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Organization of dung beetle communities (Coleoptera, Scarabaeidae) in areas of vegetation re-establishment in Feira de Santana, Bahia, Brazil

Priscila P. Lopes [1*], Júlio N. C. Louzada[2] & Fernando Z. Vaz-de-Mello [3]

[1]Departamento de Ciências Biológicas, Universidade Estadual de Feira de Santana, Km 3, BR 116, 44031-460, Feira de Santana, Bahia, Brasil
[2]Departamento de Biologia, Universidade Federal de Lavras, CP 37, 37200-000, Lavras, Minas Gerais, Brasil
[3]Departamento de Ecología y Comportamiento Animal, Instituto de Ecología, A.C., Km 2,5, antigua carretera a Coatepec, 351, Xalapa, Veracruz 91351, México
[*]Corresponding author: (pplopes@uefs.br)

(Organization of dung beetle communities (Coleoptera, Scarabaeidae) in areas of vegetation re-establishment in Feira de Santana, Bahia, Brasil) – The present work refers to the study of colonization of four vegetation physiognomies considered as succession stages by Scarabaeidae beetles in Feira de Santana, Brazil. The four environments present structures of 1) herbs, 2) herbs and bushes, 3) bushes, and 4) bushes and trees. The last one has similar vegetation elements to the original vegetation of the area (Caatinga, in transition with deciduous forest). Beetles' richness was not statistically different in the three structurally simpler habitats, the composition, as well as the abundance structure of the communities of the four sites were very similar. Guild structure changed in number and proportion of specimens, with an increase in the number of tunnelers as the vegetation grew in complexity. The positive/negatives effects on the composition and beetles's community structure were related to the interference with the dissemination of odor plumes or maintenance of sources of resources (vertebrates). The organization of the functional structure in the beetles' community should be related to the time needed for the establishment of complex ecological connections.

Key words: Caatinga, habitat restoration, community structure of Scarabaeidae.

(Organização de comunidades de besouros rola-bosta (Coleoptera, Scarabaeidae) em áreas de re-estabelecimento de vegetação em Feira de Santana, Bahia, Brasil) – O presente trabalho refere-se ao estudo de colonização de quatro fisionomias de vegetação consideradas como estágios sucessionais, em Feira de Santana, Brasil, por besouros Scarabaeidae. Os quatro ambientes possuem estruturas: 1) herbácea, 2) herbácea/arbustiva, 3) arbustivo/arbórea e 4) arbórea. Esta última com elementos de vegetação similares à vegetação original da área (Caatinga, em transição com floresta decídua). A riqueza de besouros não foi estatisticamente diferente nos três ambientes estruturalmente mais simples, e tanto a composição quanto a estrutura de abundância das comunidades dos quatro sítios foram muito semelhantes. A estrutura de guildas mudou em número e proporção de espécies, com aumento no número de "escavadores" com o aumento na complexidade estrutural da vegetação, cujos efeitos positivos / negativos sobre a composição e estrutura da comunidade de besouros foi relacionado à interferência sobre a disseminação de plumas de odor ou manutenção de fontes de recursos (vertebrados). A organização da estrutura funcional da comunidade de besouros deve ser relacionada ao tempo necessário para o estabelecimento de conexões ecológicas complexas.

Palavras-chave: Caatinga, recuperação de hábitat, estrutura de comunidades de Scarabaeidae.

Introduction

The natural, or induced, alterations in the vegetation physiognomy can modify the structure of insect communities (Bell *et al.*, 1991). These changes in the vegetation structure can be hard or soft, depending on the scale and intensity of the disturbance.

The clear cutting is one hard alteration in the landscape, that induces to a series of drastic modifications in the insect communities, such as local extinction of species (Klein, 1989), communities' restructuring, and changes in the guilds (Howden & Nealis, 1975; Klein, 1989; Samways, 1994).

