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ORIGINAL PAPER

Edaphic beetle (Insecta: Coleoptera) diversity over a forest-matrix gradient in a tropical rainforest

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Abstract

Species from natural communities show different capacities for moving across contrasting habitats, and they may gradually respond along the transition between forests and anthropogenic areas. Because beetles are effective bioindicators, we analyzed the Coleoptera assemblage structure in the transition between sugarcane matrices and forest fragment. The study was conducted in an Atlantic rainforest fragment and sugarcane matrices after 2 and 6 months of replantation. Beetles were sampled in linear transects that were 50, 100, and 200 m from the forest edge and toward both forest core and matrices. We analyzed beetle abundance, species richness and composition, and diversity numbers. The abundance and species richness were higher in the forest, and species richness was higher at the sampling site 100 m inside the forest than at the gradients within the sugarcane matrices. The species composition differed between the forest and matrices, but not between the matrices with different replantation ages. Alpha diversity based on the number of species was higher in the forest, and alpha diversity based on the Shannon index was higher in the forest and matrix after 6 months of replantation. Our results suggest that the sugarcane matrices, chiefly the matrix after 2 months of replantation, sustain an impoverished beetle assemblage when compared with the forest fragment. Despite the strong habitat distinction, the beetle fauna in the sugarcane matrices was not affected by the horizontal distance from the forest. Here, we have highlighted the importance of forest fragments embedded in harsh matrices for the maintenance of biodiversity.

Keywords Anthropogenic landscape · Habitat disturbance · Monoculture · Natural communities

Introduction

Environmental disturbances (e.g., habitat fragmentation and transformation) are a threat to the natural environment and one of the main causes of biodiversity loss (Naeem et al. 1999; Myers et al. 2000; Slingenberg et al. 2009). The disturbances arise mainly because of anthropogenic activities that modify landscapes, transforming continuous portions of native forests into remnants with heterogeneous configurations (Whitmore 1997; Laurance and Peres 2006). In the current fragmentation scenario, forest patches are surrounded by different anthropogenic matrices (Laurance and Peres 2006; Franklin and Lindenmayer 2009; Lizée et al. 2012).

Depending on the type of anthropogenic matrix and natural ecosystems embedded in them, the forest-matrix transition can affect the capacity of native species to move across such disturbed habitats (Castellon and Sieving 2006). The matrix may represent an alternative or secondary habitat for forest organisms, favoring the displacement of native populations among the fragments (Prevedello and Vieira 2010). In contrast, the matrix may represent a selective barrier, constraining the movement of animals and plants (Gascon et al. 1999). The dispersal of native species through the landscape is favored when both the conserved habitat and anthropogenic matrix have a similar vegetation structure (e.g., canopy

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cover) (Gascon et al. 1999; Heinrichs and Pauchard 2015; Williams-Guillén et al. 2015). The habitat becomes inhospitable for forest-specialist species when the matrix and original environment have a different vegetation structure, limiting or disrupting their movement among remnants (Gascon et al. 1999; Castellon and Sieving 2006).

Forest edges represent a barrier that limits anthropogenic and natural habitats. The effects of the edge on biodiversity are gradual through horizontal distances from the forest edge to the core; thus, forest-specialist species show higher success near the forest core (Oosterhoon and Kappelle 2000; Eggleton et al. 2002; Carpio et al. 2009). Similarly, in horizontal gradients from the forest edge toward anthropogenic matrices, some forest species successfully occupy the first few meters of the disturbed areas, drastically reducing, or even disappearing, with the spacing from forest remnants (Oosterhoon and Kappelle 2000; Karem et al. 2006; Filgueiras et al. 2015). Fragment portions near the forest edge have lower abundances of secondary succession trees and a lower canopy (Oosterhoon and Kappelle 2000), affecting climatic conditions and, consequently, the ecological communities in such sites. In cloud forests of Costa Rica, for example, forest core presents a high abundance of tree species, as *Quercus copeyensis* C.H. Mull. and *Q. seemannii* Liebm., which are negatively affected by edge effect, being replaced toward forest edges by secondary shrubs and tree species, as *Comarostaphylis arburoides* Lindley and *Cornus disciflora* Moc. & Sessé ex DC. (Oosterhoon and Kappelle 2000). Another example are the wasps in temperate forests of the United States, being the species *Aptesis incompta* Townes and *Cratichneumon* sp. favored by the forested habitats, while *Phanerotoma* sp. and *Dusona* sp. benefits from forest edges (Karem et al. 2006). Previous studies of horizontal gradients from disturbed to conserved environments have shown that it is possible to estimate distances at which the species from ecological communities have their distribution positively or negatively affected by the edge effects.

