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Edge effects on beetle assemblages in an Atlantic forest fragment and pasture in Sergipe, Brazil

José Oliveira Dantas[1], Adeilma Nascimento Ferreira[1], Ingrid Ruany Pimentel Oliveira[1], Moisés Oliveira Alves[1], Genésio Tâmara Ribeiro[2] & Talita Guimarães de Araújo-Piovezan[1]

1. Instituto Federal de Sergipe, Campus São Cristóvão. 2. Departamento de Engenharia Florestal, Universidade Federal de Sergipe.

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Abstract. The advancement of agricultural frontiers and pastures has contributed to the fragmentation of the forest, and these fragments are affected by disturbances of varying degrees of intensity that influence the local fauna and flora. The objective of this work was to analyze how do the magnitude and extent of edge effects and seasonality chance to richness and abundance of beetle. The experiment was conducted in an area containing forest, border and pasture belonging to the Federal Institute of Sergipe. A total of 1,173 specimens from 16 species were collected. The border areas showed a greater richness and abundance of species characterized by being an area of intermediate disturbance, while the anthropic area (pasture) presented the lowest abundance and abundance of Coleoptera and a greater variety of pest beetles, suggesting that the occurrence of some species of pest beetles may be an indication of degraded areas. The abundance and richness of the coleoptera community decreased in the rainy season. Small distances between the pasture, the edge of the forest fragment and the interior of this fragment seem to be crucial to determine the structure of the beetle community, reinforcing attention to the conservation of habitats for its development.

Keywords: Abundance; Forest fragment; Ecological microscale; Pasture; Richness.

Efeitos de borda sobre assembleias de besouros em fragmento de Mata Atlântica e pastagem em Sergipe, Brasil

Resumo. O avanço das fronteiras agrícolas e das pastagens contribuiu para a fragmentação da mata, e estes fragmentos são afetados por distúrbios de diferentes graus de intensidade que influenciam a fauna e a flora local. O objetivo deste trabalho foi analisar como a magnitude e extensão do efeito de borda e a sazonalidade influencia na riqueza e abundância de besouros. O experimento foi conduzido em uma área contendo mata, borda e pastagem pertencente ao Instituto Federal de Sergipe. Foram coletados 1.173 espécimes pertencentes a 16 espécies. As áreas de borda se destacaram apresentando maior riqueza e abundância de espécies caracterizada por ser uma área de distúrbio intermediário, enquanto que a área antropizada (pastagem) apresentou a menor riqueza e abundância de Coleópteros e maior variedade de besouros pragas, sugerindo que a ocorrência de algumas espécies de besouros-praga pode ser uma indicação de áreas degradadas. A abundância e riqueza da comunidade de coleópteros diminuíram na estação chuvosa. Pequenas distâncias entre o pasto, a borda do fragmento florestal e o interior deste fragmento parecem ser cruciais para determinar a estrutura da comunidade de besouros, reforçando a atenção à conservação de habitats para seu desenvolvimento.

Palavras-chave: Abundância; Fragmento florestal; Microescala ecológica; Pasto; Riqueza.

The Atlantic forest presents higher biological diversity than other Brazilian biomes, although it has been suffering constant human perturbations (Laurence *et al.* 2001). Currently, this Biome has 5% of original vegetation (Ministério Meio Ambiente 2012) distributed on dispersed forest fragments (Saunders *et al.* 1991), varying in their degree of size and conservation due to the deforestation for the agriculture and pasture deployment, selective logging of native trees, the construction of roads and fires (Fonseca 1985; Herrmann *et al.* 2005).

The forest fragmentation leads to a change in the species composition and abundance of the individuals. The habitat loss reduces the animals home range size and the interactions between individuals and species that could shift several common species close to the extinction and modify the assemblage structure and its biodiversity (Kobiyama *et al.* 2001; Primack & Rodrigues 2001).

The increase of the forest patch isolation causes the enhancement of the area exposition to abiotic factors (winds, temperature and humidity) that may influence the biotic factors (such as competition for food resource; vegetation regeneration). Also, human actions (pollution, climate change impacts, and soil degradation) (Mcgeoch 1998) influence the species composition.

