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Article

The effect of land use on the richness and composition of species and trophic guilds of bats (Mammalia, Chiroptera) in the urban area of Altamira – PA

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Abstract: Bats play important ecosystem roles. Anthropogenic activities cause the decrease and loss of biological diversity and, consequently, the loss of these ecosystem services. One way of measuring local habitat conditions and relating the landscape to biodiversity. Our objective is to investigate how the bat community is influenced by this change in the landscape. Collections were carried out at five points and 76 individuals of 12 species are sampled. Although the points present a high variation in relation to land use, we did not observe any correlation between species richness and guilds with land use. However, the difference in the composition of the guilds is related to the variation in land use, in which 74% of the variation in the abundance of guilds is related to the different patterns of land use. At SENAI, even though it was the place with the greatest anthropic impact, it was the one with the greatest abundance of species, while the points Module two and Sítio Jaburu had the greatest abundance of guilds. This result corroborates the idea that ecosystem services are dependent on habitat maintenance, since the greater the heterogeneity the greater the difference in the composition of the trophic guilds.

Keywords: Environmental heterogeneity, Habitat, Anthropization, Chiropterans.

1. Introduction

The distribution of species in the environmental gradient is determined by the relationship between conditions (climate, type of habitat, land use, density of vegetation) and resources (food, shelters) present in the places [1]. A new approach has been highlighted in the attempt to measure and synthesize environmental conditions and relate them to communities, landscape ecology. In this approach, we seek to synthesize environmental conditions through variables measured on a wide scale, called regional conditions, such as; (i) type of vegetation cover (natural vegetation, secondary vegetation), the pattern of land use (urban area, short or long cycle agriculture, pasture), number and shape of vegetation patches present in the landscape [2].

Habitat fragments are natural to the environment, some factors such as size, amount of resources, and amount of fragments are important to evaluate when you are going to study a specific species [3]. Fragmentation and habitat loss leads to a decrease in areas of shelter and foraging for bats [4]. In fact, the diversity of species and trophic guilds of bats, is directly linked to vegetation, more specifically to structural variables, such as the thickening of canopy and understory vegetation [5,6].

Tropical forests with dense vegetation (natural or by anthropic effect) tend to have little diversity of bats, especially due to the decrease in species that use the lowest extracts of vegetation (canopy and understory) [7–9]. This is due to the reduced foraging efficiency of some species [10]. With apparently unaffected species, sensitive and or tolerant species, and even species benefited by the change in cover and land [5,11,12]. Among the anthropic changes in use and coverage we can mention urbanization [13], artificial lighting [14], the use of pesticides in plantations [15], fragmentation and habitat loss [16–18], destruction of shelters [19], hunting [19–21], roads[22], climate change [23], competition and predation by invasive species[24], diseases [25] and collisions with wind turbines [26].

Bats are the only flying mammals, belonging to the order Chiroptera and distributed worldwide, with the exception of only the poles. About 1420 species are recognized for the world [27] and 181 in Brazil [28] 14% of the world diversity. They have great diversity in relation to morphology and eating habits [29], classified in seven guilds; (i) hematophagous, (ii) frugivores, (iii) insectivores, (iv) nectarivores, (v) folivores, (vi) piscivores and (vii) carnivores [30]. However, if we consider the species' habitat, its foraging mode and its diet, ten feeding behaviors are recognized, due to the partitioning of insectivores in four guilds; (i) aerial insectivores in open areas, which often forage above the canopy; (ii) aerial insectivores from clearings and edges, which forage in the forest, usually between the canopy and the sub-canopy; (iii) aerial insectivores from closed areas, forage in areas of denser vegetation and closer to the ground and (iv) insectivorous scavengers.

The great diversity of eating behaviors makes this group considered a key species in tropical forests [31]. Performing ecosystem services such as pollination and seed [20,32,33]. Some species of pioneer plants are pollinated and dispersed exclusively by bats [34,35]. In addition to population control of animals [12,36], due to the role in insect population regulation [37,38], including agricultural pests [36] and other organisms, both vertebrates and invertebrates [39]. Thus, studies conducted with the group, considered a key species for tropical forests, are particularly useful for understanding the functioning of environmental systems and predicting, reversing or mitigating secondary local extinctions, loss of pollinated or dispersed species by bats [40].