To evaluate how habitat transformation affects biodiversity, indicators group are frequently used to reflect the condition of the community structure (Gardner et al. 2008). Among insects, some families of edaphic beetles (e.g., Carabidae, Cicindelidae, and Scarabaeidae) represent effective indicator groups, and they are widely used in monitoring studies because of their standardized sampling, high species richness, well-defined taxonomy, and sensitivity to habitat changes (Brown 1991; Rodríguez et al. 1998; Gardner et al. 2008; Maleque et al. 2009). Soil and vegetation characteristics are determinant factors for edaphic beetle assemblages because of microclimatic conditions (e.g., temperature, light intensity, and soil and air moisture) that regulate the distribution of edaphic beetles (Reddy and Venkataiah 1990; Larsen et al. 2006; Fagundes et al. 2011; Wardhaugh et al. 2013).

After the sixteenth century, the native vegetation of the Atlantic rainforest, which is distributed throughout the coastal region of northeastern Brazil, was affected by deforestation processes throughout the colonial and post-colonial period of the country (Tabarelli et al. 2006). Currently, the region is urbanized and the agricultural landscapes are mainly dominated by sugar-cane monocultures (Ranta et al. 1998; Tabarelli et al. 2006; Enedino et al. 2018), which is in contrast with the vegetation structure of the native Atlantic rainforest. The two ecosystems share almost no plant or animal species; the forest remnants of the Atlantic rainforest are composed mainly of tree species belonging to the families Fabaceae, Euphorbiaceae, Lauraceae, Moraceae, and Sapotaceae, whereas sugarcane is grown in a monospecific habitat in which only sugarcane plants are found (Ranta et al. 1998; Pôrto et al. 2005). The forest fragments have a closed-canopy structure with lower light incidence and milder microclimatic conditions than the sugarcane ecosystem (Pinto et al. 2010). Furthermore, burning practices are outdated but still common in sugarcane plantations in Brazil (ELLA 2012). Because of such activities, edaphic beetles that successfully inhabit sugarcane matrices are constantly exposed to harsh microclimatic transformations, as fire that affects the soil and vegetation.

The objective of the current study was to evaluate the diversity of edaphic beetles in the transition from anthropogenic matrix (i.e., sugarcane agricultural lands with two plantation ages) to forest fragment in the Atlantic rainforest. We tested the following hypotheses: (1) Habitat type will affect beetle assemblage structure in the fragmented landscape of the Atlantic rainforest. (2) The horizontal gradient among habitats affects beetle abundance and species richness. (3) Age of the plantation affects beetle assemblages. For these hypotheses, we presented the following predictions: (1) the habitat types will present distinct beetle species compositions. (2) The forest fragment will present higher species richness and abundance of beetles than the sugarcane matrix. (3) The beetle species richness will increase towards the forest core and abundance will increase towards the edges of the environments analyzed. (4) The older sugarcane plantation will present higher species richness and abundance of beetles than the recently planted sugarcane plantation.