The deforestation implies in the creation of forest subsamples: inside the forest, the edge, outside the forest (Ricklefs 2010). Other facts that contribute to the shifts in species composition are the size and the shape of a forest patch. Consequently, in the

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Corresponding author:
Talita Guimarães de Araújo-Piovezan
talit_a@hotmail.com
No ORCID record

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same area, forest patches present distinct biodiversity (Gilpin & Soulé 1986; Bell *et al.* 1991).

The habitat loss could be evaluated by the richness and abundance of the functional groups, like the invertebrates (Lopes *et al.* 1994) or through the bioindicators groups (Wink *et al.* 2005), for the understanding of the ecological factors that determine the species spatial distribution, just as the possible effects of human actions to landscape changes.

In terms of diversity, the beetles represent the best successful group among the living beings (Rafael 2012), occupying a variety of ecological niches in almost all environments (Daly *et al.* 1998; Johnson & Triplehorn 2011), and they may be forest pests, carnivores, herbivores, xylophagous, frugivorous, detritivores, necrophagous (Nichols *et al.* 2007; Johnson & Triplehorn 2011; Slade *et al.* 2011).

Usually insects and other invertebrates have their diversity and abundance increased as they are closer to the border area (Didham *et al.*1996). Some insect species may respond directly to microclimatic changes and this may modify community composition in edge environments (Jokimaki *et al.* 1998).

The fragmentation of ecosystems causes edge effect on insect community within the habitat fragments (Laurence *et al.* 2001) enhancing the diversity of arthropods in the neighboring regions (Albrecht *et al.* 2010). Therefore, the objective of this work was to analyze the influence of edge effect and seasonality on a community of beetles in São Cristóvão, Sergipe.

MATERIAL AND METHODS

Study site. This study was carried out at a 400 ha fragment of tropical Atlantic forest at the Federal Education Institute of Sergipe State of Brazil (Instituto Federal de Sergipe -IFS), located in the São Cristóvão Municipality, at a legal reserve (10º 54'38,0" S e 37º11'40.8" W) around 54 m of altitude with the forest edge (10º 54'40,7" S e 37º11'39.9" W) around 29 m of altitude and the pasture (10º 54'42.7" S e 37º11'41.8" W) around 33 m of altitude (Figure 1).

We conducted this experiment from September 2013 to August 2014. The annual average temperature of the study site was 25.5 ºC. For this study region, Santos *et al.* (2013) reported climate data from 1950-2011, recording the annual average temperature of 25ºC. The average temperature of the wet season (March to August) was of 24 ºC, varying from 20 ºC to 28 º C and the average temperature of the dry season(September to February) was of 25 ºC, varying from 21 º C to 31 ºC. They also reported the average relative air humidity of 92% (based on the precipitation records from 1963 to 2011), varying from 88 % to 97%. The local weather, according to Köppen classification is rainy tropical with a dry summer.

Data Collection. This experiment was conducted monthly from September 2013 to August 2014, which includes two seasons: the dry season (September –December 2013 and January–February 2014) and the rainy season of 2014 from March to August. We established five transects with 120 m of length each, that started inside the forest fragment, continuing on its edge and ending in the pasture. Each transect was located at least 100 m apart from the others, and along each transect, we set seven pitfall traps at 20-m interval from others. Thus, there were three traps on each habitat (forest and pasture) along each transect and one trap directly on the edge (physical limit between habitats), totaling 35 traps x 12 months (420 observations).

Each pitfall trap consisted of a 0.5-L container and was buried at ground level with water, salt and liquid detergent. After one week of exposition, the insects were collected from the traps and conditioned at alcohol 70%. At laboratory, the specimens were mounted and identified on genera and species according to literature. Representative individuals of each morphospecies were taken and incorporated into the collection Entomology Laboratory of the Instituto Federal de Sergipe (LENTO-IFS).

Data analysis. To examine the effects of edge distance and seasonality on the species richness and individual abundance, we ran generalized linear models (GLM). These models are suitable for ecological data of richness and abundance due the count data nature (Warton *et al.* 2016). All the models were submitted to the residual analysis to verify the suitable error distribution. For this, we have assumed the Poisson error distribution with logarithmic function (O'Hara & Kotze 2010), and once the overdispersion of the models was verified, these models were adjusted for the Negative Binomial error distribution (Lindén & Mäntyniemi 2011; Okamura *et al.* 2012).