The Amazon rainforest has been going through an intense occupation process [41], with a change in the pattern of land use, logging and burning, giving rise to the well-known arch of deforestation [42] and more recently to Arco do Fogo [43] with an increase in deforestation of 80% in July 2019 compared to July 2018 [44]. These anthropic changes, together with the effects of climate change and increased urbanization, cause loss of habitat habitats, threatening local biodiversity [45]. In addition, the Amazon is the least sampled biome in relation to bats, approximately 23% of its area, against 85% of the Atlantic Forest, the best sampled biome for bats [46]. Thus, our objective is to describe the pattern of land use around five points sampled in the Eastern Amazon, close to the urban area of Altamira, PA and to identify the influence of land use on the richness and abundance of species and trophic guilds of bats.

2. Materials and Methods

Study area

The sampled points are located in the municipality of Altamira, state of Pará, northern Brazil (Figure 01). The sampled region has a humid tropical climate, the Am - Köppen classification - with an annual rainfall of 2.289 mm and a dry period concentrated in the months of August and September [47]. Located in the southwest of Pará, it has the third highest rate of deforestation in Brazil [44]. The region is crossed by the BR 230 - Transamazônica highway, in the arc of deforestation [42] and fire [43]. The five selected points were; P1 - Sitio Betânia, P2 - IFPA - Federal Institute of Education, Science and Technology of Pará - Campus Altamira, P3 - Sitio Jaburu, P4 - Permanent Monitoring

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Module - M2 and P5 - SENAI - National Learning Service (Figure 01, Table 01). Points P1 and P4 are areas of preserved forest whereas points P2, P3 and P5 are urban areas within the city of Altamira.

