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Richness and abundance of sand fly species in human settlements and degraded forest fragments in Maranhense Amazon

Riqueza e abundância de espécies de flebotomíneos em assentamentos humanos e fragmentos florestais degradados na Amazônia Maranhense

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The present study analyzes the variation in the richness and abundance of sandflies in rural settlements, with different degrees of forest degradation, in the Amazon of the State of Maranhão. The sandflies were captured in the municipalities of Santa Luzia (moderately degraded area), Senador La Rocque (very degraded) and Governador Nunes Freire (completely degraded), during three consecutive nights, once a month, from May/2012 to April/2014. Overall, 6,810 specimens of 35 species of sandflies, distributed in 13 genera, were captured. The most diverse was *Evandromyia* (9 species), followed by *Psathyromyia* (5), *Pressatia* (3), and *Psychodopygus* (3). The most abundant species were *Nyssomyia whitmani* (32.33%), *Evandromyia evandroi* (14.89%), *Lutzomyia longipalpis* (12.45%), *Brumptomyia avellari* (6,73%), *Pintomyia damascenoi* (6,59%), and *Migonemyia migonei* (6,46%). In all areas, species richness was greater in forest fragments than in rural peridomiciles, except in that one, whose forest fragment was very degraded. The abundance of individuals was greater in all peridomiciles. The increasing degradation of natural vegetation cover has been reducing forests and the richness of sand fly species. However, the remaining fragments of secondary forests still maintain a considerable number of species, which to a greater or lesser extent frequent adjacent rural settlements. These new environments offer sandflies opportunities (shelters and food sources) necessary for reproduction and proliferation. As a consequence, leishmaniasis begins to change its epidemiological profile, affecting susceptible human populations.
Key-words: insect vectors, biodiversity, deforestation.

O presente estudo analisa a variação na riqueza e abundância de flebotomíneos em assentamentos rurais, com diferentes graus de degradação florestal, na Amazônia do Estado do Maranhão. Os flebotomíneos foram capturados nos municípios de Santa Luzia (área moderadamente degradada), Senador La Rocque (muito degradada) e Governador Nunes Freire (completamente degradada), durante três noites consecutivas, uma vez por mês, de maio/2012 a abril/2014. No computo geral, foram capturados 6.810 espécimes de 35 espécies de flebotomíneos, distribuídas em 13 gêneros. O mais diversificado foi *Evandromyia* (9 espécies), seguido por *Psathyromyia* (5), *Pressatia* (3) e *Psychodopygus* (3). As espécies mais abundantes foram *Nyssomyia whitmani* (32,33%), *Evandromyia evandroi* (14,89%), *Lutzomyia longipalpis* (12,45%), *Brumptomyia avellari* (6,73%), *Pintomyia damascenoi* (6,59%) e *Migonemyia migonei* (6,46%). Em todas as áreas a riqueza de espécies foi maior nos fragmentos florestais do que nos peridomicílios rurais, exceto naquela, cujo fragmento florestal estava muito degradado. A abundância de indivíduos foi maior em todos os peridomicílios. A degradação crescente da cobertura vegetal natural vem reduzindo as florestas e a riqueza de espécies de flebotomíneos. Entretanto, os fragmentos de florestas secundárias remanescentes ainda mantêm um número considerável de espécies, as quais frequentam em maior ou menor grau os assentamentos rurais adjacentes. Esses novos ambientes oferecem aos flebotomíneos oportunidades (abrigos e fontes de alimento) necessárias para a reprodução e proliferação. Como consequência, as leishmanioses passam a mudar o seu perfil epidemiológico, incidindo nas populações humanas suscetíveis.
Palavras-chave: insetos vetores, biodiversidade, desmatamento.

