACT. Dung beetle assemblages (Coleoptera, Scarabaeinae) in Atlantic forest fragments in southern Brazil. The beetles of the subfamily Scarabaeinae are important organisms that participate in the cycle of decomposition, especially in tropical ecosystems. Most species feed on feces (dung) or carcasses (carrion) and are associated with animals that produce their food resources. Dung beetles are divided into three functional groups: rollers, tunnelers and dwellers. This present work aims to study the diversity of dung beetle communities inhabiting fragments of the Atlantic Forest, with the purpose of describing the ecology of the species in southern Brazil. This study was conducted in the region of Campos Novos, in Santa Catarina, where twenty sites of Atlantic forest fragments were sampled. Samplings of dung beetles were conducted using 200 pitfall traps, of which 100 were baited with human feces and another 100 with carrion. Size and environmental complexity were also measured for each forest fragment. A total of 1,502 dung beetles, belonging to six tribes, 12 genera and 33 species, were collected. Results of the Levin's index of niche breadth indicated that 11 species were categorized as being coprophagous, ten as generalists, and two as necrophagous. Most species are tunnelers (19), nine of rollers and four of dwellers. The great diversity of Scarabaeinae in the region of Campos Novos, including several rare species, adds important data to the Scarabaeinae fauna in the central-western region of Santa Catarina. It may also help choosing priority areas for conservation in the region, where human impact, with large areas of monoculture, increasingly threatens the fragments of Mixed Ombrophilous Forest.

KEYWORDS. Cycle of decomposition; diversity; ecology; feeding guild; Insecta.

The subfamily Scarabaeinae (Coleoptera, Scarabaeidae) comprises about 6,000 species (ScarabNet 2011) of beetles extremely important in the functioning of tropical ecosystems, as they actively participate in the cycling of nutrients using decaying organic matter as food for both larvae and adults (Halffter & Matthews 1966; Halffter & Edmonds 1982; Hanski & Cambefort 1991 and Simmons & Ridsdill-Smith 2011). Most species feed on feces (coprophagous) or carcasses (scavengers) and are thus intrinsically linked to animals that produce their food resources (Halffter & Matthews 1966; Halffter & Edmonds 1982; Gill 1991; Hanski 1991; Estrada *et al.* 1993; Morelli & González-Vainer 1997; Estrada *et al.* 1999; Nichols *et al.* 2009; Filgueiras *et al.* 2009). The main food resources used by Scarabaeinae beetles are droppings of large mammals (Halffter & Matthews 1966; Halffter & Edmonds 1982; Hanski & Cambefort 1991; Davis *et al.* 2002; Simmons & Ridsdill-Smith 2011). In Neotropical forests the presence of large mammals is reduced and necrophagy is more relevant when compared to open areas where there is almost complete absence of necrophagous species (Halffter & Matthews 1966).

Dung beetles are detritivores and promote the removal of soil and incorporation of organic matter in nutrient cycling, helping to clean the environment and to regulate the physical and chemical properties of soil (Halffter & Edmonds 1982; Hanski & Cambefort 1991; Slade *et.al* 2007; Nichols *et al.* 2008; Simmons & Ridsdill-Smith 2011). Furthermore, the building of tunnels by some of these beetles allows aeration and hydration of the soil, as well as the incorporation of nutrients present in feces, animal carcasses and fruits that are buried in these spaces (Halffter & Matthews 1966; Halffter & Edmonds 1982; Hanski & Cambefort 1991; Slade *et.al* 2007; Nichols *et al.* 2008).

The nesting behavior is closely related to the use of food resources. According to how the resource is used in breeding, dung beetles are divided into three functional groups: the rollers or telecoprids (those that roll balls of food on the surface of soil to some distance from the source of resource, where they bury them); tunnelers or paracoprids (those that carry food resource into the soil, making tunnels on the side or below the resource), and dwellers or endocoprids (which do not reallocate food, using it directly in the source) (Halffter & Mathews 1966; Halffter & Edmonds 1982; Hanski & Cambefort 1991). Tunnelers and rollers may further be divided into several nesting standard types, according to the complexity of their behavior (Doube 1991; Halffter & Matthews 1966; Hanski & Cambefort 1991).

