Articles

HOWLERS IN AN ANTHROPOGENIC MATRIX: HOW DOES AN *ALOUATTA BELZEBUL* GROUP DEAL WITH THE SEVERELY FRAGMENTED LANDSCAPE OF THE ATLANTIC FOREST IN NORTHEASTERN BRAZIL?

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Abstract

The red-handed-howler-monkey (*Alouatta belzebul*) is vulnerable to extinction mainly due to habitat loss and fragmentation, as well as hunting pressure. In its Atlantic Forest range, small populations inhabit 31 sparse fragments in a landscape dominated by a matrix of sugar cane plantations, pastures and urban areas. The aim of the present study was to analyze the use of space, activity pattern and diet of *A. belzebul* in a small secondary forest fragment (1.8 ha) and its surrounding anthropogenic matrix in Paraíba, Brazil, in order to understand how howlers deal with fragmentation. We used Scan Sampling and grid cell (0.25 ha each) methods to record the data. The home range was estimated to cover 8.75 ha, and, although the matrix area was more than twice as large as the forest area, the frequency of use was roughly equal (50.2 % matrix; 49.8 % forest). Daily ranges were also not significantly different between the days of forest and matrix use and for displacements; in the latter, howlers crossed sugarcane plantation, dirt roads and barbed wire fences. "Travelling" occurred more frequently in the matrix and "feeding" was more frequent in the forest. Fifty-eight different plant species were consumed, including important resources obtained in the matrix. We provide evidence that anthropogenic matrices can be included as an important part of this species' home range and food resources. This information provides support for planning urgently required habitat management strategies for the conservation of this species, aiming to ensure secure dispersal and reduce their exposure to conflict with humans and environmental constraints.

Keywords: Use of space, activity patterns, matrix permeability, Red-handed Howler Monkey.

Resumo

O guariba-de-mãos-ruivas (*Alouatta belzebul*) é ameçado de extinção, categorizado como "Vulnerável", devido à perda e fragmentação do habitat, bem como à pressão da caça. Na Mata Atlântica, pequenas populações habitam 31 fragmentos em uma paisagem dominada por uma matriz de cana-de-açúcar, pastagens e áreas urbanas. O objetivo do presente estudo foi analisar o uso do espaço, padrão de atividade e dieta de *A. belzebul* em um pequeno fragmento de floresta secundária (1.8 ha) e sua matriz antropogênica circundante na Paraíba, Brasil, a fim de compreender como os guaribas lidam com a fragmentação. Para tanto, o grupo de estudo foi monitorado através dos métodos de varredura instantânea e do esquadrinhamento da área (0.25 ha cada). A área de vida foi estimada em 8.75 ha e, embora a área da matriz seja mais do que o dobro da área de floresta, a frequência de uso foi aproximadamente igual (50.2 % na matriz; 49.8 % na floresta). Os percursos diários não apresentaram diferença significativa entre a floresta e a matriz, assim como o deslocamento: neste último os guaribas atravessaram plantações de cana-de-açúcar, estradas de terra e cercas de arame farpado. O "deslocamento" foi mais frequente na matriz e a "alimentação", na floresta. Foram consumidas 58 espécies de plantas diferentes, incluindo importantes recursos obtidos na matriz. Tais resultados fornecem evidências de que as matrizes antropogênicas podem ser incluídas como uma parte importante da área de vida e dos recursos alimentares desta espécie. Essas informações podem subsidiar o planejamento de corredores florestais, fundamentais para a espécie, garantindo uma dispersão segura e reduzindo a exposição a conflitos humanos e restrições ambientais.

Palavras-chave: Uso do espaço, padrão de atividades, fragmentação, matriz de permeabilidade, guariba-de-mãos-ruivas.