1. INTRODUCTION

Sandflies constitute a subfamily of psychodid dipterans widely distributed across the planet, being found in all geographic regions of Brazil [1]. These insects are well distributed in the state of Maranhão, being found in several municipalities where leishmaniasis is endemic. Diversity is complex, with many species distributed in the various Amazonian forest ecosystems, coconut forests, restinga, semideciduous seasonal forests and cerrados. So far, dozens of sand fly species have been found in the territory of Maranhão and many of them transmit tegumentary leishmaniasis, but only *L. longipalpis* transmits visceral leishmaniasis [2].

Until some time ago, it was believed that the diversity of sandflies in the territory of Maranhão was greater in the forest areas in the Amazon [3]. Recent studies show that the sand fly fauna is also diversified in the more open forest areas that mix with the cerrados and coconut groves with a semi-humid climate [4, 5].

With the advance of the deforestation of the original vegetation cover in the Maranhão territory, the sand fly fauna has been undergoing changes in the composition and rank of dominance of the species. Many species disappear from degraded forests and reappear in infestations of rural and periurban peridomiciles, parasitic leishmaniasis infecting different species of sand flies [6-8]. In peridomiciles, domestic animals become abundant and contribute to the approximation of vectors to human dwellings. In this way, they function as a blood food source and produce breeding grounds by accumulating organic matter [9, 10]. In these anthropogenic sites where sandflies settle, infection by *Leishmania* occurs and leishmaniasis perpetuates itself.

In the 90s and at the turn of the millennium, Rebêlo et al. (2019) [3] and Rebêlo et al. (2000) [11] carried out entomological surveys in the municipality of Buriticupu, in the eastern Amazon region, and found that over time the implementation of human settlements, with different degrees of degradation of the vegetation cover, the sand fly fauna modified its composition and rank of dominance. Concomitant studies have shown that the epidemiological profile of leishmaniasis has also changed over time, and transmission is no longer essentially forest-based, becoming rural and periurban peridomestic [12-14].

In the present study, an entomological survey was carried out in three municipalities in the Maranhão Amazon, with a history of transmission of leishmaniasis, including settlements with different implantation times and forest areas with different degrees of degradation of the vegetation cover. The aim was to verify whether there is variation in the richness and abundance of sand fly species between different forest environments and human settlements. The idea is to verify whether sandflies can function as indicators of diversity and environmental changes in an area where cutaneous leishmaniasis is transmitted.

2. MATERIAL AND METHODS

2.1 Study area

The selected Amazonian municipalities (Figure 1) were Senador La Rocque (5º26'24" S; 47º17'24" W), Santa Luzia (03º57'48" S; 45º39'30" W) and Governador Nunes Freire (2º07'12" S; 45º52'48" W). In each municipality, a rural village with notification of cases of leishmaniasis and fragments of dense evergreen seasonal forest with different degrees of environmental degradation was selected: moderately degraded; very degraded and completely degraded.

The municipality of Senador La Rocque comprises an area of 1,236.6 km², with an average altitude of 180 meters above sea level. The population fluctuates around 18 thousand inhabitants and a demographic density of 14.55 inhabitants/km². The study area itself was the village of Sumaúma (5º25'13" S; 47º14'53" W) and the forest fragment selected next to the village is very degraded, due to use by the local community. The climate is tropical with an average annual temperature of 29°C with a minimum of 22°C and a maximum of 38°C, with peaks of 40°C on the hottest days. The total rainfall is 1,506.2 mm on average. The rainy season ranges from December to May, and the dry season from June to November.