Some species of Scarabaeinae beetles have highly specific habitat preferences (Halffter 1991), many of them being unable to occupy areas with open vegetation (Klein 1989; Spector & Ayzama 2003; Almeida & Louzada 2009). Such species are strongly influenced by habitat loss and fragmentation, which may restrict their distribution or even cause their local extinction (Davis & Philips 2005; Hernández & Vaz-de-Mello 2009).

The structure of the environment is important in determining dung beetle community composition (Estrada *et al.* 1998; Halffter & Arellano 2002). Davis *et al.* (2001), when working with dung beetles in Borneo, observed that the distribution of species across different environmental characteristics may show discrete associations typical to particular biotypes within the landscape. In the Amazon Forest, Gardner *et al.* (2008) showed that the richness, abundance, and total biomass of dung beetles are strongly affected in environments of secondary forests and in eucalyptus plantations. In addition, changes in habitat complexity modify not only the communities of insects, but the whole fauna associated with forests, reducing the richness of some taxonomic groups and increasing others (Barlow *et al.* 2007).

In the Atlantic Forest of southern and southeastern Brazil, several studies on dung beetles ecology have been carried out recently (*e.g.* Louzada & Lopes 1997; Medri & Lopes 2001; Hernández & Vaz-de-Mello 2009; Hernández *et al.* 2011; Lopes *et al.* 2011; Silva *et al.,* 2011, 2012). Although the state of Santa Catarina has an historical record of 94 species (Vaz-de-Mello 2000), there is only one recent published work in the state on scarabaeid beetles associated with cattle dung, in which only four species were found in Jaragua do Sul (Flechtmann & Rodrigues 1995). Thus, this paper aims to study the diversity of copro-necrophagous beetles that inhabit fragments of Mixed Ombrophilous Forest in the west-central region of the state of Santa Catarina, with the intent to increase knowledge on the ecology of such species in southern Brazil.

MATERIAL AND METHODS

The study was conducted in the municipality of Campos Novos, Santa Catarina (27°23'S, 51°12'W), where there are small fragments of Atlantic Forest in the midst of large crop fields of soybean, maize, and wheat. Sampling sites were located at a mean altitude of 945 m, with mild mesothermal climate, according to the climatic classification of Köppen (Pandolfo *et al.* 2002) and Mixed Ombrophilous Forest formation (Leite & Klein 1990).

Twenty sampling areas were established, which corresponded to twenty Atlantic Forest fragments in the midst of maize fields. In such fragments various mammalian species of native fauna can be found, and in some of them, there is the presence of cattle. These fragments were spread over an area of approximately 400 km^2. Most sampling was carried out from February 7th to 20th, 2011, during the summer. Each area was sampled only once during the period.

For capturing the beetles, pitfall traps were used, because they are the most common method for sampling active invertebrates on soil surface (Southwood 1994). Traps were made with plastic pots with 30 cm in circumference and 20 cm height, corresponding to a volume of 1.5 liters. Such traps were buried in the ground to their top edge and protected by a plastic cap supported by small wooden sticks. Within the traps, a layer of water (200 ml) with detergent was added. Human feces were used as bait (10 g) as well as bits of pork in decomposition (10 g), to attract coprophagous and necrophagous species, respectively, with the bait hanging from the lid of the pot in a small bag of thin cloth.

The sampling protocol for each fragment consisted of five sampling points, 10 m apart from each other, and each point received two traps, one baited with human feces and other with carrion, both five meters away from each other, totaling 10 traps per fragment. After 48 hours of exposure of the traps, the captured insects were fixed in 70% alcohol and taken to the Laboratory of Terrestrial Animal Ecology (*Laboratório de Ecologia Terrestre Animal* – LECOTA/ECZ/UFSC) where they were weighed (dry weight) and identified to genus level using Vaz-de-Mello *et al.* (2011). Species identification was confirmed by Fernando Zagury Vaz-de-Mello. Individuals were dried, at 40º C, for at least 72 hours, the weighting being conducted in an analytical balance QUIMIS MOD Q-500L210C. The collected material is deposited at the Entomological Collection of the Center for Biological Sciences, *Universidade Federal de Santa Catarina* (UFSC) and at the Entomological Collection of the *Universidade Federal do Mato Grosso*.