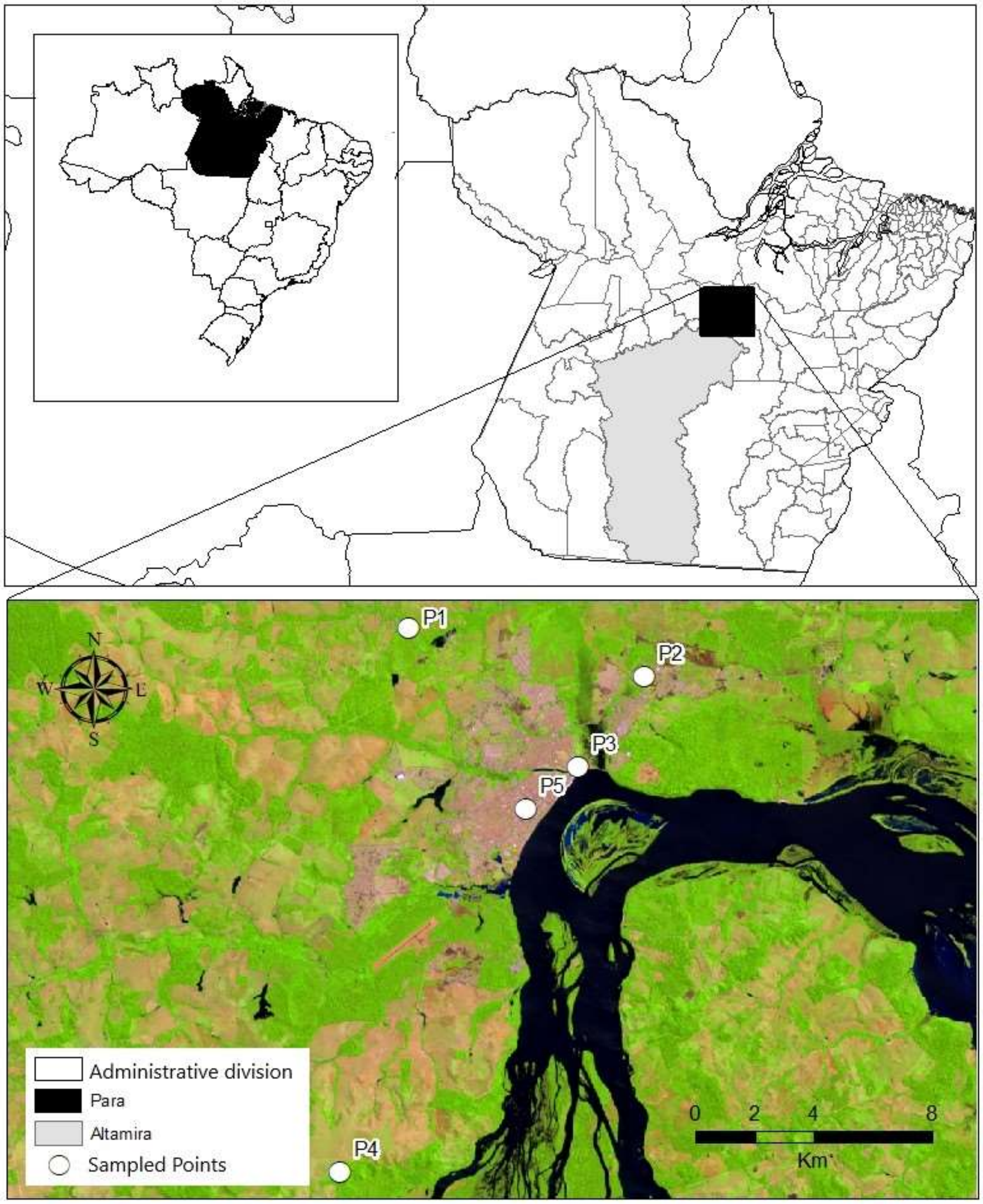

Figure 1. Location of the sampled points in the city of Altamira - PA during 2017. P1 - Site of the Catholic church Betânia, P2 - IFPA - Pará Federal Institute of Education, Science and Technology - Campus Altamira, P3 - Church park catholic - Sitio Jaburu, P4 - Permanent Monitoring Module - M2 and P5 - SENAI - National Learning Service.

Table 1: Coordinates and pattern of land use (described in percentage) for the five sampled points. The name of the points is listed in the legend of figure 01. The data are represented in percentage (%).

Acromion	Points	Coordinates	Land Use

		Latitude	Longitude	Water	Flooded Area	Urban area	Pasture	Vegetation
P1	Bethany Farm	-3.157	-52.253	0.00	0.00	0.00	52.24	47.76
P2	IFPA	-3.172	-52.182	30.13	17.10	49.97	0.00	2.80
P3	Site Jaburu	-3.199	-52.202	0.00	0.00	0.00	68.91	31.09
P4	Module 2	-3.322	-52.274	11.22	0.00	88.78	0.00	0.00
P5	SENAI	-3.212	-52.218	0.00	0.00	0.00	37.56	62.44

Data collect

For the sampling of bats, ten fog nets (9m x 2.5m) were used, which remained open for a period of six hours after sunset and checked every 30 minutes. The collections were carried out between April and September 2017, with each point being sampled for two nights, avoiding the nights of full moon and rainy nights. The captured bats were placed in a cotton bag and screened in the field with data on (i) sex, (ii) age, (iii) weight, (v) left forearm measurement and (vi) species recorded in the field. These data were used to resolve doubts of subsequent identification. Two couples of each species were collected and taken to the Ecology Laboratory of the Federal University of Pará - UFPA, where they were euthanized, fixed and preserved in 95% alcohol. The specimens were identified to the lowest taxonomic level, using specific literature [48,49]. The individuals captured and not collected were marked with numbered collars [50] and released in the same place. The species collected were classified into family, subfamily and trophic guilds, according to[30]. And the sampling effort calculated according to Straube and Bianconi (2002).