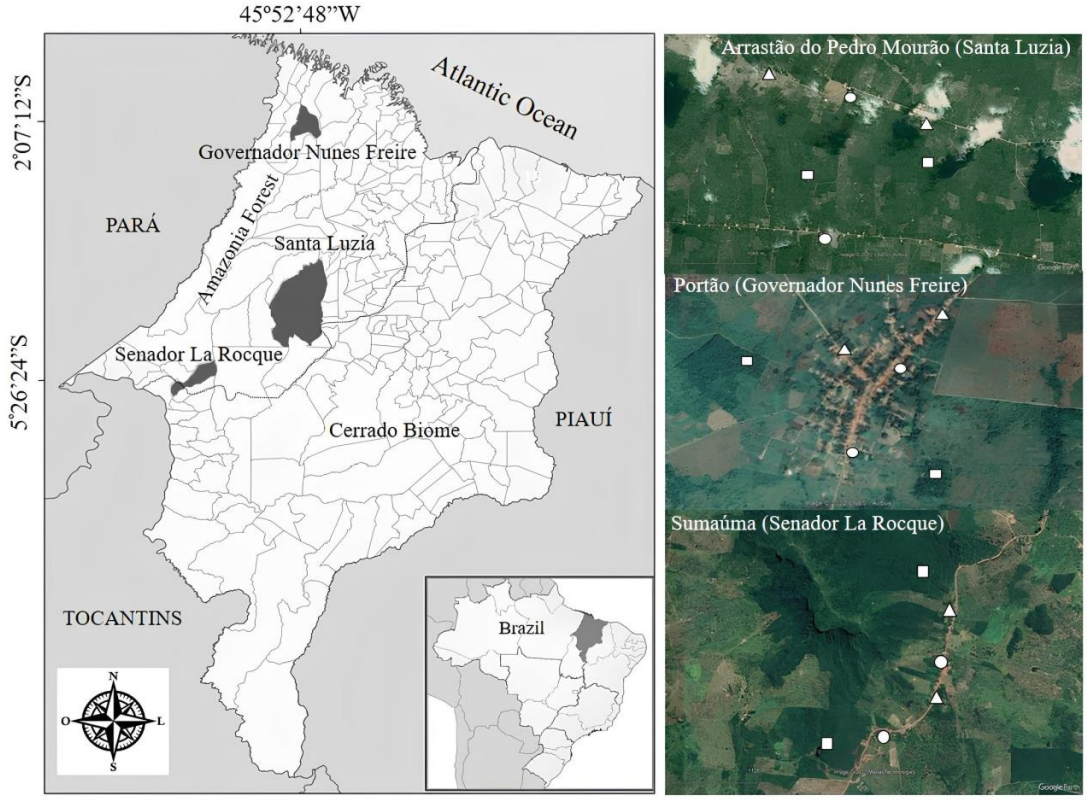

Figure 1. Map of the state of Maranhão showing the location of the municipalities of Senador La Rocque, Santa Luzia and Governador Nunes Freire, in the Amazon region covered by dense evergreen forest (DESF). Trap installation locations: forest fragment (square); intradomicile (triangle); peridomicile (circle).

The municipality of Santa Luzia has an area of 6,133,424 km², being the fourteenth largest municipality in the State of Maranhão with 75,043 inhabitants, of which 25,862 are urban and 43,530 are rural. The average altitude is 60 meters above sea level. The study site was the village of Arrastão do Pedro Mourão (4º40'00" S; 46º07'33" W) and the forest fragment selected next to the village is moderately degraded, due to use by the local community. The thermal variation during the year oscillates between 21.6°C and 32.2°C. The total precipitation is 1617 mm on average. The rainy season ranges from December to May, with monthly averages greater than 225 mm, and the dry season corresponds to the months of June to November, with averages of 59.25 mm. The water courses in the region are part of the Pindaré watershed.

Governador Nunes Freire. It comprises an area of 1,037 km², a population of approximately 25,402 inhabitants and a demographic density of 24.49 inhabitants/km². The administrative seat of the municipality is at sea level [16]. The study area itself was the village of Portão (1º54'45" S; 45º49'28" W) and the forest fragment selected next to the village is completely degraded, due to use by the local community. The thermal variation during the year oscillates between 22°C and 31.2°C. The average annual precipitation is 2,104 mm. The rainy season varies from January to July, with a monthly average of 263.95 mm; the dry season varies from August to December, with an average rainfall of 56.8 mm. The watercourses are part of the secondary watershed of converging rivers on the western coast.

