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Bats in settlements from an atlantic forest area in northeastern Brazil

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ABSTRACT

Bats are key components of ecological networks, and studies in degraded areas are especially important to understand the impact of the human settlements on bats communities. Here, we surveyed the bat fauna in Guaribas Biological Reserve, a protected area in the Atlantic Forest in Paraiba state, northeastern Brazil, and compared it with the bat fauna that occupies the nearby villages. In the villages, we recorded 650 individuals from 14 species, while 1,127 individuals from 20 species were recorded in the Reserve. Diversity estimation pointed out 19 species for the settlements, and 22 for the Reserve. A Bray-Curtis/Sorensen similarity cluster analysis informed that the Reserve areas and the villages form two distinct groups. Additionally, a Wilcox test pointed out that both areas have significantly distinct abundances and species richnesses. Only a subset of the assemblage, mainly formed by generalist or opportunist species, occupies the villages, exploring resources that are offered by human activities.

Key-Words: Bats; Anthropic impact; Similarity; Human occupation.

INTRODUCTION

With the growth of environmental degradation, the efforts to comprehend and catalogue biodiversity has become urgent. The Atlantic Forest case is one of the most urgent, as it is considered a biodiversity hotspot, holding about 1-8% of the world's species (Myers *et al.,* 2000; Ribeiro *et al.,* 2009). In the past 500 years, it has been reduced to nearly 8% of its original coverage (Colombo & Joly, 2010), and the remaining forest constitute small isolated fragments surrounded by urban and rural occupations (Brito & Bocchiglieri, 2012; Stevens, 2013).

Human occupations are the most impacting, resilient, and growing form of anthropogenic pressure on environment, ultimately causing rapid habitat alteration, loss, and fragmentation (Garden *et al.,* 2006), with a modern urban pattern (spider-

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like or fractal) that integrates with native lands and expands its anthropic influence on habitats (Pickett *et al.,* 2001). Human occupations are capable of harbouring native fauna, usually generalist species, but they can have a higher biodiversity, depending on the characteristics of the surrounding landscapes (Pickett *et al.,* 2001; Gehrt & Chelsvig, 2003). Settlements, as we define here, are any areas where a population sets residence on and implement infrastructure such as housing, traffic ways and resource distribution lines (*i.e.,* electricity, water pipes). Bats use the human settlements to explore resources facilitated by human infrastructure features, such as insects gathered by lights and occupying these environments for roosting provided by edifications (Gehrt & Chelsvig, 2003). In Brazil, 84 bat species are known to occur in urban areas (Nunes *et al.,* 2016).

Bats are key components of the tropical forests' dynamics, as they normally are the largest order of mammals in tropical localities (Voss & Emmons, 1996). They have the capacity to explore a wide range of resources, and they can provide several ecological services in a community such as pollination, seed dispersal, and forest regeneration (Sato *et al.,* 2008; Stevens *et al.,* 2004). Bats are considered good bioindicators, responding to various anthropic-linked phenomena, such as forest fragmentation (Meyer *et al.,* 2010). The objective of this study was to investigate and compare the use of human-made landscapes by bats in three villages at the margin of an Atlantic Forest protected area.

MATERIALS AND METHODS

The study was conducted in Reserva Biologica Guaribas (Guaribas Biological Reserve, hereafter GBR) (06°44'33.472"S, 35°08'33.011"W), a reserve located between the municipalities of Rio Tinto and Mamanguape, state of Paraiba, Brazil. GBR is divided in three fragments: SEMA I (673.64 ha), SEMA II (1,016.09 ha) and SEMA III (338.82 ha). SEMA I and II were chosen for the study because they are the largest and best preserved areas. The reserve has a hot and humid weather, typical of the Atlantic Forest of northeastern Brazil, with maximum temperature around 26°C and rainfall over 1,700 mm/year; the rain season is from February to July and dry season from October to December (Endres *et al.,* 2007). Local vegetation displays a mosaic of two main physiognomies: North-eastern Tabuleiro and Atlantic Forest. The Tabuleiro is a grassy savannah-like area with small-sized trees and shrubs, while the Atlantic Forest presented at the Reserve comprehends a secondary forest, with medium height canopy (15 to 20 meters) and higher tree density (over 90% canopy coverage) (Endres *et al.,* 2007; IBAMA, 2003). At GBR, both the Tabuleiro and Forest physiognomies were sampled.