Landscape Data

For landscape analysis, Landsat 8, orbit / point 226/063 images available on the Science For a Changing World website (https://earthexplorer.usgs.gov/) were used, this image is formed by eleven bands; Multispectral: 430-450 nm (Band1), 450-510 nm (Band2), 530-590nm (Band3), 640-690 nm (Band4 Red), 850-880 nm (Band5 Near Infrared), 1570-1650 nm (Band6) SWIR1), 2110-2290 nm (Band7 SWIR2), 500-680 nm (Band8); 1360-1380 nm (Band 9 Cirrus); Thermal: 10600-11190 nm (Banda10 TIRS1), 11500-12510 nm (Banda11 TIRS2), with spatial resolution of 15.0 m. For the study, the colored composition (R, G, B) of the landsat 8 image was used with bands 6, 5 and 4, with the image of July 7, 2017. This composition was selected because it highlights the selected categories.

All images were processed using the software ArcGis 10.1 and PCI Geomatica V10.1 (PCI, 2007), in which the following procedures were performed: (i) atmospheric correction to remove atmospheric imperfections - PCI Geomatica and (ii) manual classification - ArcGis. The classes used were (i) Natural Vegetation (areas occupied by dense forest at different stages of development, including vegetation resulting from natural succession processes, after total or partial suppression of primary vegetation by anthropic actions or natural causes); (ii) Anthropized Area (areas occupied by intensive and / or extensive livestock and areas with unprotected soil); (iii) Urban Area (paved road systems, squares and large human constructions, basically restricted to the urban area of the municipality of Altamira); (iv) Flooded Area (portions of drowned vegetation and swampy areas) and (v) Water.

After the classification of the image, the sampled points were plotted on the image and a circular buffer of one kilometer of radius was delimited around each point, with the percentage of each class (Water, Wetland, Anthropized area, Urban area and Vegetation) calculated. for each of the buffers. To calculate the areas, we used the WGS 1984 UTM Zona 22 Sul projection.

Data Analysis

To describe the pattern of land use, a Principal Component Analysis (PCA) of covariance (water, wetland, anthropized area, urban area, vegetation area) was performed, and graphically presenting the structure observed in the first two axes [51,52] Additionally, we perform data spatialization. Since the data on the land use pattern have multicollinearity, we use the first two axes of the PCA as the predictive variables of the landscape [53].

To test the effect of the land use pattern on the richness of species and trophic guilds, we performed multiple linear regressions, using the PCA axes as independent variables and the richness of species and that of trophic guilds as the dependent variables [54,55]. Subsequently, we performed a composition PCA [56] with an abundance of species and trophic guilds, thus identifying the pattern of distribution among the locations studied.

Finally, to test whether the composition of guilds and species is associated with the pattern of land use, we performed a mantel test [57], between the composition of species and guilds (using Bray Curtis as a similarity index) and the pattern land use (using Euclidean distance as a similarity index). All PCA's were performed with the rda function, the mantel with the mantel function and the similarity matrices with the vegdist function, all implemented in the vegan package [58] in an R environment [59].

3. Results

With a total of ten collection nights and 4,500 m2h net (900 m2h per point), 76 individuals were captured, distributed in three families, ten genera and 12 species (Table 2). The species *Carollia perspicillata* (Linnaeus, 1758), 34 individuals, was the most abundant and *Glossophaga soricina* (Pallas, 1766) and *Myotis nigricans* (Schinz, 1821) the rarest, only one individual (Table 2). The point with the greatest wealth was P1 (seven species) and the one with the lowest number was P5 (two species).

Table 2: List of species captured during fieldwork in the period from April 3 to September 1, 2017 in the city of Altamira - PA. The species are organized into family and subfamily and have the guild classification used in the work. The coordinates and names of the points can be found in the legend of table 1.