2.2 Field and laboratory procedures

The sandflies were collected in CDC light traps, installed at an average height of 1.5 m, from 6 pm to 6 am. Collections took place on three consecutive nights, once a month, from May 2012 to April 2014. For comparison purposes, six traps were installed in each municipality, two in intradomiciles, two in peridomiciles and two in fragments. forestry. The capture effort in each

area was 6 traps x 12 hours x 3 days x 24 months = 5,184 hours. Traps were hung on tree branches, in forests, in indoor rooms and in peridomestic animal shelters.

The captured specimens were transported to the Laboratory of Entomology and Vectors at the Federal University of Maranhão, where they were sorted, tagged by location, trap number and collection date, and were subsequently identified according to the Galati [1] and Young & Duncan [15]. Part of the specimens were stored in 70% alcohol, in 1.5mL plastic microtubes and incorporated into the collection of the Laboratory of Entomology and Vectors (LEV). Another part was used in molecular studies of DNA Barcoding and *Leishmania* DNA.

The study group has a license to collect zoological material, issued by the Biodiversity Authorization and Information System (SISBIO) under process N° 76036-1.

2.3 Statistical analyzes

Sand fly species richness was considered as the number of species observed in the study areas. Species abundance is the number of individuals per species, and relative abundance refers to the uniform distribution of individuals among species in the community. To compare the diversity measures of the areas and environments, the diversity profile of the Rényi series was used. The diversity value was equal to the number of species in each sample, considering $\alpha = 0$. For $\alpha = 1$, the diversity value corresponded to the Shannon index, and for $\alpha = 2$, to the Simpson index.

The clustering technique (cluster analysis) was used to verify the similarity in the composition of the sand fly fauna between environments. An ordination technique, Non-Metric Multidimensional Scaling Model (NMDS), was used to compare sand fly abundance by sex and species across areas and environments. Both the grouping and ordering technique were developed based on the Bray-Curtis similarity matrix and with the data transformed into Log (X+1), according to Clarke (1993) [16]. The significance of the groups formed from the NMDS was tested using the bifactorial similarity analysis (ANOSIM two way) based on the Bray Curtis coefficient. Subsequently, the Similarity Percentage Analysis (SIMPER) test was applied in order to identify which species contributed to the formation of groups [17]. All statistical analyses were performed using PAST version 4.03 statistical software, at a significance level of 5% [18].

3. RESULTS

3.1 Richness and abundance

A total of 35 sand fly species were found, distributed in 13 genera. The most diverse genus was *Evandromyia* (9 species), followed by *Psathyromyia* (5), *Pressatia* (3), *Psychodopygus* (3), *Brumptomyia* (2), *Lutzomyia* (2), *Micropygomyia* (2), *Nyssomyia* (2), *Pintomyia* (2), *Bichromomyia* (1), *Migonemyia* (1), *Sciopemyia* (1) and *Viannamyia* (1). However, the most abundant genus was *Nyssomyia* which contributed with 35.6% (2,374 specimens) of the total sample, followed by *Evandromyia* (18.07%: 1,203 specimens), *Lutzomyia* (12.76%: 850 specimens) and *Brumptomyia* (7.02% 468 specimens). Each of the other genders contributed less than 7% of the total sample. Species richness was highest in the municipality of Santa Luzia (22 species), followed by Senador La Rocque (16) and Governador Nunes Freire (11), according to Tables 1 to 3.

Overall, 6,664 specimens of sand fly species were collected. The abundance was higher in the municipality of Senador La Rocque (48.5%), followed by Santa Luzia (27.9%) and Governador Nunes Freire (23.6%). The species abundance rank changed according to the studied areas (Table 1-3). In the municipality of Senador La Rocque the domain was *N. whitmani* (49.2%), *L. longipalpis* (25%) and *B. avellari* (11.9%) (Table 1). In the municipality of Santa Luzia, *N. whitmani* (28%) continued to dominate, but the second and third positions changed, being occupied by *P. damascenoi* (24.1%) and *M. migonei* (22.1%) (Table 2). In Governador Nunes Freire the rank changed again and *E. evandroi* (57.3%) became the dominant species, followed by *B. flaviscutellata* (14.4%) and *N. antunesi* (10.3%) (Table 3).