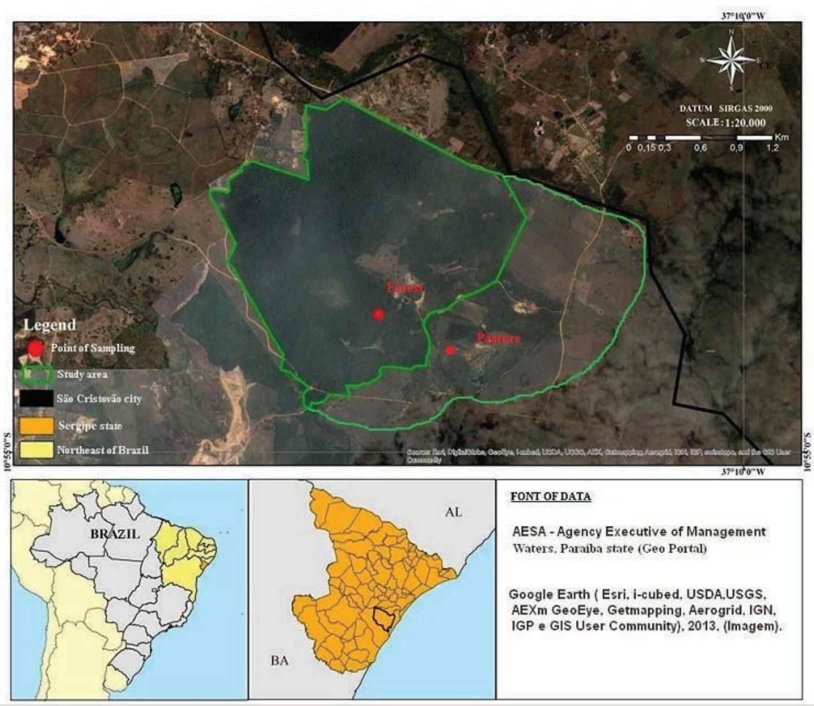

Figure 1. Study site with highlight to the forest patch, edge and pasture.

Secondly, we used a discriminant analysis to estimate the similarity (or divergence) of beetles composition between the habitats (pasture, edge and forest interior) (Williams 1983). Thus, one test was done for significant differences in the predictor variable among the predefined groups, using the Wilks' lambda test (Legendre & Legendre 2012). All analysis were made at R statistical software (R Core Team 2016).

RESULTS AND DISCUSSION

We collected 1,171 individuals, distributed in four families (Scarabaeidae, Carabidae, Bolboceratidae e Curculionidae), seven subfamilies and 16 species, where the Scarabaeidae was the most abundant through the *Dichotomius semiaeneus* Germar with 705 specimens (60.2%), *Onthophagus* sp.2 with 230 (19.64%) and *Onthophagus* sp.1 with 121 (10.33%), numbering 90.17% collected individuals (Table 1).

There was a significant difference in abundance of beetles between the forest edge, forest interior and pasture (Table 2). The beetles were more abundant on the forest edge (50.81%), followed by the inside of the forest patch (46.54%) and the pasture (2.64%; Table 1 and Figure 3).

The greater beetle's abundance on the forest fragments could be attributed to the higher resources availability, where mammals have greater probability of occurrence, consequently increasing the availability of animals' carcasses and excrements for species of Scarabaeidae (90.17% of the collected individuals). In this way, it is more likely to forestry environments more close to natural could host fruit trees, seeds and vegetables in decomposition for mammals, enhancing the supply of the food available (Silva & Silva 2011). On the other hand, in the pasture, normally, the only food supply is the cattle dung (Ronqui & Lopes 2006) and some dung beetles are known to prefer environments with diversity of dungs or they are selective to a specific animal excrement odor (Dormont *et al.* 2007).