The existence of vertical and horizontal gradients in the physiognomy, due to the soil (nutrients, pH, water), stress, or to the succession degree, is a common example of soft changes in the vegetation that alters the animal communities. In this case, the communities can answer by changes in composition, richness or relative abundance of species.

Whenever the vegetation suffers a hard alteration, such as clear cutting, its recovery may be achieved through seeds of the original vegetation already present in the area, or through the arrival of seeds from other sources. In Feira de Santana, the bush and arboreal components appear without the effective participation of close forest remnants, being dependent of distant species' sources. This process is common when the level of clear cut of the native vegetation was very strong and in vast spatial scales. This causes that in many localities the composition exhibits characteristics of Cerrado and Caatinga, even if they are geographically distant of these ecosystems.

However, very few information is available about the restructuring of the insect communities in areas where the vegetation is being re-colonized in the Neotropics. In spite of presenting open physiognomy, these places are markedly formed by plant species of multiple sources, and the new animal communities in construction can follow narrow patterns. The final pattern could be due to the source pool of animal species, the species arrival sequence, and the interactions among the settlers.

Scarabaeidae (dung beetles) are detritus feeding Coleoptera, that use dung, carcasses and decomposing fruits as alimentary and reproductive resource (HALFFTER & MATTHEWS, 1966; HALFFTER & EDMONDS, 1982). These insects are important for the dynamics of matter in ecosystems, because they remove detritus of the soil surface (HALFFTER & MATTHEWS, 1966).

HALFFTER & FAVILA (1993), suggest that the dung beetles communities are excellent models to evaluate and to monitor to what degree the changes in the vegetation alter the animal communities. It is also possible that these insects are a good tool to evaluate the animal communities' reconstruction in areas where the vegetation is colonizing again.

In this work we describe the dung beetles community in places of secondary vegetation under the influence of the Cerrado and Caatinga from Brazil.

MATERIALS AND METHODS

The study was carried out in Feira de Santana City, state of Bahia (12°16' S, 38°58' W), Brazil. The climate is of the sub-humid dry type, with a hydric deficit between October and April, and surplus on the months of April to July. The area has annual mean precipitation between 900 and 1,400 mm and annual mean temperature of 24 ºC (CEI, 1994).

The area of Feira de Santana is located in a contact zone between the Caatinga and the Deciduous Forests, being pointed as of medium to high drought risk, being with 100% of its area inserted in the Polygon of the Droughts (CEI, 1994). The city has the cattle raising as important economic activity, with 89,3% of its area occupied with grasslands (CEI, 1994), what presupposes an intense clear cutting of the original forest covering. There is little information about the composition of the original covering, since its destruction comes since Brazil's colonization, more than 450 years ago. The cattle related activities have been decreasing in importance with the years. That has allowed the occupation of some places by new vegetation.

The sampled areas were located in the State University of Feira de Santana campus, each of the four sites distant at least 150m from each other. The areas of secondary regeneration present, besides several elements of Caatinga, some plant species characteristic of the Cerrado.

Studied sites

We studied four sites with clear differences of vegetation structure. These sites represent the typical succession sequence of a plant community's reconstruction in the region. The succession sequence goes from a habitat with completely open vegetation to one with quite closed (thick) vegetation.

Site 1: Herbaceous vegetation. Area with grass and some isolated stains of *Syagrus* sp.

Site 2: Herbaceous - bush vegetation. It presents grass, many individuals of *Syagrus* sp., and some individuals of *Mimosa tenuiflora*. Seemingly, it is an area of abandoned pasture going through an initial process of succession.

Site 3: Bush vegetation. Composed mainly by patches of bush, and small trees with medium height around 2,5 m (max. of 3,5 m). *Syagrus coronata* is common in this area. In this place there are several artificial dunes among the bushes, of approximately 80 cm, covered by grasses and herbaceous plants and signs of recent fires.