Introduction

A majority of primate species are found in extremely heterogeneous environments composed of forest fragments immersed in different types of land highly modified by human activities – the anthropogenic matrix (Arroyo-Rodríguez *et al.*, 2017; Estrada *et al.*, 2017). Consequently, these human activities surrounding their natural habitat may affect and cause significant changes in activity patterns, use of space and consumption of food resources (Juan *et al.*, 2000). The behavioral flexibility of primates is particularly relevant in these landscapes, due to its potential implications for effective dispersal and food exploitation, introducing the possibility of reducing the impacts of population isolation, with demographic and genetic consequences, and environmental constraints (Jones, 2005). Understanding how particular primate species respond to fragmentation and the expanding anthropogenic matrix is fundamental for adequate planning of effective strategies for their conservation, such as wildlife corridors (Hilty *et al.*, 2006).

Howler monkeys, genus *Alouatta*, are known to present relatively high behavioral flexibility when living in these modified landscapes and are particularly known for their ability to survive in small and altered fragments (Schwarzkopf and Rylands, 1989; Kowalewski and Zunino, 1999; Bicca-Marques, 2003; Arroyo-Rodrigues *et al.*, 2007; Arroyo-Rodriguez and Dias, 2009; Orihuela *et al.,* 2014). These species frequently show plasticity concerning home range size, social structure, movement pattern and howlers can complement their diet with items present in anthropogenic matrices, like orange, guava and mango trees (Bicca-Marques and Calegaro-Marques, 1994; Asensio *et al.,* 2009; Grande, 2012; Gómez-Posada and Londoño, 2012; Chaves and Bicca-Marques, 2017; Corrêa *et al.*, 2018).

The red-handed howler monkey, *Alouatta belzebul* (Linnaeus, 1766) is endemic to Brazil and presents a disjunct distribution, with its largest part in eastern Amazonia and a small number of populations in the Atlantic Forest of northeastern Brazil. Habitat loss and fragmentation, as well as hunting pressure, are the main threats for this species, classified as Vulnerable by both the national and global lists of threatened species (MMA, 2014; Valença-Montenegro *et al.*, 2019). The situation for *Alouatta belzebul* in the Atlantic Forest is far worse than in the Amazon; in the Atlantic Forest only very small populations remain, inhabiting 31 forest fragments immersed in a landscape dominated by matrix features such as sugar cane and pasture monocultures, and urban areas (Fialho *et al.*, 2014; Ludwig *et al.*, 2016; Valença-Montenegro *et al.*, 2019). In the state of Paraíba, where most of the species' populations are concentrated in this region, the landscape is extremely anthropized, with only 1.16% and 656 km^2 covered by the original Atlantic Forest vegetation (Campanili and Prochnow, 2006).

Strategies to reverse this situation were determined in 2011 in the National Action Plan for the Conservation of Northeastern Primates (PAN PRINE) in Brazil, with one of the plan's five specific goals forest protection and restoration to promote habitat connectivity (ICMBio, 2018). Nevertheless, to adequately implement these measures to effectively enhance the survival and dispersal of primates and to reduce the demographic and genetic impacts of isolation on populations, it is essential to understand how the species are dealing with fragmentation in their specific landscapes.

The aim of the present project was to conduct an ecological-behavioral study to analyze the use of space, activity pattern and diet of an *Alouatta belzebul* group in a small Atlantic Forest fragment and its surrounding matrix in Paraíba, Brazil. On a broader scale, we expect the results to serve as a case study to understand the functional connectivity of this landscape for the species and to support further actions to promote habitat restoration and reduce population isolation.

Material and Methods

Study site

The study was carried out in the *Mata do Angico* (7°2'49"S; 35°9'56"W), at the municipality of Sapé, Paraíba state (Fig. 1), which is a small fragment of secondary Atlantic Forest with 1.8 ha. Its surrounding matrix is dominated by dirt roads, sugar cane and pasture monocultures (enclosed by barbed wire fences), orchard and bamboo areas. The *Mata do Angico* site is about 800 m distant from the private protected area *RPPN Fazenda Pacatuba*, which includes the Pacatuba Forest (~266 ha), where the highest density of howlers has been recorded for the Atlantic Forest (94.7 individual/km^2) (Hue *et al.*, 2016). Both areas are part of the "*Pacatuba-Gargau*" corridor, whose ongoing restoration has been accomplished by two NGOs and a sugarcane ethanol company, collaborating with the PAN PRINE implementation. This corridor will also benefit the *Sapajus flavius,* which is another endangered primate species.