Species accumulation curve (Mao Tau) was built to evaluate sample sufficiency and calculations for the estimators Jackknife 1 and Chao 1 were carried out to estimate the richness in the region. Both analyzes were made using EstimateS v.7.5.2 (Colwell 2005).

In order to classify the species according to their ecological characteristics,they were classified according to body weight: those weighing over 100 mg were rated as large (L), those weighing 10–100 mg as medium (M), and those with less than 10 mg, as small (S). Moreover, the species were classified into functional groups according to the literature (Cambefort & Hanski 1991; Doube 1991; Gill 1991). Species feeding niche breadth was calculated using Levin's standardized index (B_a), in the *Ecological Methodology* software (Krebs 1999) which is calculated as follows: $B = 1/\Sigma P^2_j$, where: P_j is the proportion of individuals that use the type j resource. For greater confidence in this analysis, only species with abundance greater than 10 individuals were considered. After the calculation, all measurements were standardized in a scale 0–1 using the expression: $B_a = (B–1)/(n–1)$, where B_a refers to the standardized index value of Levins, B is the index without standardization and n is the possible number of resources. The species that presented Levins index values up to 0.2 were treated as specialists (coprophagous or necrophagous) and those with values above 0.2 as generalists.

To assess the environmental complexity of the vegetation in each sampled fragment, the adapted method of quadrant-section was used (Brower *et al.* 1997) to evaluated the variables: tree height, tree basal area, shrub height, shrub basal area, minimal distance to tree and to shrub, height of leaf litter, exposed soil, canopy, leaf litter and green area cover. Measurements were conducted in collecting points two and four, in the traps of feces and carrion. By using a cross as reference, four quadrants (northeast, southeast, southwest and northwest) were marked, where measurements were made of vegetation and environment. In each quadrant, for each tree (diameter at breast height > 5 cm) and shrub (DBH < 5 cm and height > 1 m) that were closest, distances to the center of the cross, height, crown diameter and trunk diameter were all measured. This last measure was taken at breast height (DBH = 1.3 m) for the trees and ankle height (DAH = 0.1 m) for shrubs.

Moreover, in each quadrant, in a square of 1 x 1 m marked on the ground with PVC pipe, the height of leaf litter was measured, and through visual estimate, percentages of leaf litter layer, green and exposed soil area (no vegetation or leaf litter) were measured using the following classes: 0–5%, 6–25%, 26–50%, 51–75%, 76–95% and 96–100%. Using these same classes, the percentage of canopy cover in the four directions was visually estimated, with the aid of a hollow square area of 10 x 10 cm, placed at a distance of 40 cm from the eye of the observer, at an inclination of 20° in relation to the zenith (Ramos 2000).

To test the hypothesis that the spatial distribution of species is related to environmental variables, a Canonical Correspondence Analysis (CCA) was carried out in CANOCO version 4.5 (Ter Braak & Smilauer 2002). In this analysis, the abundance data of each species were transformed (square-root transformation) to be homogenized and was selected the option downweighting of rare species, to give less weight to species with lower abundance. The relation between the matrix species and the values of the vegetation/environment variables was tested through statistical Monte-Carlo (1,000 permutations under the reduced model), under the null hypothesis that there is independence between the response matrix (species) and the matrix of predictor variables. After the preliminary analysis, the auto-correlated variables were excluded. Only those species that had abundance greater than 10 individuals were included in the analyses.