Materials and methods

Study site

The study was performed in an Atlantic forest fragment of 3500 ha and the surrounding sugarcane matrices within the Serra Grande sugar processing plant located in the municipalities of Ibateguara and São José da Laje (8°30′S, 35°50′W) in the state of Alagoas, northeastern Brazil (Fig. 1). The processing plant has 9000 ha of conservation units, which are distributed over a highly fragmented landscape. The forest remnants in the region ($n=109$) range from 1.67 to 3500 ha and are surrounded by a homogeneous sugarcane matrix. The Serra Grande landscape is located on a low-altitude plateau (300–400 m asl) with shallow and wide valleys and two dystrophic soils (i.e., podsoil and pozolic) (IBGE 1985). The climate is warm and wet, with a mean annual temperature of 23 °C and mean annual rainfall of 2000 mm; the rains are concentrated between April and August, with 3 months of dry season (< 60 mm per month) from November to January (IBGE 1985; Veloso et al. 1991a, b; Oliveira et al. 2004). The native vegetation of the region is ombrophilous tropical rainforest with elements from both evergreen and semi-deciduous forests. The region is composed mainly of plants belonging to the families Lauraceae, Sapotaceae, Moraceae, and Fabaceae (Veloso et al. 1991a, b).

Beetle surveys

Between January and May 2011, beetles were sampled from three habitats: forest fragment; sugarcane plantation 2 months after replantation (M2), and sugarcane plantation 6 months after replantation (M6). The replantation, in both cases, was performed after the scorch. The beetles were collected using pitfall traps, which consisted of plastic cylinders (20 × 15 cm) with a solution of 100 mL of water (80%) and detergent (20%; to conserve the sampled material and break superficial tension of the water). The traps were installed in transects, which were composed of six sets located at the transition of the sugarcane matrix to the forest fragment: 50, 100, and 200 m from the edge to the interior of the habitats. In each set, six traps were installed transversally to the transect, 10 m apart from one another (Fig. 1). Forty transects were used: 20 in the forest fragment, 10 in M2, and 10 in M6. In total, 720 pitfall traps were used, and each habitat sampled once during the fieldwork. All traps were installed in the morning (between 06:00 and 12:00) and opened right after their installation. According to the methodology of a previous study that successfully surveyed Coleoptera assemblages in Brazil (see Fagundes et al. 2011), the traps were left for 48 h in the field, and the collected material was maintained in 70% ethanol. The specimens were identified at least to the family level, using identification key (Casari and Ide 2012), and morphotyped based on morphological characteristics that are used in each family for distinguishing species. The voucher specimens were deposited in the *Coleção Entomológica da UFPE* (CE-UFPE).

Statistical analysis

To compare the species richness and abundance of the beetles in the forest fragment and sugarcane matrices (M2 and M6), generalized linear models (GLMs) with Poisson error distribution were used. Furthermore, beetle abundance was also included as a predictor in the analysis of