Site 4: Arboreal vegetation. It is very closed, with characteristic plants of Caatinga and Cerrado vegetation (such as *Bowdichia virgilioides*, *Andira laurifolia, Swartzia apetala* (Leg., Papilionidae), *Curatella americana* (Dilleniaceae), *Himatanthus obovatus* (Apocynaceae), according to Queirós, pers. comun.). It presents canopy height of approximately 4 m.

Sampling of insects

We collected dung beetles using baited pitfall traps. We installed four traps with human dung, four with carcass and four with fermented banana, at a minimum distance of 15 m of the site border. The traps were arranged in groups of three (each with one bait type) in the corners of a 30 x 30 m square. The traps of a same group were installed 2 m apart. Each site was trapped for a period of 48 hours, during the first fortnight of June of 1995. This period corresponds to the beginning of the rainy season in the region in that year.

The sampling could not be repeated because the sampled areas were destroyed for building means in the following months, but the small sampling effort is being considered as a relevant sample of the community because of the attracting power of baited traps, which increase the number of collected individuals and species.

Community structure description

We studied the composition of species, species richness, distribution of abundance and guild structure of the dung beetles' communities active in each site.

For the analysis of the communities´ composition similarity levels we used Sorensen's similarity coefficient, which is useful for binary data, when the interest is only on composition of species (KREBS, 1989).

We compared the site richness using the estimate of the number of species, calculated by Jackknife procedure, and its confidence intervals (HELTSHE & FORRESTER, 1983; KREBS, 1989; PALMER, 1990).

We compared the distribution of the species abundance in the community using the Kolmogorov-Smirnov test, at 0.05 of probability. This test is useful to compare the shape of the Whittaker plot (KREBS, 1989).

The dung beetle community can also be divided in guilds according to its strategy of resources relocation

(CAMBEFORT & HANSKI, 1991). The most common division is the one that groups the species in rollers (which carry resource portions for sites distant from the source), tunnelers (which take resource portions into tunnels dug beside or below the resource deposit) and dwellers (which live immediately below or inside of the resource source, where they reproduce) (HALFFTER & EDMONDS, 1982).

RESULTS

Composition of species

Most species we sampled (Table 1) have broad distributions, such as *Canthon lituratum, Coprophanaeus jasius, Diabroctis mimas, Pseudocanthon xanthurum*, *Onthophagus rubrescens, Trichillum externepunctatum* and *Digitonthophagus gazella* (MARTÍNEZ, 1959; F.Z.V.M., personal observation), some of these occurring in the Cerrado (*Canthon* sp.2), as well as in some other open Brazilian formations. The species registered strictly in the Caatinga are *Calhyboma verruciferum*, *Coprophanaeus pertyi* (PEREIRA & D'ANDRETTA, 1955a, b; MARTÍNEZ & PEREIRA, 1966) and *Canthidium humerale* (personal observation). *Dichotomius geminatus* is common for the whole coast of the Northeast and of Espírito Santo state (LOUZADA *et al.*, 1996).

There are no information of surveys at a community level in areas of Cerrado or Caatinga, but only isolated information on the distribution of some species that occur in these formations. Most species have broad distributions and are frequently found in areas of Caatinga and Cerrado.

The four sites presented faunistic similarity above 75% (Table 2). All sites had large similarity in species composition, in spite of noticeable physiognomic differences in the vegetation, what suggests that there is a "core" species composition, and the remaining 25% of dissimilarity are due to exclusive species in the communities of each vegetation type.

Table 1. Individuals number of dung beetles sampled in four vegetation physiognomies in Feira de Santana, BA.