Table 1: Number of sand fly specimens captured in the municipality of Senador La Rocque. N = Absolute numbers; % = Percentage numbers; Σ = Sum.

Environments	Intradomicile			Peridomicile			Forest			Total	
Species/Sex	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	N	%
Nyssomyia whitmani	35	59	94	532	360	892	320	284	604	1590	49.2
Lutzomyia longipalpis	39	27	66	443	264	707	26	9	35	808	25.0
Brumptomyia avellari	2	2	4	114	60	174	86	119	205	383	11.9
Evandromyia carmelinoi	2	2	4	7	1	8	87	47	134	146	4.5
Evandromyia evandroi		6	6	40	47	87	4	15	19	112	3.5
Psathyromyia dreisbachi	3	3	6	5	3	8	31	41	72	86	2.7
Bichromomyia flaviscutellata					1	1	17	15	32	33	1.0
Psathyromyia hermanlenti				2		2	16	7	23	25	0.8
Nyssomyia antunesi	1	3	4		6	6				10	0.3
Migonemyia trinidadensis				1	2	3		5	5	8	0.2
Evandromyia termitophila					7	7				7	0.2
Evandromyia lenti				4		4	2		2	6	0.2
Evandromyia saulensis								6	6	6	0.2
Psathyromyia shannoni		1	1		1	1		3	3	5	0.2
Sciopemyia sordellii		2	2		3	3				5	0.2
Lutzomyia gomezi					2	2				2	0.1
Number of individuals	82	105	187	1148	757	1905	589	551	1140	3232	49.2
Percentage numbers	45.8	54.2	5.8	63.4	36.6	58.9	55.2	44.8	35.3	100.0	100.0
Species richness	6	9	9	9	13	15	9	11	12	16	

Table 2: Number of sand fly specimens captured in the municipality of Santa Luzia, from May/2012 to April/2014. N = Absolute numbers; % = Percentage numbers; Σ = Sum.

Environments	Intradomicile			Peridomicile			Forest			Total	
Species/Sex	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	N	%
Nyssomyia whitmani	48	37	85	112	86	198	131	106	237	520	28.0
Pintomyia damascenoi	32	23	55	224	76	300	59	35	94	449	24.1
Migonemyia migonei	29	20	49	175	117	292	54	16	70	411	22.1
Pressatia choti	2	3	5	24	23	47	28	23	51	103	5.5
Psychodopygus arthuri							35	44	79	79	4.2
Pressatia trispinosa	4	2	6	17	14	31	14	5	19	56	3.0
Pressatia triachanta	2	4	6	16	9	25	13	5	18	49	2.6
Micropygomyia longipennis					11	11	10	20	30	41	2.2
Lutzomyia longipalpis	5	1	6	25	9	34				40	2.2
Brumptomyia avellari	4	1	5	5	5	10	21	2	23	38	2.0
Pintomyia serrana							8	8	16	16	0.9
Viannamyia furcata					8	8	3	4	7	15	0.8
Brumptomyia brumpti							10		10	10	0.5
Evandromyia saulensis							5	5	10	10	0.5
Psathyromyia scaffi							6	1	7	7	0.4
Evandromyia sallesi							2	3	5	5	0.3
Psathyromyia dendrophyla								3	3	3	0.2
Evandromyia monstruosa								2	2	2	0.1
Evandromyia corumbaensis							2		2	2	0.1
Evandromyia teratodes					2	2				2	0.1
Evandromyia evandroi				1		1				1	0.1
Psathyromyia shannoni								1	1	1	0.1
Number of individuals	126	91	217	599	360	959	401	283	684	1860	100.0
Percentage numbers	58.1	41.9	11.7	62.5	37.5	51.6	58.6	41.3	36.8	100.0	
Species richness	8	8	8	9	11	12	16	16	19	22	

Table 3: Number of sand fly specimens captured in the municipality of Governador Nunes Freire. N = Absolute numbers; % = Percentage numbers; Σ = Sum.