FAMILY Subfamily Species	Trophic Guild	P1	P2	P3	P4	P5	Total
MORMOOPIDAE							4
Pteronotus sp.	Aerial insectivore	X					4
PHYLLOSTOMIDAE							76
Carolliinae							
Carollia perspicillata (Linnaeus, 1758)	Frugivore	X	X		X		50
Rhinophylla							
Rhynophilla fischercie (Carter, 1966)	Frugivore		X		X		2
Desmodontinea		X			X		5
Desmodus rotundus (É. Geoffroy, 1810)	Hematophagous	X			X		5
Glossophaginae							
Glossophaga soricina (Pallas, 1766)	Nectarivore					X	1
Phyllostominae							
Phyllostomus hastatus (Pallas, 1767)	Omnivorous				X		3
Tonatia bidens (Spix, 1823)	Gleaning Insetivore	X					4
Stenodermatinae							
Artibeus lituratus (Olfers, 1818)	Frugivore	X				X	3
Sturnira lillium (É. Geoffroy, 1810)	Omnivorous	X			X		3
VESPERTILIONIDAE							1
Myotinae							
Myotis nigricans (Schinz, 1821)	Background Clutered Spece Insetivore		X				1

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With regard to land use (Figure 02; Table 01) Sitio Betânia presented the largest amount of natural vegetation (62%) and SENAI the largest urban area (88%) (Figure 02; Table 01). On the other hand, we observed only one area, Sitio Jaburu, with the presence of a wetland (17%) (Figure 02; Table 01). The PCA, performed with landscape data, presented 99.47% of explanation in the first two axes, 63.37% in the first and 36.09 in the second axis (Figure 03). As a standard, we observed the formation of three groups; (i) P1, P2 and P4 with large areas of pasture and natural vegetation, (ii) P5 with a large portion of built urban area and (iii) P3 with the presence of water and wetlands (Figure 3).