The three villages chosen for samplings were Caiana (06°44'39"S, 35°09'26"W) and João Pereira (06°40'20"S, 35°10'56"W) both located in the proximity (an average of 960 m) of SEMA II, and Imbiribeira (06°39'50"S, 35°08'53"W) located in the proximity (approximately 2 km) of SEMA I (Figure 1). The villages are in the direct influence area of GBR as they were built in the edge of the SEMA fragments (the houses and crops as close as 5 meters from the Reserve's in Caiana). There is presence of small-scale agriculture of subsistence, as well as domestic animals and cattle. The sampling points were selected according to their position relative to the buildings and the lowest degree of human interference possible during sampling sessions (*e.g.,* vehicle traffic, commerce, trespassers) in order to avoid scaring off the bats from the nets by light and noise, and accessibility. Due to their insertion in the GBR's direct influence area, and geographical proximity, the three villages were considered as a single group for the analysis.

The samplings at the Reserve and at the settlements were conducted between July 2012 and July 2013, using eight mist nets (7 × 3 m) at ground level, opened at dusk (18:00) and closed at midnight. All three villages were sampled monthly for two consecutive days each, one locality at a time. The Reserve was sampled monthly as well, three days for forest, three days for Tabuleiro. Ten individuals (5 male, 5 female) of each species were collected as testimony material, as well as specimens with difficult diagnosis. After reaching the capture limit, the surpassing individuals were measured, marked with a color-coded collar and then were released *in situ.* All individuals were weighted, sexed and had their reproductive stage recorded, the measurements (body length, length of tail, foot, ear, and forearm) were taken according to the methodology proposed by Simmons & Voss (2009), and identified following Gardner (2007). All individuals collected followed the processing protocol of Simmons & Voss (2009). All samplings were conducted under license nº 10665 (SISBIO-IBAMA).

The sampling effort was calculated following Straube & Bianconi (2002) (Mist net area × number of mist nets × hours per night × number of nights). For the diversity analysis, recaptures were excluded to perform the Chao 1 estimator (Chao, 1987), which allows good estimation even with few captures (Es-

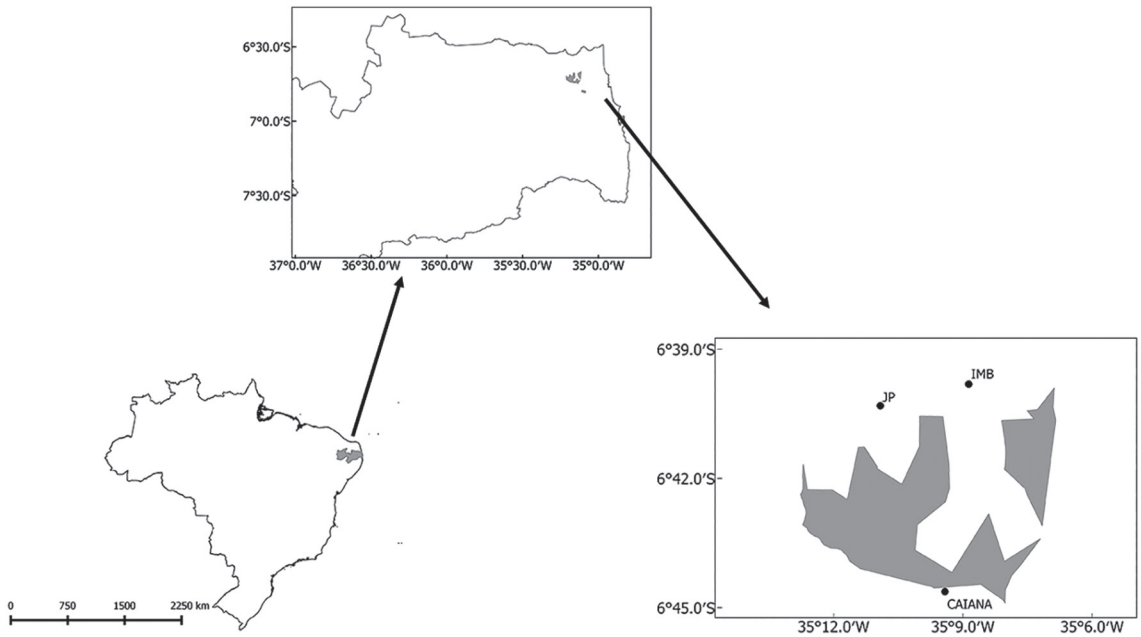

FIGURE 1: Map of Guaribas Biological Reserve (GRB) and the villages sampled.