Environments	Intradomicile			Peridomicile			Forest			Total	
Species/Sex	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	N	%
Evandromyia evandroi	42	44	86	423	246	669	63	83	146	901	57.3
Bichromomyia flaviscutellata	-	-	-	18	21	39	84	104	188	227	14.4
Nyssomyia antunesi	4	3	7	29	29	58	55	42	97	162	10.3
Nyssomyia whitmani	3	1	4	52	29	81	3	4	7	92	5.9
Psychodopygus complexa	-	-	-		1	1	20	18	38	39	2.5
Brumptomyia avellari				29	8	37	-	-	-	37	2.4
Micropygomyia trinidadensis	2	-	2	14	11	25	3	4	7	34	2.2
Psychodopygus davisi				5	4	9	15	11	26	35	2.2
Migonemyia migonei	-	-	-	13	16	29	-	-	-	29	1.8
Psathyromyia hermanlenti	-	-	-	9	4	13	-	-	-	13	0.8
Evandromyia walkeri				-	-	-	3	-	3	3	0.2
Number of individuals	51	48	99	592	369	961	246	266	512	1572	100.0
Percentage numbers	51.5	48.5	6.3	61.6	38.4	61.1	48	52	32.6	100	
Species richness	4	3	4	9	10	10	8	7	8	11	

3.2 Diversity and similarity indices between areas

Diversity was greater in the municipality of Santa Luzia, according to the Shannon (1.988) and Simpson (0.8067) indices, and there was no difference between Senador La Rocque (Si = 0.6773; Sh = 1.48) and Governador Nunes Freire (Si = 0.6341; Sh = 1.47), as shown in figure 2a). In Senador La Rocque there was no difference in the diversity indices between the forest (Si = 0.6667; Sh = 1.504), intradomicile (Si = 0.6192; Sh = 1.257) and peridomicile (Si = 0.6325; Sh = 1.223) (Figure 2b). In the municipality of Santa Luzia, diversity was greater in the forest (Si = 0.8259; Sh = 2.171) than in the peridomicile (Si = 0.7611; Sh = 1.682) and intradomicile (Si = 0.728; Sh = 1.522) (Figure 2c). In Governador Nunes Freire, diversity was very low in the intradomicile (Si = 0.2383; Sh = 0.5181) and higher in other environments, but there was no statistical difference between the peridomicile (Si = 0.4996; Sh = 1.195) and the forest (Si = 0.7395; Sh = 1.533) (Figure 2d).