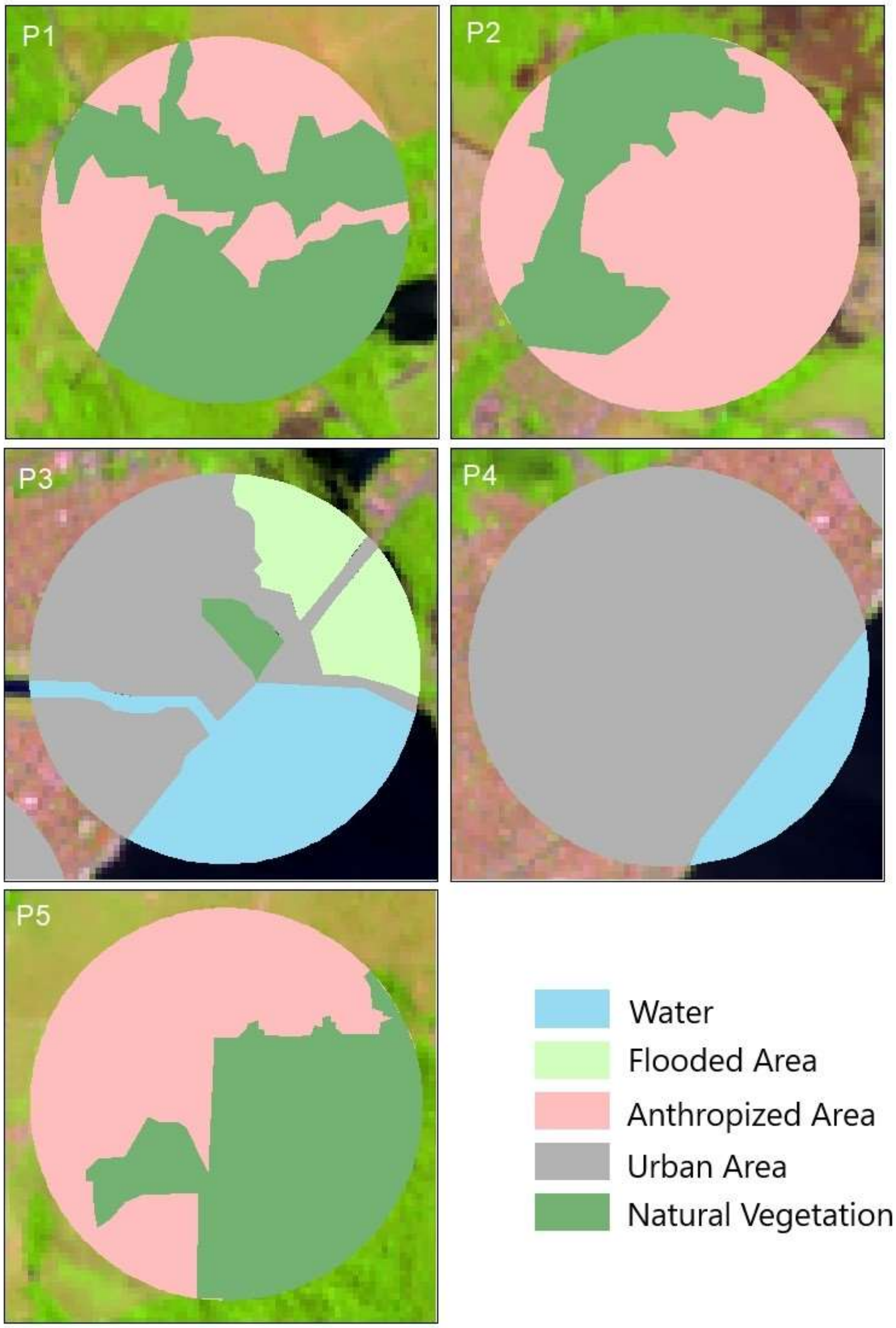

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Figure 2: Image resulting from the classification of circular buffers. The location and description of the points is summarized in Figure 01 and Table 01. The names of the points can be seen in the legend of figure 01.

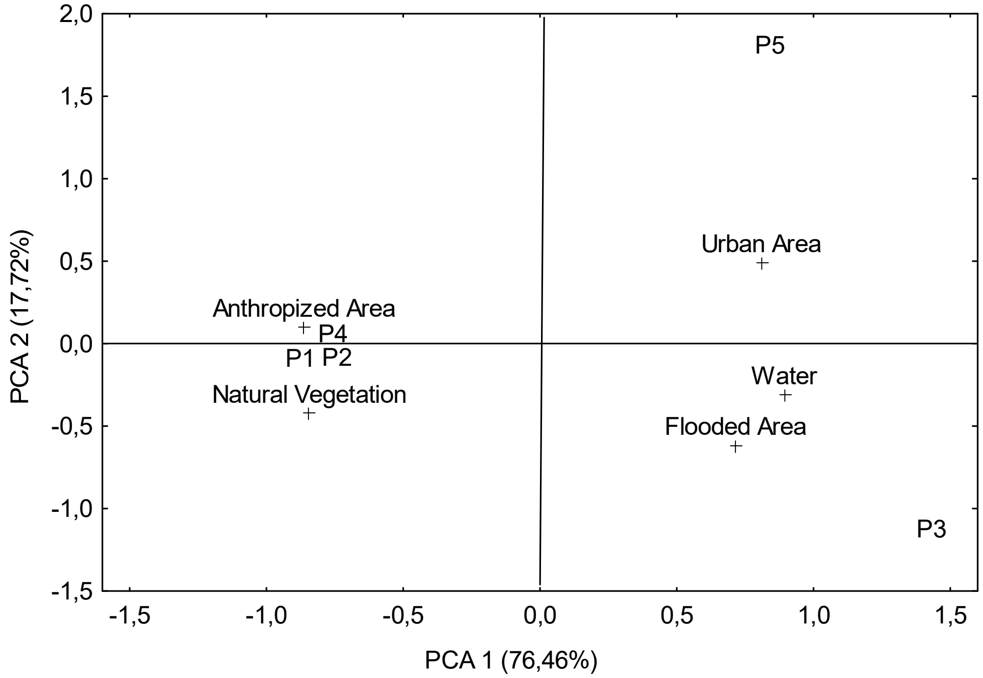

Figure 3: Principal component analysis - PCA made with landscape data from the classification of land use around the sampled points in the city of Altamira - PA. The name of the points is listed in the legend of figure 01.