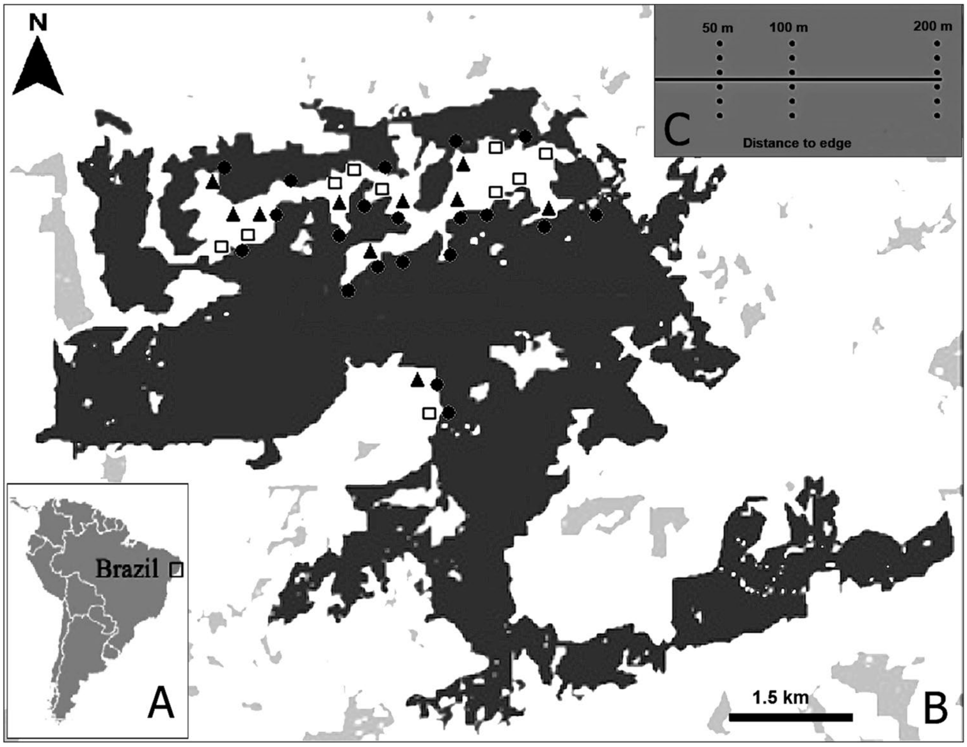

Fig. 1 Map of South America (**a**) showing the sampling sites in the forest fragment (n = 20) and sugarcane matrices (n = 20) in northeastern Brazil (**b**). Scheme of the trap locations in the gradients in the forest and matrix habits, with pitfall traps indicated using dark circles (**c**). The sampled sugarcane matrices surrounded the forest fragment. The surrounding fragments in the landscape are indicated using light gray. Circles = forest fragment; Triangles = sugarcane matrix after 2 months of replantation; squares = sugarcane matrix after 6 months of replantation

species richness, to clarify whether abundance may be affecting species richness. Abundance and richness were the response variables, and habitat type (forest fragment, M2, and M6) and gradient of the habitats (50, 100, and 200 m) were the predictive variables. Analyses of beetle species richness and abundance were fitted with the predictor variables and the interactions between them. Akaike information Criterion (AIC) values were used to obtain the best model for the data (Johnson and Omland 2004). The predictor variables were ranked based on the p-value obtained from likelihood ratio tests. The ranked variables were tested, and those with $p < 0.05$ were kept for the best model (see Zuur et al. 2009). To compare the models, stepAIC in MASS library was also used, and the models with lower AIC values were selected. The best models obtained using the Zuur et al. (2009) criteria were compared to the ones obtained by stepAIC through likelihood ratio tests. If there was a significant difference between models, the one with the lowest AIC was selected. When there was no difference, the most parsimonious model (i.e. with less variables) was selected (Crawley 2013). The assumptions of normality of the residuals were visually analyzed with normal q-q plots; outliers were evaluated through Cook's distance, but none was found (Cook's distance < 1). The data were analyzed using R software version 3.2.0 (R Core Team 2015).

To compare the species composition of the beetles sampled from the forest remnant and matrices, non-metric multidimensional scaling (NMDS) was performed for a visual and explorative evaluation. Analysis of similarities (ANOSIM) was performed to check for statistical differences in the species compositions of the habitats. Habitat type was used as the factor, and species composition, as the attribute. The Jaccard index was calculated for the samples, and NMDS ordination was performed with 2,500 repetitions. Both ANOSIM and NMDS were performed using Primer software version 6.0 (Clarke and Gorley 2006).

To estimate beetle diversity in the forest fragment and matrices, analyses of alpha (D_α), beta (D_β), and gamma (D_γ) diversities were performed using diversity number (Jost 2006). The diversity was evaluated using the number of species (${}^0D$) and Shannon diversity (${}^1D$) (Hill 1973; Jost 2006). ${}^0D_\alpha$ and ${}^1D_\alpha$ indicate the mean number of species in the assemblages and number of abundant species in the assemblages, respectively. ${}^0D_\beta$ and ${}^1D_\beta$ indicate the number of distinct assemblages based on species richness and abundance of species, respectively, and represent the species turnover among the samples. ${}^0D_\gamma$ and ${}^1D_\gamma$ indicate the total number of species and number of abundant species in the landscape, respectively (Jost 2006; Molina and Farinós 2012).