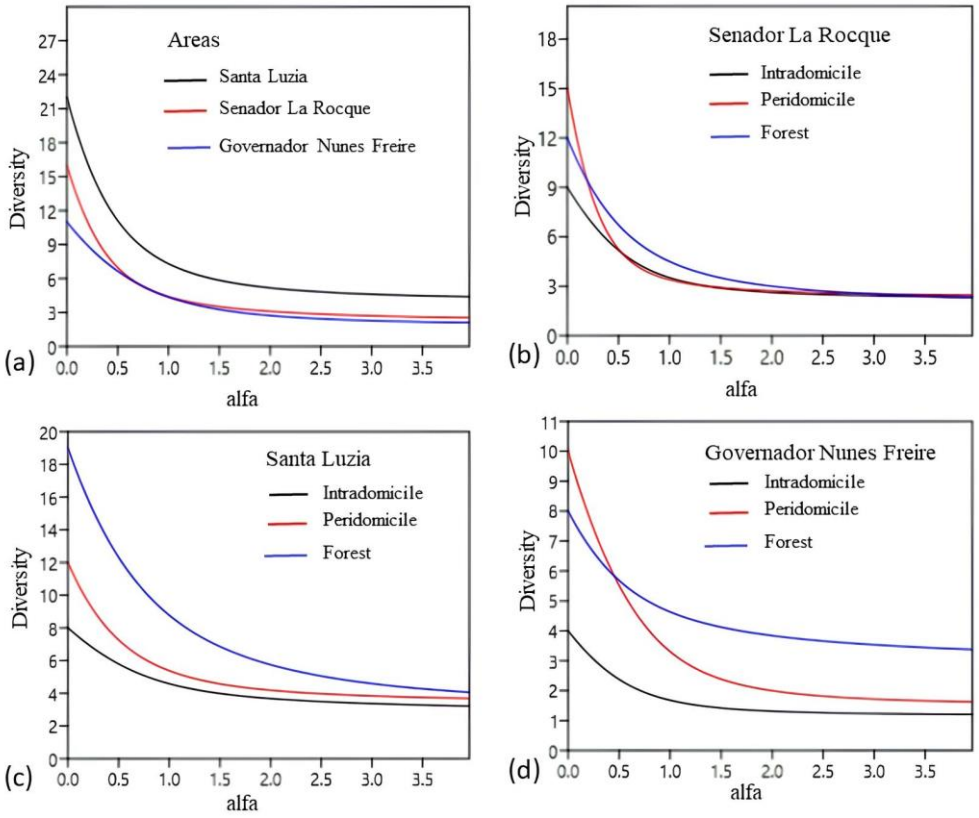

Figure 2: Rényi diversity profiles as a function of sand fly species diversity for the municipalities of Senador La Rocque, Santa Luzia and Governador Nunes Freire, state of Maranhão, Brazil. Alpha (α) zero = log richness,1 = Shannon index, 2 = Simpson index

3.3 Association with environments

In the municipalities of Senador La Rocque and Governador Nunes Freire, where the vegetation was very degraded and completely degraded, respectively, species richness was greater in the peridomestic environment. Unlike Santa Luzia, where species richness prevailed in the forest area, as it is moderately degraded. The abundance, however, was greater in the peridomicile of the three municipalities (Tables 1-3).

In the municipality of Senador La Rocque, 15 species were found in the peridomicile, against 12 in the forest and 9 indoors (Table 1). Abundance was also higher in the peridomicile (54.8%) than in the forest (38.7%) and indoors (6.6%). Seven species occurred in all environments studied. Two were only found in the peridomicile; two, only occurred in the intra and peridomicile; four in the forest and peridomicile; and one in the forest. Overall, males predominated over females in the peridomicile (males: 63.4%; females: 36.6%) and in the forest (males: 55.2%; females: 44.8%); while in the intradomicile, females (54.2%) prevailed over males (45.8%).

In Santa Luzia, species richness prevailed in the forest (19), when compared with the peridomicile (12) and the intradomicile (8); abundance, however, was higher in the peridomicile (51.6%) compared to the forest (36.8%) and inside the house (11.7%) (Table 2). Ten species only occurred in the forest; seven in all environments; two just in the peridomicile; two in the forest and peridomicile; and one in anthropogenic environments (inside and outside the home). Overall, males predominated over females in intradomiciles (males: 58.1%; females: 41.9%), in peridomiciles (males: 62.5%; females: 37.5%) and in forests (males: 58.6%; females: 41.3%).

In the municipality of Governador Nunes Freire, species richness prevailed in the peridomicile (10 species), which was frequented by all species present in the forest (8), except *E. walkeri* (Table 3). Four species entered the home, mainly *E. evandroi*. The abundance was also higher in the peridomicile (61.1%) than in the forest (32.6%) and inside the house (6.3%). Three species were found only in the peridomicile; Five species occurred in all environments. The others occurred in

the forest and peridomicile. Overall, males predominated over females in the intradomicile (males: 51.5%; females: 48.5%) and peridomicile (males: 61.6%; females: 38.4%); while in the forests females (52%) prevailed over males (48%).