In addition, it is known that the forest fragmentation affects the success of the establishment of certain species of beetles that might be able to occupy or not the perturbed areas, according to the habitat loss and the isolation degree of the forest fragment, the habitat connectivity reduction (Didham *et al.* 1996 & Harrison & Bruna 1999). The Atlantic forest fragment studied here is a continuous fragment of ~ 400 Ha, surrounded by pasture and cultured areas that affect the shelters and resource availability for the beetles assemblages. Probably, because of this only 2.64 % of the beetles collected were occupying the pasture.

The richness of the beetles was very similar among the pasture, the forest inside and the forest edge (Table 1). The same result was found by Ganho & Morione (2003), where the beetles families occurred in the same proportion in different types of forest fragments.

Table 1. Beetles (morpho) species with respective family and abundance recorded in the habitats (pasture, edge and interior of the fragment) and seasonality in Brazilian Atlantic Rainforest, Sergipe, Northeastern Brazil (September 2013 to August 2014).

		Phytophysiognomy	Forest		Edge		Pasture		Total
Family		**Seasonality**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	
Bolboceratidae									
	Bolbapium minutum		2	2	1	0	0	0	5
Carabidae									
	Clivina sp.		0	0	0	0	2	6	8
	Odontochila cupricollis koll		1	0	1	0	0	1	3
Curculionidae									
	Conotracelus sp.		0	1	0	0	0	0	1
Scarabidae									
	Phanaeus splendidulus		0	0	3	0	0	0	3
	Leucothyreus alvarengai		0	1	0	0	0	0	1
	Euetheola humilis		0	0	0	0	0	1	1
	Dyscinetus sp.		0	0	0	0	0	1	1
	Onthophagus hirculus		1	0	0	2	0	0	3
	Dichotomius semiaeneus		45	257	72	329	1	1	705
	Canthon sp.3		0	5	4	0	0	0	9
	Canthon sp.2		2	3	0	2	3	0	10
	Canthon sp.1		9	14	3	9	0	2	37
	Onthophagus sp.1		37	26	22	31	1	4	121
	Onthophagus sp.2		11	112	22	78	7	0	230
	Onthophagus sp.3		2	16	17	0	0	0	35
		Subtotal	**110**	**437**	**145**	**451**	**14**	**16**	
		Total	**547**		**596**		**30**		**1173**

Table 2. Analysis of deviance of the generalized linear models showing the effects of edge distance and seasonality on species richness and abundance of beetles at a fragment of Atlantic forest of São Cristovão, Sergipe, Brazil.

y-var	Terms	d.f.	Deviance	P > |X²|
Richness				
(Poisson)	Edge distance	6	66.46	<0.001
	Seasonality	1	6.07	<0.05
	Residuals	62	101.19	
Abundance				
(Negative Binomial)	Edge distance	6	85.91	<0.001
	Seasonality	1	7.42	<0.01
	Residuals	**62**	**87.40**	