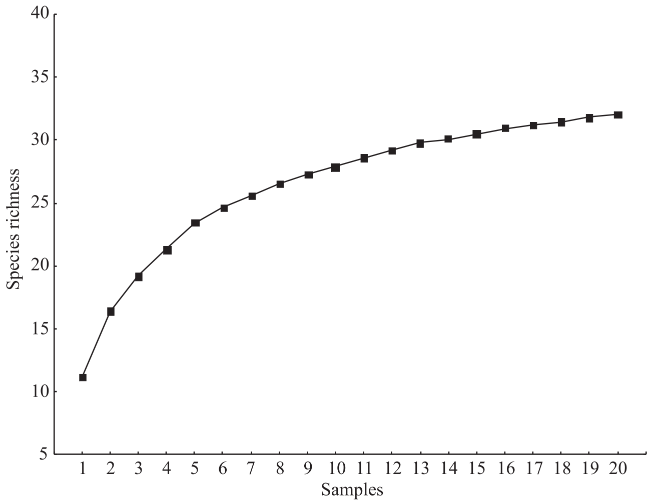

Fig. 1. Species accumulation curve (Mao Tao) of dung beetles in 20 forest fragments, sampled with baited pitfall traps, in February 2011, in the region of Campos Novos, Santa Catarina, Brazil.

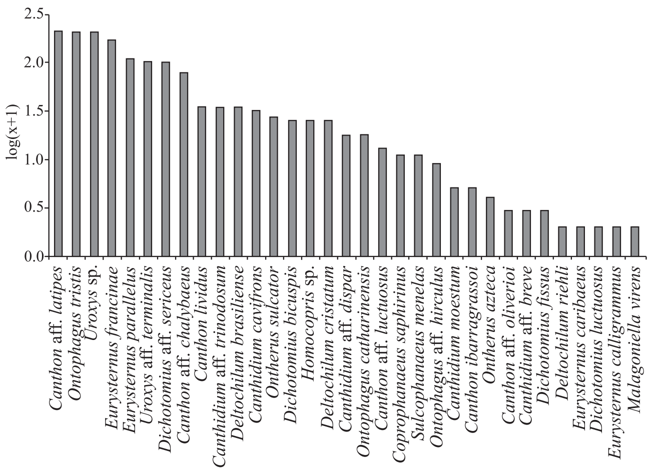

Fig. 2. Diagram of abundance distribution in log (X +1) of the assemblage of copro-necrophagous Scarabaeinae collected in February 2011 in twenty Atlantic Forest fragments in the region of Campos Novos, Santa Catarina, Brazil.

RESULTS

A total of 1,502 Scarabaeinae beetles were collected, belonging to six tribes, 12 genera and 33 species (Table I). Species accumulation curve of dung beetles indicates sample sufficiency in the study (Fig. 1), since the number of species observed was at least 87% of the estimated values of species richness by estimators Jackknife 1 (37.7 species) and Chao 1 (35.3 species).

The most abundant species in the region were *Canthon latipes* (n = 212, 14.1%), *Onthophagus tristis* (n = 204, 13.6%), *Uroxys* sp. (n = 204, 13.6%) and *Eurysternus francinae* (n = 169, 11.3%), which together represent 52.6% of total captured individuals (Fig. 2). Species with only one collected individual (singletons) were *Dichotomius luctuosus*, *Dichotomius riehli*, *Malagoniella virens*, *Eurysternus calligrammus* and *Eurysternus caribaeus*. Species with only two captured individuals (doubletons) were *Canthidium* aff. *breve* and *Dichotomius fissus* (Fig. 2).

The species showed great diversity in size, reflecting the morphological diversity found in this subfamily. Thus, among the ten largest species we may highlight *D. fissus,* with a mean of 437 mg of dry weight (with about 2.5 cm in length), *D. brasiliense* with 362 mg and *C. saphirinus* with 361 mg. There were 15 species of medium size and seven small species. The smallest one was *C.* aff. *breve* with a mean weight of 5 mg (0.3 cm in length). Other small species were *O. catharinensis*, *O.* aff. *hirculus*, both weighting 6 mg, and *Uroxys* sp. and *C. cavifrons* both with 7 mg (Table I).

The species that most contributed in terms of biomass, possibly being the most important in the transformation of organic matter in this ecosystem, were two with large size, *D.* aff. *sericeus* and *D. brasiliense*, and two of medium size, *E. francinae* and *C. latipes* (Fig. 3).