The region is of tropical climate, hot and humid, with temperatures ranging from 20 °C to 28 °C. There are two marked seasons: the wet season (March-August) and the dry season (September-February) when many trees lose their leaves. The annual rainfall in 2017 was 131.1 mm (data from Usina Japungu laboratory).

Data Collection

From January to December 2017 howlers were observed for four or five days per month, from dawn until dusk. The group composition varied from four to five individuals: 1 adult male; 1 sub-adult male; 0-1 adult female; 2 juveniles (sex undetermined). Data about activity patterns, use of space (including GPS readings) and diet were obtained using the scan sampling method, at intervals of 15 minutes (Altmann, 1974; Setz and Hoyos, 1986; Setz, 1991; Cullen Jr. and Valladares-Pádua, 1997; Ludwig *et al.*, 2015).

Plant species observed to be consumed by howlers were collected and identified by botanists at the Federal University of Paraíba (UFPB) herbarium (JPB- Herbário Lauro Pires Xavier). Additionally, fecal samples were collected monthly, washed and screened in the laboratory, and seeds were identified in the same herbarium. Each plant species registered in a fecal sample was considered as one occurrence of frequency for the month. So, every percentage mentioned here is a combination of the number of scans where the animals were eating that plant added to the fecal sample with the seeds of the same plant seeds detected. The identification followed the Flora System of Brazil, which is part of the Reflora Program of the Botanical Garden of Rio de Janeiro (Flora do Brasil, 2020).

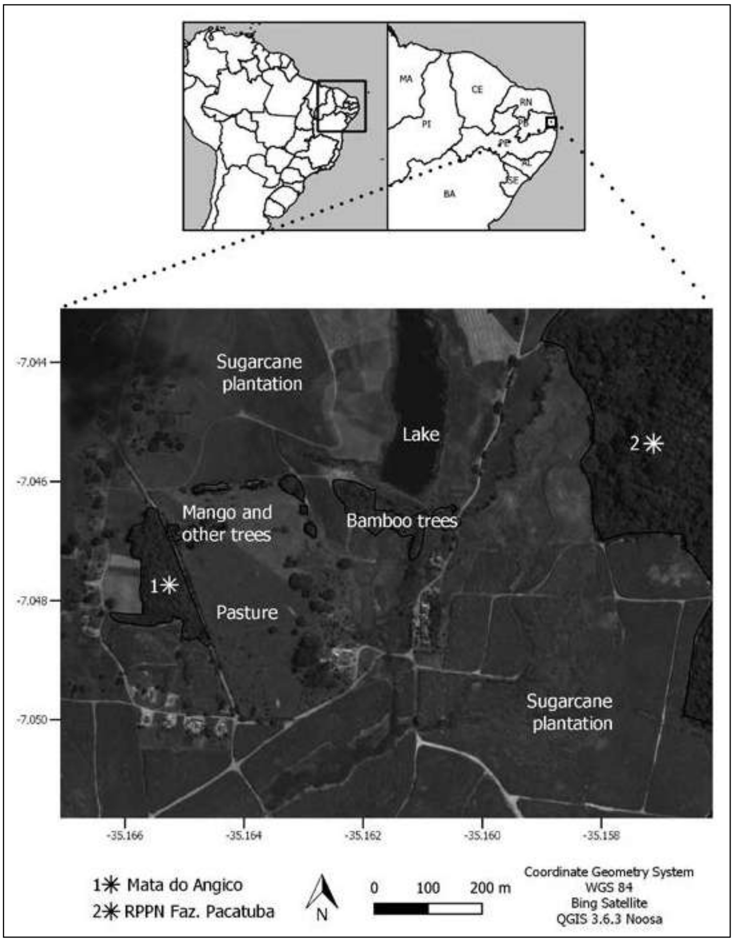

Figure 1. Study site: Mata do Angico and its surrounding matrix (dirt roads, sugar cane plantation and pasture, orchard and bamboo areas), about 800 m from the private protected area RPPN Fazenda Pacatuba.