The pattern of land use was not related to species richness (F (2.2) = 0.821; r = 0.021; p = 0.548) or trophic guilds (F (2.2) = 3.485; r = 0.013 p = 0.222). The composition PCA performed with species abundance data showed 82.64% of explanation in the first two axes, 49.88% in the first and 32.76% in the second axis (Figure 04a). As a standard we observe that *Artibeus lituratus* (Olfers, 1818) and *Glossophaga soricina* (Pallas, 1766) present greater abundance in the SENAI area, *Carollia perspicillata* (Linnaeus, 1758) in Betânia, Sitio Jaburu and IFPA and Artibeus planisrostris in the Permanent Monitoring Module (Figure 04a). The composition PCA performed with guild abundance data (Figure 04b) presented 90.16% of explanation in the first two axes, 55.26% in the first and 34.09% in the second axis. As a standard, we observed that the nectarivore guild is more abundant in P5, the clearing insectivores and frugivores more abundant in P4, P2 and P3 and the other guilds in P1 (Figure 04b). The distribution pattern of the species cannot be related to land use (r = -0.251; p = 0.850). However, the composition of the guilds was 74.40% related to the pattern of land use (r = 0.744; p <0.001).

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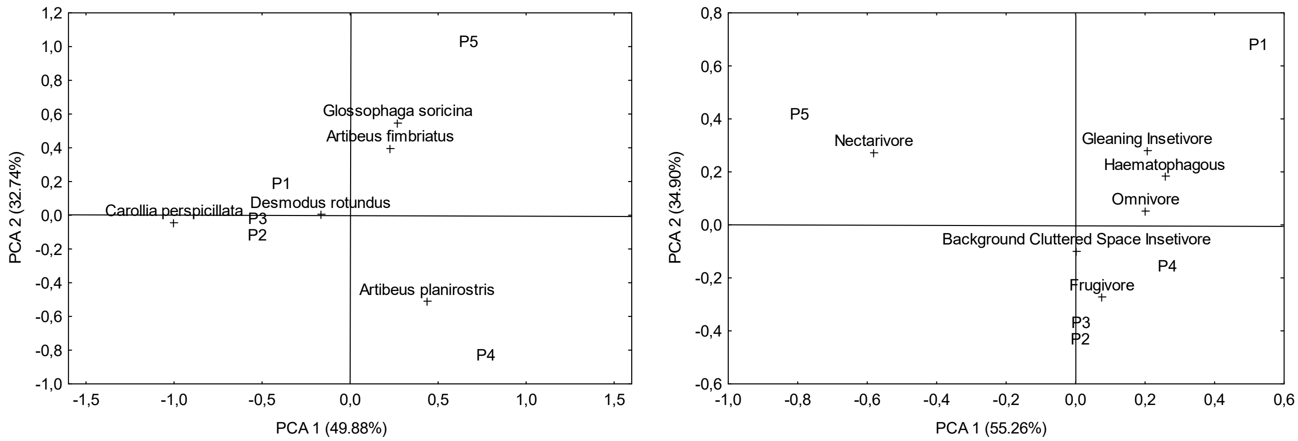

Figure 4: Analysis of main components of composition - PCA made with abundance of species (a) and abundance of trophic guilds (b). P1 - Sitio Betânia, P2 - IFPA - Federal Institute of Education, Science and Technology of Pará - Campus Altamira, P3 - Sitio Jaburu, P4 - Permanent Monitoring Module - M2 and P5 - SENAI - National Learning Service.

4. Discussion

The dominance of species of the Phyllostomidae family in neotropical studies, especially for the Amazon biome, can be explained, first, by the family being the most diverse and with the greatest species richness for the Amazon [60–63]. Additionally, the abundance of Phyllostomidae, in comparison with other families sampled in the study, can be explained by the use of fog nets as a sampling method. Fog nets tend to be efficient in sampling bats that use the lowest stratum of vegetation and that move using spatial memory, instead of sonar, a behavior observed in Phyllostomidae [64–66] and especially in the frugivorous guild, one of the most abundant within Phyllostomidae.