Species/Physiognomy	Herb.	Herb./bush	Bush	Arboreal
Ateuchus sp.		1	4	1
Canthidium humerale (Germar, 1824)		5	118	11
Canthidium manni Arrow, 1913	1	1	14	12
Canthidium sp.1				1
Canthidium sp.2			44	6
Canthidium sp.3			1	1
Canthidium sp.4				2
Dichotomius geminatus (Arrow, 1913)		1	1	8
Trichillum externepunctatum (Borre, 1880)	2	12	4	
Uroxys corporaali				10
Calhyboma verruciferum (Felsche, 1911)		5	1	7
Canthon lituratum (Germar, 1824)	37	148	67	13
Canthon sp.1	1	2		1
Canthon sp.2	5	4	11	1
Canthon sp.3	4	18	3	
Canthon sp.4		3	2	
Pseudocanthon xanthurum (Blanchard, 1843)		3		
Coprophanaeus jasius (Olivier, 1789)			1	1
Coprophanaeus pertyi (d'Olsoufieff, 1924)	9	17	39	40
Diabroctis mimas (Linné, 1758)			7	
Digitonthophagus gazella (Fabricius, 1783)		1		
Onthophagus ranunculus Arrow, 1913	7	27	11	2
Onthophagus rubrescens Blanchard, 1843	1			
Number of species	9	15	16	16
Exclusive species	1	2	1	3
Number of individuals	67	248	328	117

Richness of species

There was a steep rise in species richness of the dung beetle community with the addition of bushes in the plant community. The number of species rose from 9 in the herbaceous habitat, to 15 in the herbaceous-bush vegetation, and remained at approximately the same richness level in the other sites of more complex vegetation physiognomies (Fig. 1). Five species were registered in all sites and 7 species had distributions exclusive to one of the four sites (Table 1).

Only the herbaceous habitat can be considered statistically different from the others in regard to species numbers (Table 3).

Table 2. Sorensen's similarity coefficients for species composition of dung beetles communities from four vegetation physiognomies in Feira de Santana, Bahia.

	Herbaceous	Herb/bush	Bush	Arboreal
Herbaceous	1,00	-	-	-
Herb/bush	0,80	1,00	-	-
Bush	0,76	0,84	1,00	-
Arboreal	0,75	0,79	0,83	1,00

Table 3. Number of observed and expected species in four vegetation physiognomies in Feira de Santana, BA, calculated through Jackknife procedure.

Habit	Observed	Estimated	Max	Min	SD
Herbaceous	9	11,3	13,6	8,9	0,75
Herb/bush	15	18,8	24,8	12,7	1,89
Bush	16	19	25,8	12,2	2,12
Arboreal	16	22	32,3	11,7	3,24

Distribution of species abundance

The four vegetation physiognomic types showed the same distribution of species abundance, according to Kolmogorov-Smirnov, at 5% of probability. But there was a tendency towards a more even distribution of resources as the vegetation becomes structurally more complex (Fig. 1).

It seems that in the construction of the dung beetle community, the gain in richness follows an increase in resource availability or better use and share of the resources (Fig. 2).

Guild Structure

The vegetation re-composition alters the distribution of number of species per guild (Fig. 2). As the habitat becomes more complex the proportion of rollers in the community diminishes as the proportion of tunnelers rises. There were no dweller species captured.

Discussion

The construction of animal communities is an interesting subject to the restoration of degraded areas. This study allows the design of the construction of the dung beetle community in areas under the influence of Cerrado and Caatinga vegetation. Some of our results can be explained by the limitations and conditions imposed to the insects by each structural type of vegetation. As the plant community is recomposed, there is a modification in its structure. The structure of the plant community can affect the dung beetle community through microclimatic characteristics (Martinez & Montes de Oca, 1994) and physical interference in the deposition, localization and attraction of alimentary resources. The microclimatic characteristics that most affect the dung beetles are light (Halffter & Mathews, 1966; Wensler, 1974; Doube & Wardhagh, 1991), temperature (Bartholomew & Heinrich, 1978; Young, 1984), the resource desiccation speed (Hanski, 1987), and humidity, that can affect both the resource desiccation speed and reproduction (Barkhouse & Ridsdill-Smith, 1986; Martinez & Montes de Oca, 1994).