bérard & Bergallo, 2008). This index was calculated using EstimateS (Colwell, 2006). The Wilcoxon test was performed in order to detect differences on diversity and abundance between GBR and the villages. To test if the villages and the GBR represented two different assemblages, as well as testing the degree of similarity between them, we performed Sorensen/Bray-Curtis similarity test dendrograms using diversity alone. Both tests were performed using Vegan package for R (Oksanen *et al.,* 2012; R Core Team, 2014). The differences of abundance between the GBR and the villages were tested for the most common species using Fisher's exact test, performed on R (R Core Team, 2014).

RESULTS

The sampling effort in each environment of the GBR and the three villages was 30,240 m²/h (10,080 m²/h per village) each. Captures in Imbiribeira, Caiana and João Pereira accounted for 650 captures belonging to 14 species, 12 genera and 3 families (Table 1). The family Phyllostomidae comprised 99% of the captures, with *Artibeus planirostris, Carollia perspicillata, Artibeus lituratus, Dermanura cinerea* and *Desmodus rotundus* being the most frequent species. The Chao 1 estimator predicted 19 species for the villages. The samplings conducted in the GBR accounted for 1,127 individuals belonging to 20 species, 18 genera and 3 families (Table 2). The family Phyllostomidae represented 98.8% of the captures, with the same predominant species as the villages. The estimator Chao 1 predicted around 22 species for GBR. The latest species list available for the area accounts 34 species (Feijó *et al.,* 2016).

The Sorensen/Bray-Curtis similarity tests pointed that the Tabuleiro and Forest areas (the Reserve physiognomies) are the most similar pairing, with 83% of similarity, forming a cluster. The villages formed a similarity cluster, with similarity of 76%. The similarity between the village cluster and the GBR cluster had the lowest score (54% similarity), indicating that the GBR and the village have non-equivalent community structure (Figure 2). The higher values of abundance and diversity found in the Reserve were significantly different compared to the villages' according to the Wilcoxon test ($W = 312$, $p = 0.003$ for abundance and $W = 304$, $p = 0.002$ for diversity).

Comparing the relative abundance of the most five most abundant species between the villages and the Reserve, only *Dermanura cinerea* and *Desmodus rotundus* presented significant difference (Table 3). *Dermanura cinerea* was more abundant in the GBR, and *D. rotundus* in the villages.

DISCUSSION

Our results indicate that the bat fauna occupying the human landscapes on the edges of large forest

TABLE 1: Bat species captured by ground-level mist nets in Guaribas Biological Reserve (Tabuleiro and Atlantic forest) in the period of July 2012 to July 2013. Species discriminated in families and subfamilies, absolute abundance (AB) and relative abundance (AR).

Family	Subfamily	Genus	Species	AB	AR
Emballorunidae		*Saccopteryx*	*S. leptura*	2	0,20%
Phyllostomidae	Carollinae	*Carollia*	*C. perspicillata*	184	16,30%
		Rhinophylla	*R.* cf. *pumilio*	1	0,10%
	Desmodontinae	*Desmodus*	*D. rotundus*	16	1,40%
	Glossophagini	*Glossophaga*	*G. soricina*	66	5,90%
	Sternodermatinae	*Artibeus*	*A. planirostris*	605	53,70%
		Artibeus	*A. lituratus*	70	6,20%
		Artibeus	*A. obscurus*	4	0,40%
		Dermanura	*D. cinérea*	128	11,40%
		Platyrrhinus	*P. lineatus*	9	0,80%
		Sturnira	*S. lilium*	15	1,30%
		Chiroderma	*C. villosum*	4	0,40%
	Phyllostominae	*Lophostoma*	*L. silvicolum*	2	0,20%
		Phyllostomus	*P. discolor*	5	0,40%
		Tonatia	*T. saurophila*	2	0,20%
		Lampronycteris	*L. brachyotis*	1	0,10%
		Lonchorhina	*L. aurita*	1	0,10%
		Micronycteris	*M. schimidtorum*	1	0,10%
Vespertilioninae	Myotinae	*Myotis*	*M. nigricans*	10	0,90%
	Natalidae	*Natalus*	*N.* cf. *stramineus*	1	0,10%