Results

A total of 505 individuals were captured, and 71 morphotypes and 17 families of Coleoptera were identified. The forest fragment encompassed 77.42% of the beetles collected, and of the 56 morphotypes identified, 42 were exclusively obtained from this habitat. However, 24 morphotypes from the forest fragment were singletons, and 20 were doubletons. M2 encompassed 9.50% of the total beetles sampled, and of the 20 morphotypes identified, five were exclusive to this habitat. Thirteen morphotypes in M2 were singletons, and four were doubletons. M6 encompassed 13.06% of the beetles sampled, and of the 17 morphotypes identified, four were exclusive to this habitat (see supplementary material). Three morphotypes in M6 were singletons, and five were doubletons.

Of the families that showed representative abundance ($n > 10$), three were mainly collected from the forest: Chrysomelidae (68.75% in forest), Curculionidae (88.23%), and Scarabaeidae (96.15%). Carabidae and Nitidulidae showed an almost equal distribution among the forest and matrices, and Cicindelidae was mainly collected from the matrices (60.78% obtained in matrices). Both species richness and abundance of the beetles were affected by habitat type ($X^2 = 25.902$, d.f. = 2, $p < 0.001$ and $X^2 = 87.002$, d.f. = 2, $p < 0.001$, respectively). The beetle species richness and abundance were significantly higher in the forest fragment than in the matrices (Fig. 2). In addition, beetle species richness presented a significantly positive relation with beetle abundance ($X^2 = 25.390$, d.f. = 1, $p < 0.001$, $R^2 = 0.53$) (see Fig. S1). The gradients of the habitats and interaction of habitat type and gradients were not retained by the best-supported models to explain the beetle species richness and abundance.

Among the families sampled, Scarabaeidae and Carabidae showed a higher number of morphotypes ($S = 18$ and 15, respectively), which together accounted for 47.14% of the species richness. The forest fragment yielded 14 families, of which seven were collected exclusively from this habitat (see supplementary material). In the matrices, eight families were recorded (six in M2 and seven in M6), and one was restricted to the matrix habitat (Eucnemidae, found in only M2) (Table 1). Morphotype dominance was distinct among the forest fragment and matrices, and *Dichotomius iannuzziae* Valois, Vaz-de-Mello and Silva and *Trichillum* sp.1 were dominant in the forest but not abundant in the matrices. Nitidulidae sp.1 was dominant in all three habitats, and Niditulidae sp.1, Cicindelidae sp.1 and Cicindelidae sp.2, were the dominant morphotypes in both M2 and M6 (Fig. 3). The species composition exhibited significant segregation among the habitat types (Global-R: 0.613, $p = 0.001$) (Fig. 4).

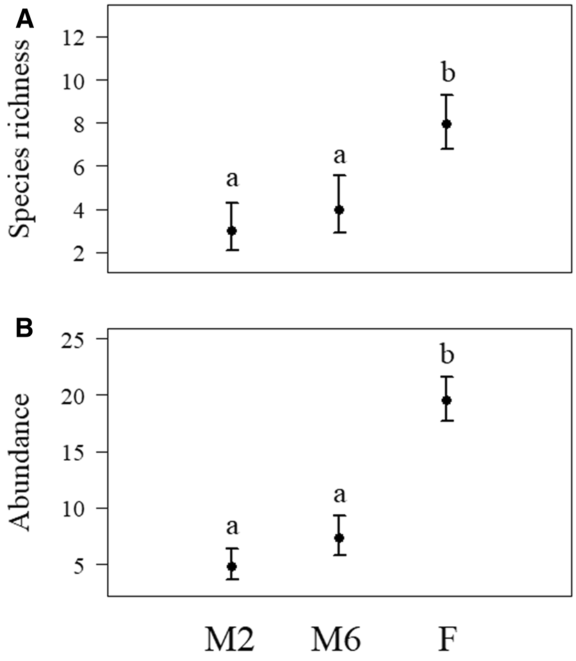

Fig. 2 General linear models presenting mean ± 95% confidence intervals of beetle species richness (*a*) and abundance (*b*) sampled from sugarcane matrices after 2 and 6 months of replantation (*M2* and *M6*, respectively) and forest fragment (*F*) in the Atlantic rainforest, northeastern Brazil. Different letters indicate significant differences