Day ranges were estimated from the connection of the GPS readings. The use of space was obtained by adding the frequency of use of the GPS readings in the quadrants. The grid cell method, by far the most used method in studies on primates, was used with quadrants of 0.25 ha (NRC, 1981; Brockelman and Ali, 1987; Ostro *et al.*, 1999; Grueter *et al.*, 2009). In this method all quadrants visited by the animals are included in the home range. These quadrants were distinguished by forest (Mata do Angico) or matrix (including all components mentioned above as non-forest), and the frequency of use determined by time dedicated by the animals in activities in each of them. Data were classified according to the presence of the animals in the forest versus the matrix environments. The binomial test for two proportions and T test (two samples assuming different variances) were applied using BioEstat 5.3 and were considered to be significantly different whenever a p-value < 0.05 was obtained.

Results

Overall, 5,724 records were obtained during 505 hours of directly observing the howler group. The howlers used the matrix slightly more (50.2 %) than the forest (49.8 %), and in both environments specific locations were more frequently used, such as trees used as sleeping or resting sites, or for feeding (Fig. 2). In the matrix, the use of *Bambusa* sp. (bamboo) and orchard areas was predominant at the expense of other landscape elements, such as pasture and sugarcane monocultures. Bamboo areas were used mainly for resting or traveling to the orchards, which were dominated by mango, banana and cajá (*Spondias mombin*) trees.

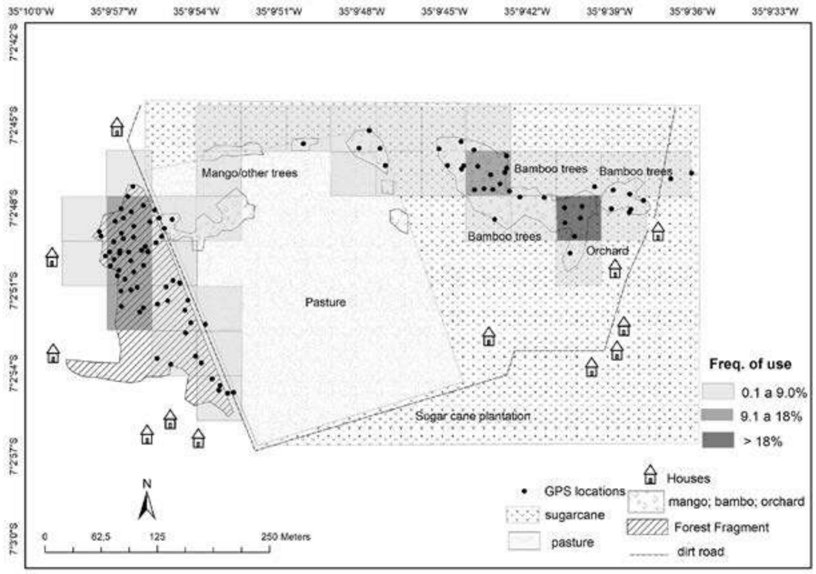

Figure 2. Home range and use of space of the studied Alouatta belzebul group in the forest fragment "Mata do Angico" and its surrounding matrix, Sapé, Paraíba (7°2'49"S; 35°9'56"W). The area of each quadrant is 0.25 ha.