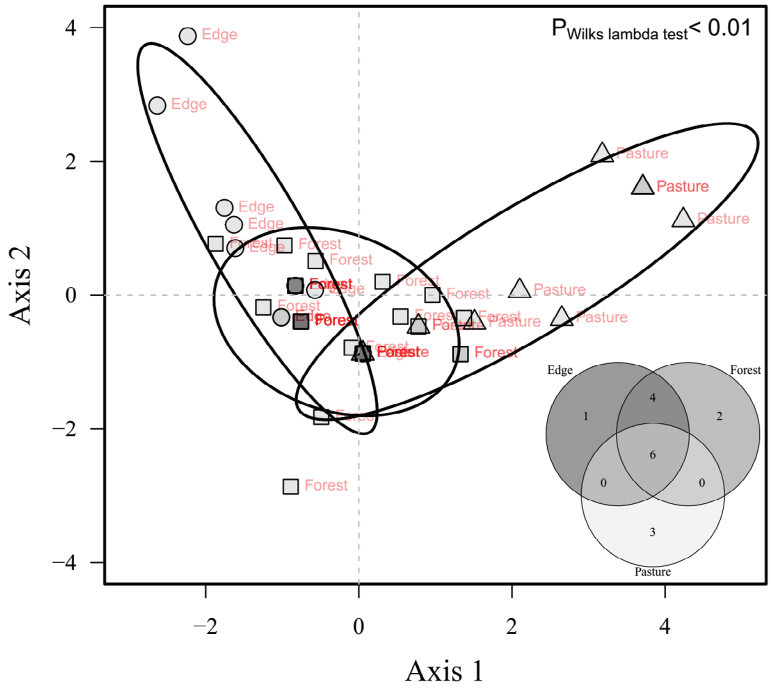

Figure 2. Plot of the Linear discriminant analysis shows the groups of the different phytophysiognomies (pasture, edge and forest) for beetles species composition at an Atlantic forest fragment, São Cristóvão, Sergipe, Brazil. The ellipses were made on confidence intervals of 85%. The venn diagram (details) shows the exclusive and non-exclusive species for each phytophysiognomy.

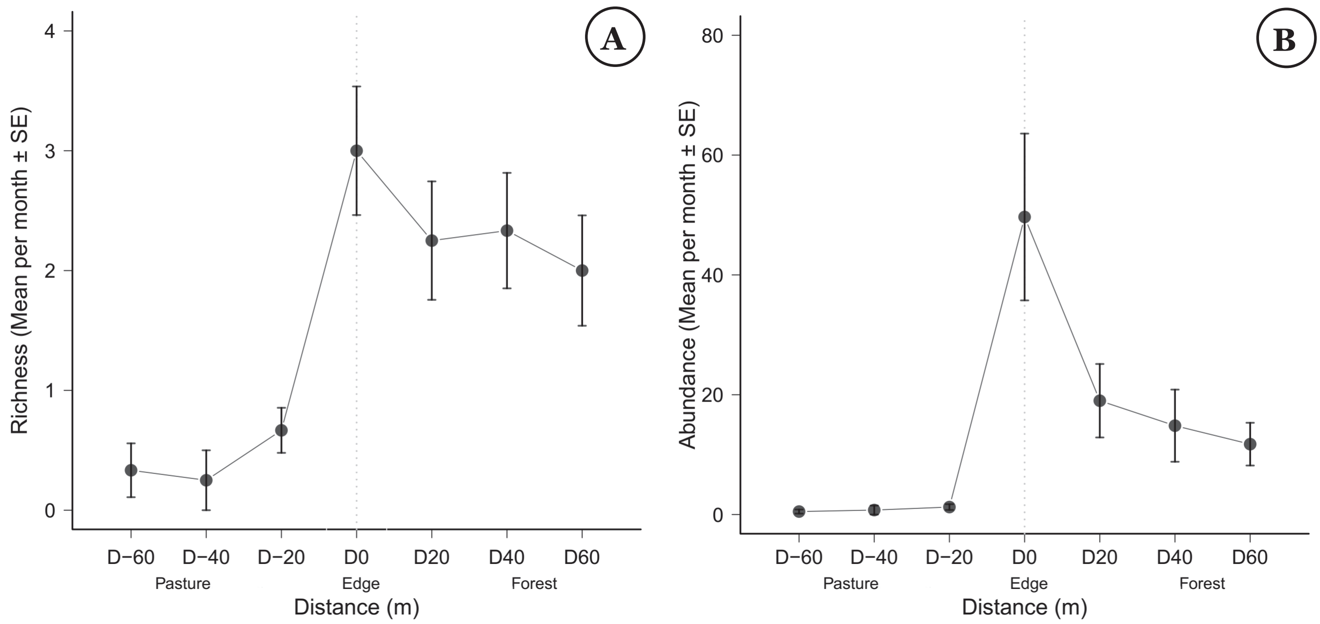

Figure 3. Species richness (A) and number of beetle individual (B) across the forest-pasture ecotone at a fragment Atlantic forest, São Cristóvão, Sergipe, Brazil. The results are based in generalized linear models showed in Table 2.

Although some species occur in more than one habitat, species composition is different among the sampled environments ($p<0.01$; Figure 2). Six species were common to the three types of vegetation fragments and five of them were from Scarabidae: *D. semiaeneus*, *Onthophagus* sp.2, *Onthophagus* sp.1, *Canthon* sp.1 and *Canthon* sp.2. Although the *D. semiaeneus* (0.14% of abundance in pasture), *Onthophagus* sp.2 (3.04%) and *Onthophagus* sp.1 (4.13%) take place in all types of vegetation fragments, their abundance records at anthropic areas were lower than 5 percent, suggesting that these species avoid perturbed areas.