The forest fragment showed a mean of approximately eight morphotypes per transect, which is higher than M2 (three) and M6 (nearly five) (Table 2). Both forest fragment and M6 yielded approximately five abundant morphotypes in the samplings, whereas M2 yielded almost three abundant morphotypes per sampling (Table 2). In the landscape of the study site, about 18 abundant morphotypes were present, with six morphotypes per sampling and five abundant morphotypes per sampling (Table 2). With respect to species richness, the landscape encompassed approximately 11 distinct beetle assemblages; according to Shannon diversity, four distinct assemblages were present (Table 2).

Table 1 Species and morphotype richness of beetle families in the forest fragment (F) and sugarcane matrices after two and six months of replantation (M2 and M6, respectively) in the Atlantic rainforest, northeastern Brazil

Family	Habitats			
	F	M2	M6	Total
Bostrichidae	1	0	1	2
Carabidae	7	5	5	11
Chrysomelidae	7	3	2	8
Cicindelidae	4	4	3	4
Coccinelidae[b]	0	0	1	1
Curculionidae	6	0	2	7
Elateridae	1	1	1	2
Eucnemidae[b]	0	1	0	1
Geotrupidae[a]	1	0	0	1
Histeridae[a]	1	0	0	1
Melolonthidae[a]	5	0	0	5
Nitidulidae	1	3	4	2
Noteridae[a]	1	0	0	1
Phalacridae[a]	1	0	0	1
Scarabaeidae	16	5	3	18
Staphylinidae[a]	4	0	0	4
Tenebrionidae[a]	1	0	0	1

[a]Distribution restricted to the forest fragment

[b]Distribution restricted to the matrix

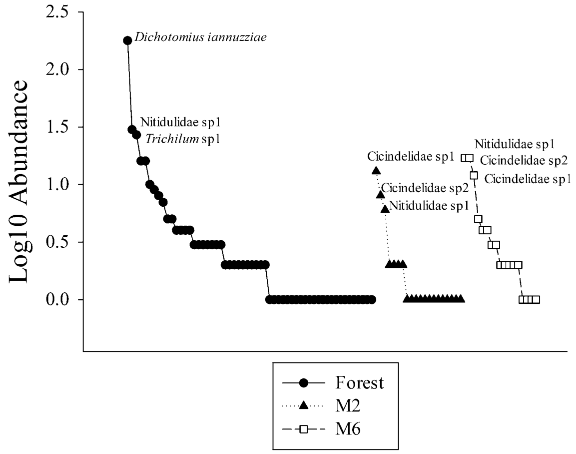

Fig. 3 Dominant species and morphotypes of the forest fragment and sugarcane matrices after 2 and 6 months of replantation (*M2* and *M6*, respectively) in the Atlantic rainforest, northeastern Brazil

Discussion

In this study, we assessed the effects of habitat type and horizontal transition between the sugarcane matrix and forest fragment with respect to edaphic beetle assemblage. Our results suggest that the sugarcane matrix sustains an impoverished beetle assemblage when compared with the forest fragment. The abundance, species richness, species composition, dominant species, and diversity numbers were different between the forest fragment and matrices. In addition, the replantation age of the sugarcane matrix did not have any clear effects on the beetle assemblage that was able to live in such a harsh environment.

The beetle abundance, species richness, and diversity numbers were lower in the sugarcane matrices than in the forest fragment. A similar pattern was observed in a previous study in which forest remnants and *Pinus* plantations