The group spent most of the time resting (57.9 %), followed by travelling (18.9 %), feeding (16.7 %) and social interaction (5 %). Feeding was significantly more frequent in the forest (58.7 %) ($Z = 4.25$; $gl = 1$; $p < 0.0001$), while travelling was more frequent in the matrix environment (55.2 %) ($Z = -5.64$; $gl = 1$; $p < 0.0001$). The predominant forest strata used for the activities in both areas was the canopy (91.1 %).

The animals consumed mainly leaves (75 %), mostly mature (43.4 %), followed by fruits (18.2 %), flowers (5.7 %) and others (1.0 %). Leaves were the item predominant in diet in both environments. It was consumed equally across the seasons, while fruits were consumed more frequently in the wet season (63.3 %). Fruits were consumed significantly more in the matrix ($Z = -2.8$; $gl = 1$; $p = 0.002$), and flowers in the forest ($Z = 6.1$; $gl = 1$; $p < 0.0001$), based on behavioral observations and fecal sample seeds, howlers consumed 58 plant species (16 unidentified). The majority (55.2 %; n = 16 samples) of the 29 fecal samples analyzed had seeds, where seven different species could be identified. The main plant species recorded for flower consumption were lianas.

Grouped in 27 families, Fabaceae presented the highest number of genera of plant resources for the howlers (N = 10) and was the most frequently consumed (41.9 %) (Table 1). The consumption of arboreal species predominated, and the forest environment provided a greater richness of species. The most consumed plant species was *Machaerium hirtum* (26.8 %), followed by *Anadenanthera colubrina* (11 %) – dominant in the forest – and *Mangifera indica* (10.7 %) and *Cecropia palmata* (9.13 %) – mainly obtained in the matrix.

The used quadrants covered a total home range of 8.75 ha, with the majority falling in the matrix (6 ha; n = 24 squares) and a smaller area of forest (2.75 ha; n = 11 squares) (Fig. 2). Day ranges showed no significant difference between forest use (339 ± 182m) and matrix use (375 ± 151m) ($t = -0.7$; $gl = 51$; $p = 0.22$). To travel through the anthropogenic matrix, howlers crossed sugarcane plantations and dirt roads on the ground, and, walked along barbed wire fences that border the pasture (Fig. 3). They used the same path regularly in trees that joined above roads and fences next to some sparse trees in the landscape. The maximum open ("without trees") distance crossed was 66 m, through sugarcane monocultures planted in lines perpendicular to the departure and arrival environments. A total of 20 crossings were recorded between the forest and the bamboo trees (318 m), each took in average four hours, stopping in the sparse trees.

Figure 3. A Red-handed Howler Monkey walking along a barbed wire fence around the pasture in the matrix.

Table 1. Plant species, items consumed recorded by direct observations and fecal samples (fr: fruit; ml: mature leaf; yl: young leaf; fl: flower; o: other), type (A: arboreal or L: liana), season of the year it was consumed (W: wet season; D: dry season) and environments that is located (F: forest and/or M: matrix) by the *Alouatta belzebul* group and relative frequencies, with items > 9% in bold.