The vegetation structure can also affect the deposition, localization and attraction of resources. In places where the vegetation is very thick, the feces produced by birds and arboreal mammals can be retained in the vegetation, diminishing the amount of resources that reach the ground (Oppenheimer, 1977). In this kind of vegetation the flight ability of large sized species might be restrained (Nealis, 1977).

Dispersion of odor plumes is also influenced by vegetation density. In intricate vegetation the odor plumes might not be efficiently dispersed, while in open areas the lack of wind barriers will make it be dispersed too rapidly. In both cases, the localization or orientation towards the source of resources by the Scarabaeidae can be affected.

In our study areas we dealt with a gradient of vegetation complexity and density due to the growth of arboreal and bushy vegetation. In one of the extremes of the gradient (herbaceous vegetation), the Scarabaeidae community is poorer than the others, what can be due to the faster drying of the resources, high solar exposition and fast dissipation of odor plumes. As bushy and arboreal elements are added to the herbaceous vegetation species richness is increased to a level of 16 species (Table 1). This increase in number of species is probably associated to the alleviation of microclimatic conditions and increase in habitat heterogeneity. As the microclimatic conditions are less extreme due to tree shadows, one would expect the presence of dwellers. This is not the case here, probably because the temperature and humidity, although milder than in the summer, may still allow fast desiccation of resources.

Habitat heterogeneity is considered as an important determinant of species diversity (Williams, 1964, Bell *et al.*, 1991). In theory, this is observed because the larger habitat heterogeneity corresponds to a larger amount and more varied resources. This in turn would allow the coexistence of competing species that would otherwise have to share or compete for the same resources. This pattern of richness linked to habitat heterogeneity is registered in many taxa (spiders – Uetz, 1991; primates – Schwarzkopf & Rylands, 1989; and birds – Beedy, 1981).

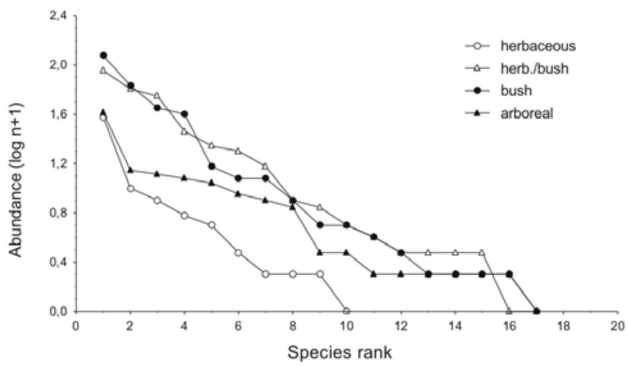

Fig. 1. Abundance distribution (Whittaker Plot) of four Scarabaeidae communities, active in sites with different vegetation structures in Feira de Santana, BA, Brazil. There was no significant difference detected in the shape of the curves (Kolmogorov-Smirnov test, at 5% probability).

The fact that both intermediate habitats have higher richness could draw us to think that they are some kind of ecotone, where the fauna specialized in sunny (herbaceous) or shaded (bushy/arboreal) would meet. The results presented in Table 2 deny that possibility. Seemingly, both intermediate sites share species that are absent from the extreme habitats. In these habitats (herbaceous and arboreal), most species are found in all four sites or at least in three of them (Table 1). Besides, the large similarity in fauna composition (Table 2) allows us to reach the conclusion that the same pool of species is colonizing the different vegetation physiognomies, with little habitat specialization from the species. The small amount of dissimilarity among sites must be due to those species.

The different functional structure of succession stage is probably determined also by the vegetation structure. In the same way that it may alter the localization and orientation of resources through physical barriers to the dissipation of odor plumes, the vegetation may also impose difficulties to the rolling of resource balls. This would be an interesting explanation to the smaller numbers of rollers in relation to tunnelers as the complexity of the vegetation grew.