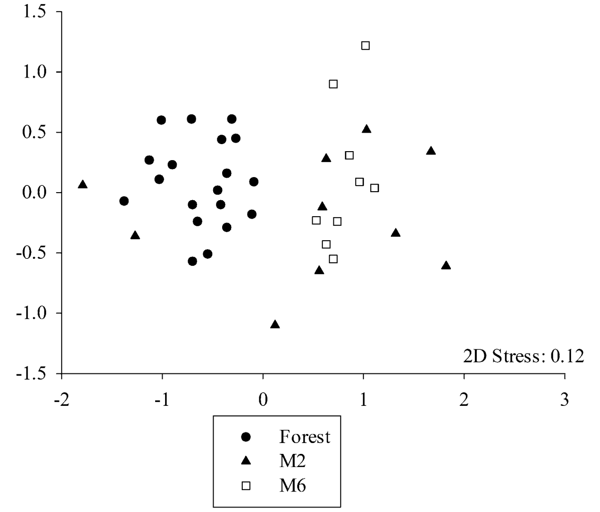

Fig. 4 NMDS ordination of beetles sampled from the forest fragment and sugarcane matrices after 2 and 6 months of replantation (*M2* and *M6*, respectively)

were compared, with the anthropogenic site presenting a lower diversity of beetles than the forested habitat (Fagundes et al. 2011). Because of the environmental conditions generated by the vegetation structure within forests, such habitats provide higher microclimatic stability and soil moisture when compared with *Pinus* areas and favor beetle diversity (Fagundes et al. 2011). The annual sugarcane cycle includes slash-and-burn practices, a common method in this system that results in drastic changes in the landscape (D'Anunciação et al. 2013). Although there are insect species that flourish within sites after burning, most of the species are negatively affected, which reduces their abundance in the months after burning (Araújo et al. 2005). Therefore, we suggest that the practices used in sugarcane plantations result in inhospitable environments for beetles, and few species and individuals can successfully occupy this type of matrix.

The beetle species composition in the forest remnant was distinct when compared with that in the sugarcane matrices. The species composition exhibits subtle changes to habitat modification, whereas species richness and abundance are parameters that sometimes do not show clear responses to landscape transformation (Uehara-Prado et al. 2006; Barlow et al. 2007; Nichols et al. 2007). In this study, we could observe potential indicator groups that may be associated with conserved or disturbed conditions. For example, beetles from the families Chrysomelidae, Curculionidae, and Scarabaeidae were collected mostly from the forest fragment. The microclimatic requirement is an important characteristic for bioindicators, and Scarabaeidae has species with high habitat specificity (Noss 1990; Larsen et al. 2006; Nichols et al. 2007; Gardner et al. 2008). Chrysomelidae and Curculionidae are herbivorous beetles with strict or generalist food habits, and some species are considered as crop plagues (Kubo and Ando 1989; Ávila and Parra 2003; Hulcr et al. 2007; Martínez et al. 2013; Bozsik 2014). The high plant diversity presented by the forest, when compared with the sugarcane matrix, may favor the presence of a high number of Chrysomelidae and Curculiondae species because of the assortment of different food resources. Notwithstanding, M2 and M6 did not present clear distinctions in the beetle species composition. Our result indicates that sugarcane plantations, irrespective of replantation age, act as hard edges and present a barrier that constrains the dispersal of beetles that inhabit Atlantic rainforest remnants.

Three families dominated the beetle assemblage in the studied habitats: Scarabaeidae, Nitidulidae, and Cicindelidae. The beetles that belonged to Scarabaeidae were the most abundant in the forest samplings, chiefly because of *D. iannuzziae*. In tropical rainforests, dung beetles are a representative group among Coleoptera and are found in higher abundances in more conserved habitats (Nichols et al. 2007; Audino et al. 2014; Filgueiras et al. 2015). *Dichotomius* beetles are commonly found in the forest remnants of the Atlantic forest, and *D. iannuzziae* (reported as *D. sericeus* in previous studies of the region) is dominant in many dung beetle assemblages (Filgueiras et al. 2009, 2015; Costa et al. 2013). Interestingly, nitidulid beetles were dominant in all three habitats, although they showed higher abundance in the forest fragment than in the matrices. Nitidulid beetles show a wide variety of feeding habits (e.g., predator, saprophagous, detritivorous) and successfully occupy environments with different habitat configurations and conservation status (Elzen et al. 1999; Barbosa et al. 2002; Aguirre and Dirzo 2008). Habitat modification and fragmentation negatively affect Nitidulidae diversity, and this was evident in our study (a lower abundance of this family in the matrices)