Among the captured species, nineteen are tunnelers, ten rollers and only four are dwellers (Table I). Regarding food habits, of the 23 species with sufficient abundance for the

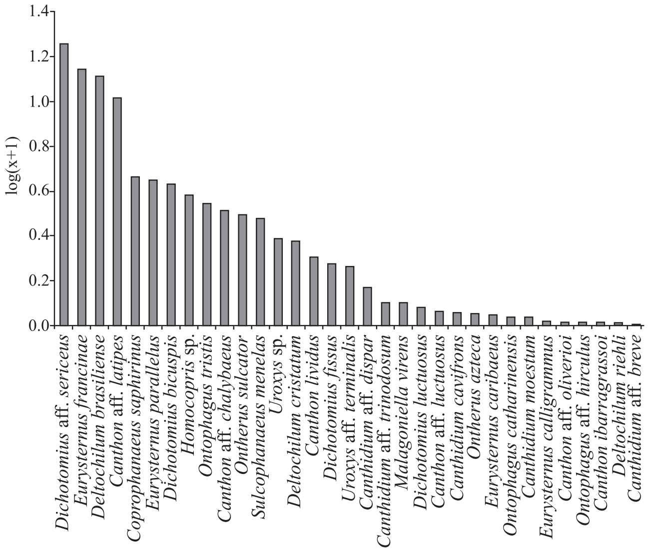

Fig. 3. Diagram of biomass distribution in log (X +1) of the assemblage of copro-necrophagous Scarabaeinae collected in February 2011 in twenty Atlantic Forest fragments in the region of Campos Novos, Santa Catarina, Brazil.

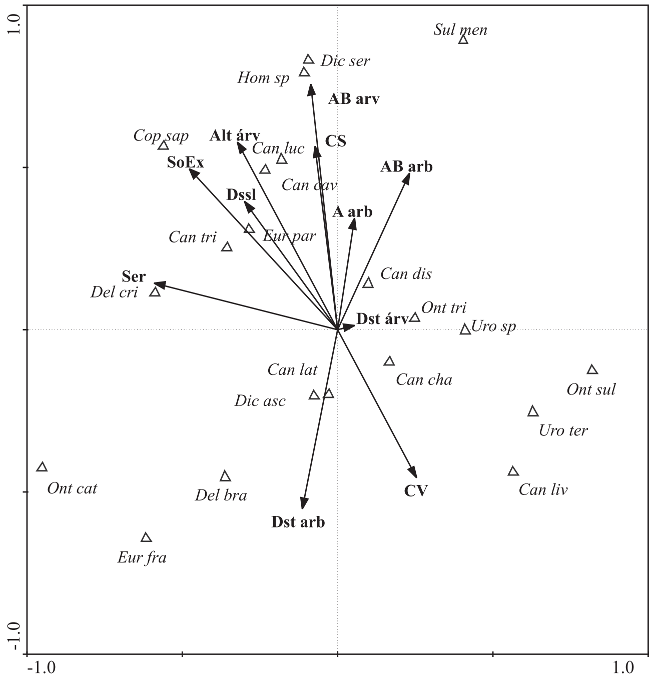

Fig. 4. Canonical correspondence analysis between the species of dung beetles and environmental variables in twenty Atlantic Forest fragments in Campos Novos, Santa Catarina, Brazil. Ser = height of leaf litter, SoEx = exposed soil, Dssl = canopy, Alt árv = tree height, AB arv = tree basal area, CS = leaf litter cover, A arb = shrub height, AB arb = shrub basal area, Dst árv = distance of tree, CV = green area cover, Dst arb = distance to shrub. Species are marked with the first three letters of their genus, followed by the first three letters of their specific name.

calculation of the trophic niche width, 11 species were rated as coprophagous, 10 as generalists and two as strictly necrophagous, *C.* aff. *dispar* and *C.* aff. *luctuosus* (Table I). Is worth mentioning that *U.* aff. *terminalis* was most observed in field in fragments where cattle had open access. The only individual of *M. virens*, captured in traps of feces, was found in a fragment located near a lake, where the presence of nutria (*Myocastor coypus* (Molina, 1782)) was noted.