There is also the possibility that in some habitats the community is organized according to the reference habitats of the colonizing fauna (MacArthur, 1972). In that way, the species that colonized the region or stayed in it, even after the clear cut of most natural habitats, would in theory find more favorable conditions in the secondary habitats, more similar to the original ones or the new sources.

The study region presented in the past spots of transition vegetation between Caatinga and Seasonal forest also having strong evidences of being in contact with the Cerrado vegetation. With the human colonization this vegetation gave place to extensive pastures, composed by a matrix of pastures and small fragments of secondary growth similar to the original vegetation. As the years gone by, and the cattle raising business lost importance in the region, many pastures and surrounding areas were abandoned and acquired the aspect of a so called "dirty field", i. e., a pasture with bushes and taller vegetation from secondary growth. This formation composes most of the present landscape in the region. The lack of extensive surveys in the original formations leave us, though, without any possibility of comparison with the real structures found in dung beetle communities in Cerrado and Caatinga, and in transition vegetation between them.

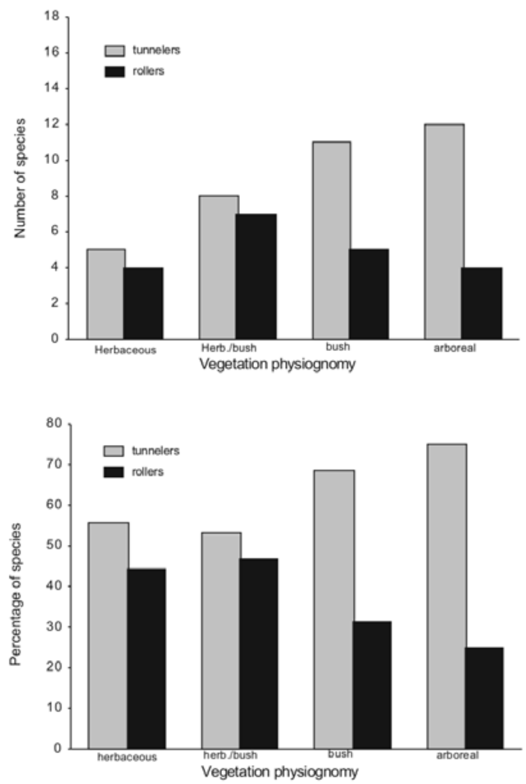

Fig. 2. Guild distribution of tunnelers and rollers in the four vegetation physiognomies according to number of species and percentage in species of each guild.

The original fauna composition from a region is usually much altered after the changes introduced in the landscape (Samways, 1994). The present fauna of Scarabaeidae of the study region is probably composed in its majority by species which are habitat generalists (both from Cerrado and from Caatinga) and by species associated to Cerrado *sensu stricto*, which is physiognomically similar to the region's matrix (herbs/bushes and bushes types). This supposition is reinforced by the fact that most species were collected in all sites (Table I) and the habitats with herbs/bushes and bushes vegetation showed the highest diversity.

The adoption of each one of the known resource allocation strategies, or diet specificity, have implications in the differential susceptibility of the species to abiotic and biotic factors. In a last analysis, this leads to the restructuring of the community following habitat modifications. The resilience of the Scarabaeidae communities allows their use as biological indicators for the monitoring of human effects on natural ecosystems (HALFFTER & FAVILA, 1993).

The overall pattern we detected is that, in the organization of the dung beetle community the richness is steeply risen with the addition of more complex vegetation elements, just like the abundance structure becomes more even. Seemingly, the species colonizing the four vegetations come from the same species pool without a noticeable established species sequence. The community guild structure seems to be the property that is more slightly changed, probably due to the need of time to the establishment of more complex biological relations. The more precise characterization of structures and processes of modification of natural habitats or their reconstruction demand an intensification of surveys about fauna and flora, both spatially and temporally, so that the real impact of devastation and the possibility of recovery can be attained.

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