TABLE 2: Bat species captured by ground-level mist nets in the villages around Guaribas Biological Reserve in the period of July 2012 to July 2013. Species discriminated in families and subfamilies, absolute abundance (AB) and relative abundance (AR).

Family	Subfamily	Genus	Species	AB	AR
Emballorunidae	Emballoruninae	*Saccopterix*	*S. leptura*	1	0,20%
		Peropteryx	*P. leucoptera*	1	0,20%
Mormoopidae		*Pteronotus*	*P. personatus*	1	0,20%
Phyllostomidae	Carolliinae	*Carollia*	*C. perispicillata*	110	16,90%
	Desmodontinae	*Desmodus*	*D. rotundus*	21	3,20%
	Glossophaginae	*Glossophaga*	*G. soricina*	1	0,20%
	Phyllostominae	*Lophostoma*	*L. brasiliense*	1	0,20%
		Phyllostomus	*P. discolor*	2	0,30%
	Stenodermatinae	*Artibeus*	*A. planirostris*	365	56,20%
			A. lituratus	50	7,70%
			A. obscurus	13	2,00%
		Dermanura	*D. cinerea*	47	7,20%
		Platyrrhinus	*P. lineatus*	17	2,60%
		Sturnira	*S. lilium*	20	3,10%

patches is a filtered subset of the forest assemblage. The species that manage to thrive and occupy the area – in this study *Artibeus planirostris, A. lituratus* and *Carollia perspicillata* – are generalist species and adapt well to disturbed environments (Brito & Bocchiglieri, 2012) and are known to explore several man-made structures as roosts (Nunes *et al.* 2016), with no detectable differences between the subpopulations occupying the villages and the ones in the Reserve. Several species have a single individual registered, which could be an indicator that they do not occupy effectively the area, and could have been trapped during an occasional excursion through the more open areas outside the forest.

Desmodus rotundus was more abundant in the villages, possibly due to the availability of food resources in the form of domestic mammals (cattle included) in the area (Esbérard *et al.,* 1994), as well as its capacity to explore human-made roosts such as culverts and buildings (Scheffer *et al.,* 2014). *Dermanura cinerea* is a frugivore, like *Artibeus* and *Carollia,* but it appears not to be as generalist as the other species.

TABLE 3: Relative abundance and Fisher's exact test values for the five most abundant species occurring in Guaribas Biological reserve and the villages. Fisher's test performed comparing the Reserve and the villages.

Species	Biological Reserve % (total = 1,127)	Villages % (total = 650)	*p*-value for Fisher's exact test
Artibeus planirrostris	53,7% (605)	56,2% (365)	$p = 0.3228$ n.s.
Carollia perspicillata	16,3% (184)	16,9% (110)	$p = 0.7409$ n.s.
Artibeus lituratus	6.2% (70)	7.7% (50)	$p = 0.3259$ n.s.
Desmodus rotundus	1,4 % (16)	3,2% (21)	$p = 0.01465$
Dermanura cinerea	11,4% (128)	7,2% (47)	$p = 0.004879$

The lower abundance of *Dermanura cinerea* in the villages might indicate that those areas are not attractive for the species. Sparks *et al.* (2005) and Tuttle *et al.* (2006) pointed that urbanization and human occupation can affect the availability of foraging sites, but the lack of data on *D. cinerea*'s ecology do not allow us to test any suppositions (Reis *et al.,* 2007). *Sturnira lilium* was found at very similar rates in and outside GBR's area. The species is known for preferring the consumption of fruit from the Solanaceae family (Mello *et al.,* 2008), which are easily found both inside the GBR's grounds (especially in the tabuleiro and closer to the margins of the trails), and in the green around the villages. The large offer of its main food items might explain why the species were equally abundant.