The spatial distribution of dung beetle abundance according to the structure of the environment has shown that some beetle species relate to certain characteristics of their habitat. Canonical correlation analysis was significant (F = 1.627, P = 0.008), and the first axis explained 30% and the second axis 29% of the variability of data (Fig. 4). The difference in the distribution of some species of beetles in the forest fragments thus shows a relation: *D. cristatum* was mainly associated with the areas of taller layers of leaf litter; *C. saphirinus* occurred mostly in areas with exposed soil and taller trees and *D.* aff. *sericeus* and *Homocopris* sp. occurred in areas of thicker tree forest and large percentage of leaf litter cover. Conversely, *O. sulcator*, *U.* aff. *terminalis* and *C. lividus* occurred in areas of soil with higher percentage of green cover and smaller trees in height. *Onthophagus catharinensis*, *D. brasiliense* and *E. francinae* occurred in more open areas, with greater distance and lower basal area of shrubs, however, *S. menelas* occurred in areas with thicker and closer shrubs (Fig. 4).

DISCUSSION

The great richness of dung beetles (n = 33) shows that the diversity of such insects in the forest fragments studied is significantly high, and it underscores the importance of research studies in regions where the fauna is still poorly known. This shows the importance of forest fragments within agricultural landscapes for the maintenance of diversity, enabling the conservation of species that otherwise would likely be locally extinct (Estrada *et al.* 1998; Halffter & Arellano 2002; Díaz *et al.* 2010).

In the fragments examined, there were a greater number of tunnelers species compared to the other functional groups. This pattern is common in tropical forests and seems to be related to the diversity of Scarabaeinae beetles in the Neotropical region (Halffter *et al.* 1992; Louzada & Lopes 1997).

The attractiveness of different types of resources is a pattern known for several species (Halffter & Matthews 1966; Vaz-de-Mello *et al.* 1998; Hernández 2007). With regard to resource utilization, almost half of the species collected in this study (11 of 23 species) were considered coprophagous. Scarabaeinae beetles are high specialized in coprophagy, (Halffter & Matthews 1966; Halffter & Edmonds 1982; Hanski & Cambefort 1991), a pattern that seems to be related to increased availability of mammal excrement in the ecosystem, since carcasses are less frequent and are spatially limited (Halffter & Matthews 1966). In addition, ten species were considered to be generalists. It is known that the use of more than one type of food resources (trophic generality) decreases the competition for scarce and ephemeral food such as feces, carcasses and rotten fruits (Halffter & Halffter 2009)

Table I. Ecological characteristics of species of copro-necrophagous Scarabaeinae beetles collected in 20 Atlantic Forest fragments in the region of Campos Novos, Santa Catarina, Brazil, in February 2011. Size (S: small, M: medium, L: large). Functional group based in the literature (P: paracoprid, T: telecoprid, E: endocoprid). Food preference (C: coprophagous, G: generalist, N: necrophagous). N: number of individuals. Feeding preference determined by the Levin's standardized index (Ba).