There was also an exclusive occurrence of some Scarabidae species inside the forest fragments, such as the *Phanaeus splendidulus* Fabricius in the forest edge. The same was observed by Rodriguez (2016) for the *P. splendidulus*. Other species that occurred only in the forest patch were *Onthophagus* sp.3 (number of individuals = 35), *Canthon* sp.3 (7), *Onthophagus hirculus* Mannerheim (3), *Leucothyreus alvarengai* Frey (1), enforcing the needs of these beetles to forest environments.

For Bolboceratidae, we recorded the First occurrence of *Bolbapium minutum* Luederwaldt (5 individuals; Table 1) at Sergipe State-Brazil. Its occurrence was exclusively inside the forest fragment, enforcing that this studied forest patch is important for their survival.

For Carabidae, We also found *Odontochila cupricollis* (Carabidae) occupying all three kinds of vegetation but with low representativeness of individuals but the *Clivina* sp. presented the higher number of individuals at the perturbed areas (n=8; Table 1) among all the beetles collected, being a dominant species at pasture. The Carabidae (*Clivina* sp. and *O. cupricollis)* are known to be predators beetles (French & Elliott 1999).

On the other hand, the distance between the forest edge and the forest patch inside showed significant difference in the

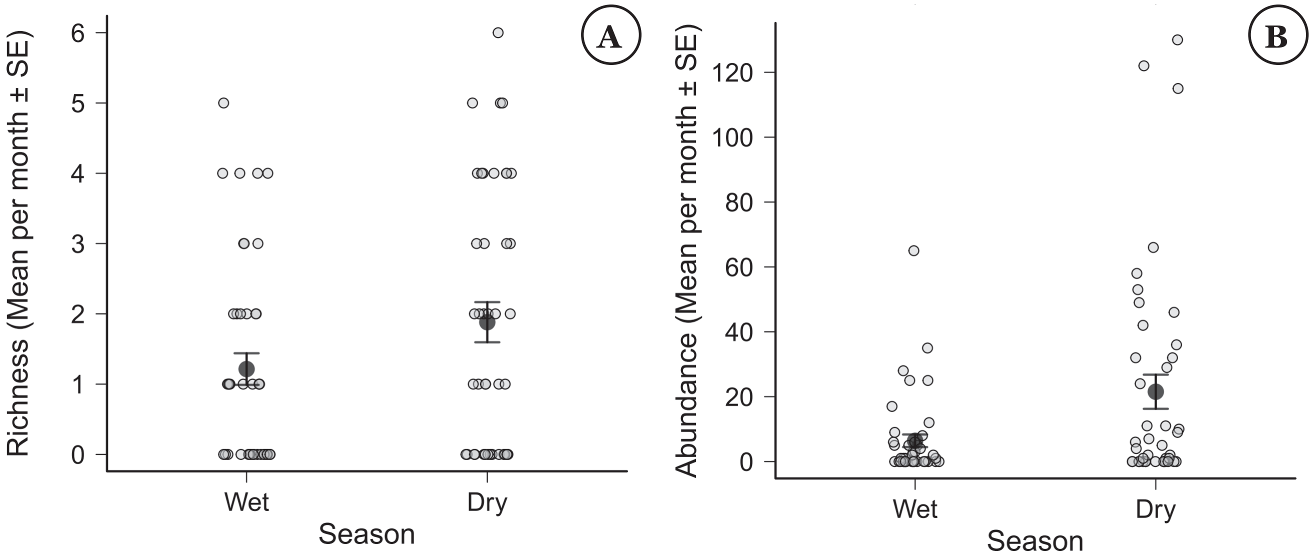

Figure 4. Species richness (A) and number of beetle individuals (B) at dry and wet seasons sampled along all study. The results are based in generalized linear models showed in Table 2.

abundance and richness of the beetles ($p<0.05$; Table 2). The closer to the forest edge, the greater species abundance and richness is found, especially within the 20-m interval. However, following the direction from the forest edge to the pasture, the species abundance and richness reduce drastically, bolstering the ecological hypothesis of the intermediate disturbance (Townsend *et al.* 2008). This hypothesis shows that areas which undergo intermediate perturbations, such as forest edge, have greater species diversity, while areas that sustain intensive perturbation, such as pasture, present an establishment of several dominant species that are more resistant to high perturbations. However, areas inside the forest undergo low perturbations. Therefore, they present greater species on the ecological succession process with more degree of competitive exclusion than the intermediate perturbed areas (Ricklefs 2010).