The clusters formed indicate that, albeit being composed by two vegetation types (open savanna-like field *versus* forest), the tabuleiro and forest areas in Reserve are more similar than the three villages sampled. The villages differ in several aspects, such as usage of soil, vegetation cover, size, number of inhabitant and proximity to GBR. Proximity to the Reserve, however, appears not to be the dominant factor in the similarity, as Caiana – which is the village closest to the Reserve – was grouped with Imbiribeira. João Pereira is both closer to Imbiribeira, and both are at similar distance of the Reserve, but is the less similar of the three.

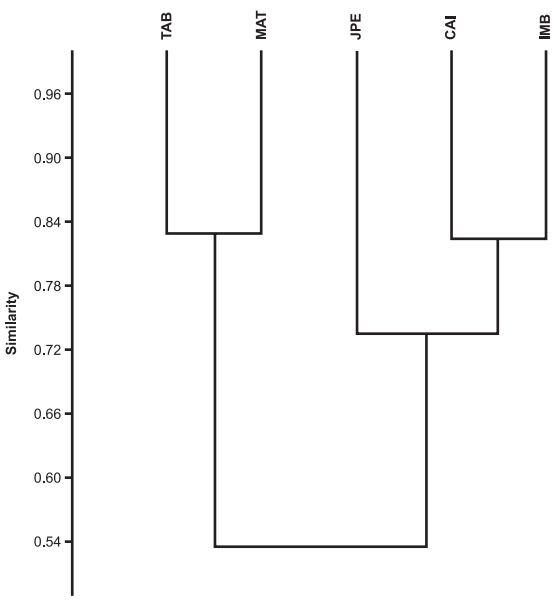

FIGURE 2: The Sorensen/Bray-Curtis Similarity test Dendrogram for Biological Reserve areas and the villages. Where JPER, IMB, CAI, correspond to the each of the villages, and MATA and TAB correspond to Guaribas Biological Reserve (Atlantic forest and Tabuleiro, respectively).

A group of factors might come together to allow the villages to support the registered assemblage: the low level and small area of human impact on the villages compared to the ones caused by typical urban infrastructure (road pavement, public illumination, higher building density); the presence of crops and other vegetation within the limits of the villages; the surrounding agricultural landscape; and the proximity with the Reserve, that helps maintaining diversity. GBR is surrounded by sugar cane plantations and cities, and could act as a demographic source to nearby areas that may not be able to support their bat populations long-term, (as in a source-sink model) (Begon *et al.,* 2006). Avila-Flores & Fenton (2005), Dixon (2012) and Loeb *et al.* (2009) registered that species' diversity might be maintained to some level in unfavourable areas, as long as there is enough vegetation in the proximity providing more adequate environmental support, a situation similar to the one registered in our work.

CONCLUSION

Only a subset of the bat assemblage of Guaribas Biological Reserve occupies effectively the nearby villages, the subset mainly formed by resilient and generalist species. The majority of the species registered had only a single individual captured, which might indicate that those species make occasional use of the areas.

RESUMO

Morcegos são integrantes importantes de redes ecológicas, e estudos em áreas degradadas são especialmente importantes para entender o impacto das ocupações humanas em taxocenoses de morcegos. Foi amostrada a fauna de morcegos da Reserva Biológica Guaribas, uma área de Floresta Atlântica protegida no estado da Paraíba, nordeste do Brasil, e comparada com a fauna encontrada em vilas próximas. Nas vilas, 650 morcegos de 14 espécies foram registrados; na reserva, 1.127 de 20 espécies. Estimações de diversidade preveem 19 espécies para as vilas, e 22 para a reserva. Uma análise de similaridade de Sorensen/Bray-Curtis informou que a as áreas da reserva e as vilas formam dois grupos distintos. O teste de Wilcoxon apontou que ambas as áreas têm diferenças significativas de abundância e riqueza. Apenas um subgrupo da taxocenose total, formado por espécies generalistas ou oportunistas, ocupa as vilas, explorando recursos disponibilizados pelas atividades humanas.

Palavras-Chave: Morcegos; Impactos antrópicos; Similaridade; Ocupações humanas.

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