Table 2 Diversity partitioning for the forest fragment and sugarcane matrices after 2 and 6 months of replantation (M2 and M6, respectively) in the Atlantic rainforest, northeastern Brazil

	Habitats			Components of diversity		
	Forest	M2	M6	γ	α	β
^0D	7.95	3	4.88	70	5.97	11.71
^1D	5.14	2.87	5.32	18.66	4.89	3.80

(Goehring et al. 2002; Aguirre and Dirzo 2008; Fagundes et al. 2011). However, among the beetle families obtained in the current study, Nitidulidae apparently was one of the most resilient to the harsh conditions of the sugarcane matrices. Tiger beetles (Cicindelidae) were also dominant in the matrices. Such beetles are considered excellent bioindicators, and vegetal structure acts as a strong selective barrier for their distribution (Pearson and Cassola 1992). However, this family has species that are adapted to occupy different habitat configurations (Pearson and Cassola 1992; Rodríguez et al. 1998). In the current study, one morphotype of Cicindelidae was collected chiefly from the forest, and the others were exclusive to the sugarcane matrices and exhibited a plastic pattern of habitat occupation.

Studies that consider family richness instead of species and genus richness may present less robust predictions and responses of biodiversity to changes in the environment (Kallimanis et al. 2012; Monk et al. 2012). The high diversity of Coleoptera in tropical forests, associated with the relatively low number of taxonomists in this region, is a crucial limiting factor for identification at the species level. Notwithstanding, in this study, we considered the taxonomic unit of the recorded morphospecies. Studies that compare biodiversity response at the species level and broader taxonomic groups consider the higher taxonomic levels as a unit of diversity (Mandelik et al. 2007; Monk et al. 2012; Kallimanis et al. 2012). The ecological importance of each species was maintained in this study; thus, we could analyze the effects of how Coleoptera species richness and diversity responded to the different habitat types and transition between the sugarcane matrices and forest fragment.

We expected the abundance to increase towards the edge of the habitats and the richness to gradually increase towards the forest core. However, this pattern was not observed through the gradients towards the forest and matrices. The forest edges represented the biological barriers of two distinct environments (Ries et al. 2004). This habitat has intermediate abiotic conditions (e.g., light intensity and temperature) when compared with the forest core and anthropogenic matrices (Murcia 1995), affecting biological elements in these sites. In natural communities, some beetle species benefit from edges and open areas (Didham et al. 1998; Karen et al. 2008; Costa et al. 2013). However, even species that are adapted to disturbances have limits. Hard edges cause strong selection of biodiversity in an area (López-Barrera et al. 2007). We suggest that, because of the strong distinction between the studied habitats, the impoverished beetle fauna in the sugarcane plantations was not affected by the distance from the forest fragment. Although edge effects have a mean penetration distance of 100 m (Broadbent et al. 2008), our data suggest that the beetles do not show clear effects in the gradient from the forest edge to the forest core. The northeastern region of the Atlantic rainforest is highly fragmented, and previous studies of this landscape have presented a scenario of biotic simplification and homogenization (Ranta et al. 1998; Oliveira et al. 2004). With respect to beetle abundance and species richness, beetle fauna present a homogenous distribution through the forest edge to the forest core.

We have highlighted the importance of maintenance of forest fragments in agricultural landscapes that have harsh matrices, as in sugarcane plantations. Hard edge effects are present in the fragment/matrix transition, which negatively affect the distribution of beetles with impoverished assemblages that can occupy anthropogenic habitats. Governmental policies are urgently required to maintain the ecological communities and ecosystems in this landscape because the prospects for the conservation of this ecosystem are alarming.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest (financial and non-financial).

Ethical approval The experiment was not invasive and complied with Brazilian law (SISBIO/ICMBIO Permit Number: 1982628). At the end of the experiment, the specimens were deposited in the Entomological Collection of the Federal University of Pernambuco, according to standard procedures. This study had no human participants; thus, no "informed consent" was required.

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