Family/ Plant species	A/L	Items	D	W	F	M	%
Anacardiaceae							
Mangifera indica L.*	A	fr, ml, yl	x	x		x	10.70
Spondias mombin L.	A	fr, ml	x	x		x	1.89
Annonaceae							
Annona sp.	A	fr		x	x		0.10
Araliaceae							
Schefflera morototoni (Aubl.) Maguire *et al.*	A	yl		x	x		0.10
Arecaceae							
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	A	ml	x		x		0.21
Syagrus oleracea (Mart.) Becc.	A	fr, ml	x		x		1.05
Aristolochiaceae							
Aristolochia sp.	L	ml, yl	x	x		x	1.26
Bambuseae							
Bambusa sp.	A	ml, yl	x	x		x	0.63
Bignoniaceae							
Fridericia sp.	L	flo		x	x		1.78
Handroanthus sp.	A	ml, yl	x	x		x	2.62
sp.16	?	yl		x			0.21
Boraginaceae							
Cordia superba Cham.	A	fr	x	x	x		0.21
Capparaceae							
Capparis flexuosa (L.) L.	A	yl		x	x		0.63
Erythroxylaceae							
Erythroxylum sp.	A	fr		x	x		2.31
Fabaceae							
Anadenanthera colubrina (Vell.) Brenan	A	flo, fr, ml, yl	x	x	x		11.02
Inga sp.	A	ml, yl	x	x	x		0.52
Enterolobium contortisiliquum (Vell.) Morong	A	ml	x	x		x	0.84
Machaerium hirtum (Vell.) Stellfeld	A	ml, yl, flo	x	x	x		26.76
Calopogonium sericeum (Benth.) Chodat and Hassl.	L	ml	x	x	x		0.84
Bowdichia virgilioides Kunth	A	ml, yl	x	x	x		0.42
Geoffroea spinosa Jacq.	A	ml	x		x		1.15
Senegalia polyphylla (DC.) Britton and Rose	A	o	x		x		0.10
Centrosema plumieri (Turpin ex Pers.) Benth.	L	ml	x		x		0.10
Andira sp.	A	ml	x		x		0.21
Lamiaceae							
Vitex rufescens A.Juss.	A	yl	x		x		0.52
Leguminosa							
Samanea inopinata (Harms) Barneby and J.W.Grimes	A	ml	x	x		x	0.52
Loganiaceae							
Strychnos parviflora Spruce ex Benth.	A	fr, ml	x	x	x		1.99

Continued on page 12

Table 1. *Continued from page 11*

Family/ Plant species	A/L	Items	D	W	F	M	%
Malpighiaceae							
sp.8	?	yl, flo	x				0.42
Byrsonima sp.	A	fr	x	x		x	0.31
Malvaceae							
Guazuma ulmifolia Lam.	A	ml, yl	x	x		x	1.15
Meliaceae							
Guarea guidonia (L.) Sleumer	A	ml	x	x	x		0.21
Moraceae							
Artocarpus heterophyllus Lam.	A	fr	x		x		0.10
Musaceae							
*Musa acuminata Colla**	A	fr		x		x	0.31
Nyctaginaceae							
Guapira opposita (Vell.) Reitz	A	ml	x		x		0.31
Guapira laxa (Netto) Furlan	A	ml		x	x		0.10
Guapira sp.	A	ml, yl		x	x		0.63
Polygalaceae							
Securidaca diversifolia(L.) S.F.Blake	L	yl	x		x		0.10
Polygonaceae							
Coccoloba sp.	A	ml, yl	x	x		x	4.09
Rhamnaceae							
Ziziphus undulata Reissek	A	ml, fr	x	x		x	4.72
Rubiaceae							
Genipa americana L.	A	ml	x			x	0.10
sp.7	?	fr	x				0.10
Sapindaceae							
Talisia esculenta (Cambess.) Radlk.	A	fr, yl	x	x	x		1.47
Solanaceae							
Solanum sp.	A	fr	x		x		0.21
Urticaceae							
Cecropia palmata Willd.	A	ml, yl	x	x		x	9.13
Pourouma guianensis Aubl.	A	yl	x		x		0.10
Indeterminate							
sp.1 up to sp.15	?	fr, ml, yl					7.35
Water							0.52
Total							100 %

*Exotic species

Discussion

In our study *Alouatta belzebul* used the matrix surrounding the small forest fragment, including all non-forest elements, at a higher frequency than expected for an arboreal primate. The results provided evidence for the importance of these landscape elements for all the observed howler activities, mainly for traveling and feeding. The distribution and abundance of key species of consumption in the matrix or opportunity to move to other places, such as the orchard, in addition to safe places to rest, as the bamboo patches, can explain this higher frequency of use.