Tribe/Species	Mean weight (mg)	Functional Group	Feeding preference	Feces	Carrion	N	Ba
Ateuchini (S = 2; N = 306)							
Uroxys aff. *terminalis* Waterhouse, 1891	8 (S)	P	C	98	4	102	0.08
Uroxys sp.	7(S)	P	G	182	22	204	0.23
Coprini (S = 12; N = 267)							
Canthidium aff. *breve* (Germar, 1824)	5(S)	P	–	2	0	2	–
Canthidium cavifrons Balthasar, 1939	7(S)	P	G	6	25	31	0.45
Canthidium aff. *dispar* Harold, 1867	28(M)	P	N	0	17	17	0
Canthidium moestum Harold, 1867	22(M)	P	G	1	3	4	0.60
Canthidium aff. *trinodosum* (Boheman, 1858)	8(S)	P	C	32	1	33	0.06
Dichotomius bicuspis Germar,1824	137(L)	P	G	18	6	24	0.60
Dichotomius fissus (Harold, 1867)	437(L)	P	–	0	2	2	–
Dichotomius aff. *sericeus* (Harold, 1867)	171(L)	P	C	91	9	100	0.19
Dichotomius luctuosus (Harold, 1869)	201(L)	P	–	1	0	1	–
Homocopris sp.	118(L)	P	C	24	0	24	0
Ontherus azteca Harold, 1869	44(M)	P	–	3	0	3	–
Ontherus sulcator (Fabricius, 1775)	82(M)	P	C	26	0	26	0
Deltochilini (S = 9; N = 401)							
Canthon chalybaeus Blanchard, 1845	32(M)	T	G	27	54	81	0.8
Canthon ibarragrassoi Martinez,1952	8(S)	T	–	0	4	4	–
Canthon latipes Blanchard, 1845	44(M)	T	C	208	4	212	0.03
Canthon lividus Blanchard, 1845	30(M)	T	G	13	21	34	0.89
Canthon aff. *luctuosus* Harold, 1868	13(M)	T	N	0	12	12	0
Canthon aff. *oliverioi* Pereira & Martínez, 1956	14(M)	T	G	2	1	3	0.80
Deltochilum brasiliense (Castelnau, 1840)	362(L)	T	G	25	8	33	0.58
Deltochilum cristatum Paulian, 1938	58(M)	T	G	5	19	24	0.49
Deltochilum riehli Harold, 1868	27(M)	T	–	1	0	1	–
Malagoniella virens (Harold, 1869)	249(L)	T	–	1	0	1	–
Oniticellini (S = 4; N = 279)							
Eurysternus calligrammus Dalman, 1824	40(M)	E	–	1	0	1	–
Eurysternus caribaeus (Herbst, 1789)	109(L)	E	–	1	0	1	–
Eurysternus francinae Génier, 2009	76(M)	E	C	169	0	169	0
Eurysternus parallelus Castelnau, 1840	32(M)	E	C	108	0	108	0
Onthophagini (S = 3; N = 229)							
Onthophagus catharinensis Paulian, 1936	6(S)	P	C	17	0	17	0
Onthophagus aff. *hirculus* Mannerheim, 1829	6(S)	P	–	8	0	8	–
Onthophagus tristis Harold, 1873	12(M)	P	C	203	1	204	0.01
Phanaeini (S = 2; N = 20)							
Coprophanaeus saphirinus (Sturm, 1828)	361(L)	P	G	7	3	10	0.72
Sulcophanaeus menelas (Castelnau, 1840)	200(L)	P	C	10	0	10	0
Total abundance				1290	212	1502	

and can also provide the species with a wider use of the environment, which would have contributed to the great diversity of Scarabaeinae beetles in the Neotropical region (Halffter & Halffter 2009), whereas specificity tends to restrict the occupation of new ecosystems in which their resource is not available.

Necrophagy in Scarabaeinae is considered important in Neotropical forests, where there are reduced numbers of large mammals (Halffter & Matthews 1966). Southeast Asia, where large mammals are scarce, is the only comparable biogeographic region, considering the presence of many necrophagous beetles (Halffter & Matthews 1966; Gill 1991; Halffter 1991). In this study, we have found two scavengers (necrophagous), *C.* aff. *dispar* and *C.* aff. *luctuosus.*

Within the tribe Coprini, *C. moestum* was generalist, which supports the works of Silva *et al.* (2008, 2009, 2011). This species is distributed throughout the southern region of Brazil, in Argentina and Uruguay (Martínez 1959; Martínez &

Halffter 1986; González-Vainer & Morelli 2008). *Homocopris* sp., which is coprophagous, belongs to a genus recently revalidated. This genus is distributed in Chile and Brazil. In Brazil it can be found in the southern and southeastern Atlantic Forest (Vaz-de-Mello *et al.* 2010). *Ontherus sulcator*, which is coprophagous, is a common species and widely distributed in the Neotropical region, mostly found in herbivore dung and human feces (Martínez 1959), may also be attracted to carcasses and artificial light (Génier 1996).

As for the species of the tribe Deltochilini, *C. chalybaeus* was generalist, agreeing with the results of Silva *et al.* (2007). Luederwaldt (1911) and Martínez (1987) have claimed that this species is found in carcasses from early stages to advanced decomposition. Martínez (1959) states that this species is found in excrement in the early stages of decomposition, and is widely distributed across South America. The species *C. latipes* was rated as coprophagous and Martínez (1959) claims that it can be found in herbivore and human feces. Pereira & Martínez (1956) have also found *C. latipes* behaving as saprophagous beetles, at ripe jelly palm fruit (*Butia* sp.). This dung beetle is distributed in mountain forest environments in southern and southeastern Brazil, Argentina and Uruguay (Vulcano & Pereira 1964; Martínez 1987). *Canthon lividus* had generalist feeding habits, as reported in the works of Martínez (1959), Halffter & Matthews (1966) and Silva *et al.* (2011). It can be found in Brazil, Argentina, Paraguay and Uruguay (Martínez, 1959). *Deltochilum brasiliense* was also generalist, in accordance with Almeida & Louzada (2009) and Silva *et al.* (2011). It can be found in the center-south region of Brazil and Argentina.