The species sampled in our study, and belonging to the frugivorous guild, have a great adaptation to anthropic areas, using fruits of *Piper spp*. (Monkey pepper), *Ficus spp*. (Figus tree) and *Cecropia spp*. (Embaúba) as a food resource [34,67–69]. An example is the dominance of *Carollia perspicillata* (Linnaeus, 1758) (n = 50), a species generally associated with anthropized areas. In addition to the species presenting a great ecological plasticity, its area of distribution encompasses a large part of the neotropical region [48,70,71], considered a common species in the Amazon [61,63].

The abundances of different species of Phyllostomidae are associated with different rates of deforestation, including from forest areas and with little fragmentation, *Phyllostomus hastatus* (Pallas, 1767), *Tonatia bidens* (Spix, 1823) and *Sturnira lillium* (É. Geoffroy, 1810) until anthropized areas, *Artibeus lituratus* (Olfers, 1818) and *Carollia perspicillata* (Linnaeus, 1758) [72–74]. This difference can be related to food resources, such as insects, nectar, pollen and even leaves, present in these places [48]. Places with a greater amount of vegetation, as observed in points three and four, tend to have a greater abundance of insects [75], used as a food resource for insectivorous species such as *T. bidens* [76] and other omnivorous food resources used, such as *P. hastatus* and *S. lillium* [77]. Thus, the greatest wealth observed in points with a large percentage of forest may be due to; (i) greater availability of food [78]; (ii) greater number of shelters, mainly hollow trunks and treetops [79] and (iii) less susceptibility to predators, [80] due to closed canopy.

The occurrence of *Desmodus rotundus* (É. Geoffroy, 1810), the only hematophagous observed at points P1 and P4 is possibly related to the existence of pasture areas close to the sampled points, due to the availability of food resources, coming from cattle. The occurrence of *Glossophaga soricina* (Pallas, 1766), the only nectarivore captured at point P5, the most urbanized area observed in the study, may be due to the occurrence of plant species such as *Bombacacia sp.* (Bombacaceae), *Agave sp.* (Agavaceae) and *Cactaceae*, introduced for urban landscaping and common in the area where the species was sampled. Although the species is frequent and abundant in open areas, 30 to 70% of tree cover [81] and with low anthropogenic disturbance, it may have been attracted by the presence of food resources. *Myotis nigricans* (Schinz, 1821), clearing insectivore, and *Pteronotus sp.*, Aerial insectivore, captured only at the point that has a large amount of wetland, can be explained by; (i) presence of insects used as a food resource by the species and that have emerged from the wetland or were looking for breeding areas and; (ii) the presence of artificial lighting, street and park public lighting that borders the sampled area, which attracts species of insects used as a food resource. Environments that have flooded areas and even the presence of artificial lighting promote the concentration of insects and thus facilitate the foraging of bats [82–85], making it possible to catch insectivores through fog nets [85–88].

5. Conclusions

The development of the study made it possible to analyze how the bat communities are being influenced by the composition of the habitats in which they are inserted, in addition, it also made possible a study on the land use around the sampled areas. In general, what we can see is that the studied areas have a great variation in land use, which did not significantly influence the richness of bat trophic guilds. However, the difference in the composition of trophic guilds is closely related to the heterogeneity of the landscape. This result suggests that the maintenance of ecosystem services and dependent on the maintenance of habitat heterogeneity is inversely related to the degradation and urbanization of the areas. Thus, it is necessary to maintain green areas, even within urban areas, since one of the ecosystem services provided is the control of pest insects, such as mosquitoes. With regard to abundance, what we observed was a greater abundance of species at SENAI, even though this is the place with the greatest anthropic impact. With regard to trophic guilds, it was observed that the IFPA, Module two and Sitio Jaburu showed a greater abundance of guilds, and their composition varied along the sampled points which is related to land use.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, Thiago Bernardi Vieira and Leandra Rose Palheta; methodology, Thiago Bernardi Vieira and Jakeline Arcanjo de Arcanjo; software, Jakeline Arcanjo de Arcanjo.; formal analysis, Thiago Bernardi Vieira; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, Leticia Lima Correia; writing—review and editing, Leticia Lima Correia, Jakeline Arcanjo de Arcanjo, Leandra Rose Palheta and Thiago Bernardi Vieira. All authors have read and agreed to the published version of the manuscript.

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