It is clear that reduction and fragmentation of natural primate habitats limits dispersal and restricts diets; for this reason, the matrix proved to be an important element for supplementing the animals' diet, as observed in other atelids (Grande, 2012), including howler species (Pozo-Montuy *et al.*, 2011; 2013; Chaves and

Bicca-Marques, 2017; Arroyo-Rodríguez *et al.*, 2017). This allows for the maintenance of populations at high densities even in small fragments (Pozo-Montuy *et al.*, 2011; 2013), such as the study fragment. Nearby RPPN Pacatuba has a superabundance of howlers, with a density of 32.2 groups of howlers/km² and an estimated population of 252 individuals living in a fragment of 266.53 ha (Hue *et al.*, 2016). Our group in Mata do Angico was likely formed by individuals dispersing from this forest.

The highest frequency of use was in quadrants that offered some advantage to howlers, such as a tree that accommodated the whole group with protection, shade, and a place to rest or sleep (like the bamboo patches). Howlers also frequently used quadrants with food resources. The home range size of the group was within the expected variation limits for the species (Bonvicino, 1989; Souza, 2005; Coutinho, 2012; Silva, 2015). Generally, primates of the genus *Alouatta* have small home ranges in relation to their body size (Crockett and Eisenberg, 1987). However, unlike the cited studies, where primates used only the forests, here the matrix comprised the largest part of the howlers' home range. This reinforces the idea that howler groups may expand their home ranges in low quality environments, permitting their survival in small fragments (Pozo-Montuy *et al.*, 2013). Besides of the matrix dominate the landscape, it could provide the animals the fruit item most consumed (mango).

On the other hand, day range sizes were below those previously reported for the species (Bonvicino, 1989; Jardim, 1997; Pina, 1999; Pinto, 2001; Camargo, 2005; Souza, 2005; Coutinho, 2012). The average values obtained in the present study fell below even lowest day range ever recorded, which was of 450 m, in the private reserve near the study area (Bonvicino, 1989). Another similarly low average day range (454 m) was recorded for an *Alouatta caraya* group inhabiting a forest fragment of 2 ha (Bicca-Marques, 1994).

The spatial arrangement of fragments can favor or hinder dispersal, depending on a species' perception capacity, which is defined as the maximum distance that an animal can directly recognize the landscape around it. This influences movement between fragments and can be used to infer functional connectivity in the landscape (Lorini, 2015). In this modified landscape, howlers' ability to move through the sugarcane matrix was facilitated by the orientation of the planting lines, that allowed the animals to detect the destination habitat, thereby, allowing for faster arrival at the destination and the detection of possible threats in the pathway. However, these benefits may be minimized after harvest, with the animals being more exposed and disoriented while crossing these more open areas.

As expected, the temporal budget of daily activities was found to be different between the environments used and were similar to patterns previously found for the species (Bonvicino, 1989; Souza, 2005; Coutinho, 2012; Silva, 2015). Richness of plant species consumed is higher in the forest, suggesting that animals need to travel less in this environment to obtain food and that they feed more frequently in the forest when compared to the matrix environment. The continuity of the canopy observed in the forest, unlike the matrix, may also result in less time dedicated to travelling in this environment. The canopy was the main stratum used by howlers, providing greater security against semi-arboreal predators, a more extensive visual range and higher availability of resources (Mendes, 1989).