Of the species of Oniticellini, *E. francinae* was coprophagous, agreeing with the work of Génier (2009), who has examined specimens collected in human feces, with the exception of one specimen collected in cattle dung. This species can be found throughout the Atlantic Forest at altitudes above 1,000 m, except in southern Brazil, where the latitude seems to compensate for the altitude (Génier 2009). *Eurysternus parallelus* was rated as coprophagous, agreeing with the results of Silva *et al.* (2011), but differing from those of Louzada & Lopes (1997), who have also captured it in carrion traps. This species is distributed throughout southern and southeastern Brazil, Argentina and Paraguay (Martínez 1959; Génier 2009).

Of the species of Onthophagini, *O. catharinensis* was coprophagous, in accordance with the results of Silva *et al.* (2011). The distribution of this species includes the state of Santa Catarina, from where it was originally described (Paulian 1936), Rio Grande do Sul and Paraná. Lopes *et al.* (2011) propose that this species may be an indicator of preserved areas. *Onthophagus tristis* was coprophagous, as also found by Silva *et al.* (2011).

As for the species of Phanaeini, *C. saphirinus* was rated as generalist. According to Martínez (1959) it is coprophagous and found in the droppings of herbivores. It occurs in southeastern and southern Brazil, Argentina and Paraguay (Martínez 1959; Arnaud 2002; Edmonds & Zidek 2010), having a color variation among different populations (Edmonds & Zidek 2010). *Sulcophanaeus menelas* was rated as coprophagous, agreeing with Edmonds (2000), who states that it has strict coprophagous feeding habits, and it can be found in different types of droppings. It can be found in Bolivia, Argentina, Uruguay and southern Brazil, and prefers open areas to forested areas (Edmonds 2000).

Habitat structural complexity and resource availability are important factors in determing the dung beetle community (Gardner *et al.* 2008; Almeida & Louzada 2009; Neves *et al.* 2010, and for revision see Nichols *et al.* 2007). The forest coverage and type of vegetation are factors that influence the assemblage of dung beetles in different environments (Halffter & Arellano 2002; Hernández & Vaz-de-Mello 2009). Estrada *et al.* (1998) observed that the diversity of dung beetles had a positive relationship with measures of vertical and horizontal diversity of vegetation. Davis *et al.* (2001), working with dung beetles in Borneo, observed that the distribution of species across different environmental characteristics might show discrete associations that are typical to particular biotypes within the landscape. When comparing different environments with varying degrees of disturbance in Mexico, Halffter & Arellano (2002) proposed that the structure of the environment is more important in determining community composition of dung beetles than the allocation of resources in areas occupied by livestock.

Factors such as sunlight and humidity are important, since reproductive aspects would be affected (Martínez & Vásquez 1995). In a study conducted in Brazil, in the Amazon rainforest, Gardner *et al.* (2008) showed that assemblage of Scarabaeinae beetles are strongly and negatively affected in secondary forest environments. The microclimatic differences due to low, relatively open canopies with hot and dry understory environments, could help explain the observed impoverishment of dung beetle communities.

Knowledge of the species and studies on the ecological and behavioral characteristics of each species are the first steps in finding species indicators to assess the conservation status of a particular ecosystem (Brown 1997). Changes in habitat complexity can alter not only the communities of insects, but also the whole fauna associated with forests, reducing the richness of some taxonomic groups and increasing others (Barlow *et al.* 2007; Noriega *et al.* 2007).

In order to preserve the community of dung beetles and their ecosystem services there is, therefore, a need for landscape conservation planning, with special attention to habitat structure (Barlow *et al.* 2010), reduction of isolation and increased connectivity between fragments (Numa *et al.* 2009).

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