Ganho & Marione (2003) found that beetles were more abundant in the areas of forest recovering, with intermediate perturbation (ecotones) due to the light intermediate intensity and consequently, greater richness of the plants available for mammals and indirectly higher occurrence of mammals dung and carcasses, which are the main beetles feed stock. In addition, ecotones are characterized by presenting higher biodiversity and occurrence of endemic species (Milan & Moro 2016).

Taking into consideration the small spatial scale of beetles dispersion in comparison to mammals, it is crucial to observe that small distances from the forest edge (~20m) to pasture or to forest patch inside represent big differences in the beetles assemblages composition. Moreover, there is a rise in the dominant species abundance as the forest fragmentation degree increases, affecting the individuals distribution (Nichols *et al.* 2007).

In general, animals diversity is correlated to food resource (Townsend *et al.* 2008) as Silva (2012) showed an enhance of ants diversity from the forest edge to the forest patch inside, linking this fact to the increase of the litter volume driven for forest interior, once ants seem to need litter to build their nests. Other beetles (Scarabaeidae) study bared none abundance and richness difference between these fragments, suggesting beetles food resource (mammals dung) were similar among the forest patch inside and its edge (França *et al.* 2011).

There was a significant difference in the richness and abundance of beetles between the dry and wet seasons (Table 2), with higher richness and abundance in the dry season (Figure 4). By the dry season we collected 904 beetles of 15 species (77.2%,) and by the rainy season we collected 267 beetles of 11 species (22,8%) (Table 1). The *P. splendidulus* was only found at the rainy season. The *Onthophagus* sp.2 was found in the pasture only during the rainy season.

Paiva (2009), studying beetles assemblages fluctuations (Scarabaeidae) affected by the rainy season and air humidity showed results that corroborate with this study, just as Condé (2008), showing that the beetles abundance (Scarabaeidae) was greater among the dry months (September to February), with 75% of the total of individuals collected, and the beetles abundance and richness for the rainy season was reduced. On the other hand, for other groups, of dung beetles assemblages, Andresen (2005) exhibited a higher dung beetles abundance for the enhance of the rainfall.

The rainfall has an important role on the beetles assemblages structure related to their behavior and diet dynamics, once the rainfall alters the proportion and quality of the vegetation resources available to mammals, which affects the mammals dung and carcasses availability to beetles. Therefore, the beetles assemblage of the Atlantic forest of Sergipe has their behavior development influenced by the rainfall periods during the year.

The beetles assemblage of the Atlantic forest of Sergipe has their behavior development influenced by the rainfall periods during the year, probably because the rainfall could not possibly contribute to the increase of beetles food available.

The environment fragmentation is a process of disruption of the continuous space of the habitat. It causes habitat structure changes, due to the decrease of the original size of the fragment or to the increase of the degree of isolation of the forest fragment (Milan & moro 2016), disfavoring the local species. In this way, the forest loss reduces the species diversity, promoting the occurrence of dominant species adapted to intensive disturbance of the abiotic factors, once the species become more vulnerable to the external pressures (Forero-Medina & Vieira 2007).

Considering that beetles assemblages are very sensitive to forest loss, varying their abundance and richness at a 20m-distance from the forest edge to forest fragment or to the pasture, beetles are marvelous indicators of the degrees of preservation of the environments and must be used for the conserved plans approaches. On the other hand, because soft changes in the forest patch fragmentation surrogate beetles community, their abundance and richness are more dependent on the conserved areas. Thus, habitats conservation is a desirable condition for the survival of beetles assemblages.

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