Regarding howler diet, the item "leaf" predominated, as expected for the genus considered to be the most folivorous among Neotropical primates (Crockett, 1998). Folivory may buffer extirpation risk, as howler populations can survive in small areas compared to other primates (Ludwig *et al.*, 2008). The high consumption of fruits in the matrix was mainly due to the use of orchards in the surrounding community. As mentioned by Bonvicino (1989), in the study area, fruit production predominates in the rainy season, when the animals consumed more of this food item. In dry season the fruits consumed were mainly from the orchard. The use of a matrix to consume predominantly orchard items was also reported for *Alouatta caraya* (Grande, 2012). Also, flowers were consumed mainly from lianas, which are widely available in the forest but scarce in the matrix, which may explain this difference. Adding the plant species identified (42 taxa) consumed by the studied group to the species previously recorded in howler diets at RPPN Fazenda Pacatuba (Bonvicino, 1989; Souza, 2005; Coutinho, 2012), gives a total of 96 taxa (including arboreal and non-arboreal plants- like shrubs, lianas and epiphytes) with a prevalence of tree species. As a floristic and phytosociological study identified the presence of 68 arboreal species in the RPPN (Dionísio, 2002), it seems that despite the low diversity of food resources, howlers are feeding on much of what is available.

Environmental enrichment and planting of forest corridors with the aim of conserving threatened species, must consider the main food resources consumed by the target species. This and other studies highlight some key tree species (not including the exotic ones) of great importance: *Brosimum* sp., *Tapirira guianensis*, *Ficus* sp. and *Cecropia* sp. (Bonvicino, 1989); *Tabebuia nodosa* and *Simarouba amara* (Coutinho, 2012); *Trichilia hirta*, *Bowdichia virgiloides* and *Tabebuia* sp. (Souza, 2005); *Anadenanthera colubrina* and *Machaerium hirtum* (present study). Despite little feeding on bamboo trees, these patches were frequently used by howlers for travelling and resting. This plant is widely cultivated in the state of Paraíba due to its use for cement packaging (Embrapa, 2018), and these bamboo patches may act as stepping-stones for the displacement of howlers in the matrix (Hernández, 2014).

The present results corroborate the high capacity of some primates in adapting their activities to new environmental conditions, using the matrix at higher frequencies in order to supplement their diet and even using cultivated areas for resting and other activities. Nevertheless, primates in these conditions may be more exposed to threats due to the proximity of residential houses, unpaved roads with a moderate flow of vehicles, and the presence of domestic animals observed in the study area. This may increase the occurrence of electrocutions, roadkill and attacks by dogs (Lokschin *et al.,* 2007). In an area not so far from the study area (~3.5 km), there are records of deaths of howlers by electrocution (Ludwig, personal observation). In this context, the survival of howlers in this landscape must be directly related to improving the functional and structural connectivity of the remaining habitats, and implementing wildlife corridors (Hilty *et al.*, 2006). Planning such ecological corridors, including the restoration and enrichment of the fragmented areas with the key plant species indicated here, is as a cornerstone strategy for species conservation. These measures may allow howlers to move more safely from one fragment to another, favoring effective dispersal between groups and the search for new food sources, thereby mitigating the impacts of habitat fragmentation (Beier and Noss, 1998; Haddad *et al.*, 2003).

The ecological-behavioral information about a small group of *A. belzebul* inhabiting a highly fragmented environment reported here contributes to our understanding of how howlers can deal with this kind of context and indicates some possibilities that can be implemented in order to reverse this threat. Further in-depth spatial analyses may provide detailed answers about the landscape scale effect on the population structure of species. In practical terms, the existence of *A. belzebul* in the northeastern Atlantic Forest depends on the effective implementation of urgent measures to reduce habitat fragmentation.

Acknowledgments

We are grateful to Usina Japungu for permitting the study in RPPN Fazenda Pacatuba and surrounding areas, and especially to Mr. Antonio Campos, for the logistical support. We'd like to acknowledge Dr. Rubens Teixeira de Queiroz and Luiz Henrique Liberato Moreira, from the UFPB herbarium, for the identification of botanical material and species. Also, we are grateful to Luciana Gosi Pacca, for the map of the study site, and to the two reviewers which contributed to improve this paper. Gabriela Ludwig received a postdoc scholarship from Fundação de Apoio à Pesquisa do Estado da Paraíba (Fapesq–PB) and CNPq. Gabriel Yan Figueiredo Lima received a scholarship from the CIEE-ICMBio program.

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