As for the similarity between the areas, it was verified by the Bray-Curtis index, that it was higher between Senador La Rocque and Santa Luzia (s = 0.23802) than with Governador Nunes Freire and Senador La Rocque (s = 0.126978) and Santa Luzia and Governador Nunes Freire (s = 0.092657). In all municipalities, the similarity of the sand fly fauna was greater between the forest and the peridomicile than between these environments and the intradomicile. It was like this Senador La Rocque (peridomicile x forest: s = 0.56289; forest x intradomicile: s = 0.226074 e peridomicile x intradomicile: s = 0.178776), Santa Luzia (peridomicile x forest: s = 0.576993; intradomicile x forest: s = 0.484501; peridomicile x intradomicile: s = 0.372532); e Governador Nunes Freire (peridomicile x forest: s = 0.362525; intradomicile x forest: s = 0.338462; peridomicile x intradomicile: s = 0.188392).

The NMDS analysis showed that there was no difference in the abundance of sandflies between the sexes, but the difference in the order of species abundance between the areas was statistically significant (Rfactor sex = 0.25, p = 0.916; RFactor Level of degradation = 0.458; p = 0.0047), as shown in Figure 3. Between Santa Luzia (a moderately degraded area) and Senador La Rocque (very degraded area), the one who contributed the most was *P. dreisbachi* (14.3), followed by *P. trispinosa* (9.33), *P. triachanta* (8.17) and *L. longipalpis* (7.2). Among the moderately degraded and completely degraded area (Governador Nunes Freire), the person who contributed the most was *P. choti* (17.2), followed by *P. trispinosa* (9.33), *P. triachanta* (8.17), *L. longipalpis* (7.2), *P. davisi* (7.2) and *B. flaviscutellata* (7.2). However, differences between very degraded and completely degraded areas were mainly influenced by *L. longipalpis* (135), *E. carmelinoi* (24.3), *P. dreisbachi* (14.3), *B. flaviscutellata* (7.2) and *P. davisi* (7.2).

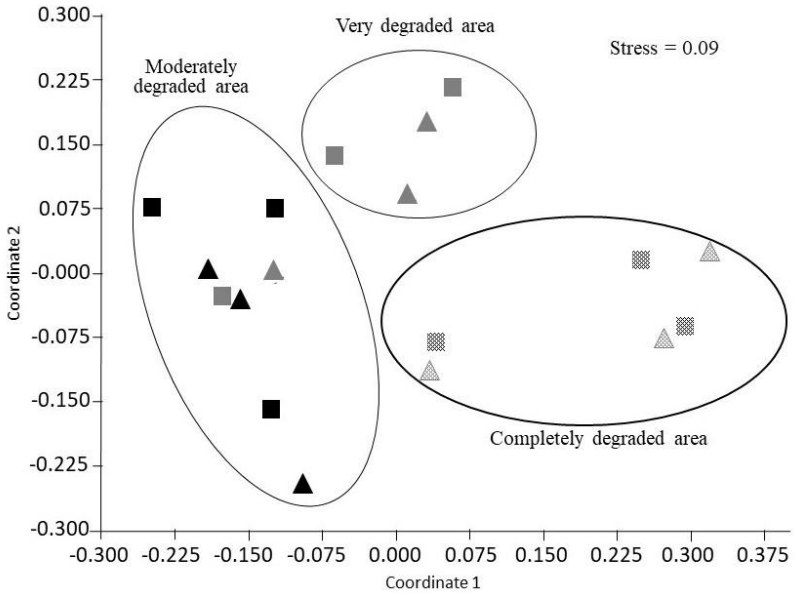

Figure 3: Non-metric multidimensional scaling for association of sandflies between areas with moderate degradation (Santa Luzia), very degraded (Senador La Rocque) and completely degraded (Governador Nunes Freire). Male: Square; Female: Triangle.

4. DISCUSSION

Studies carried out in the state of Maranhão have shown that altered primary forest areas [3, 5, 19, 20] and even secondary forests in metropolitan areas [21], contribute immensely to the greater local diversity of sandflies. In these environments, a large number of species with different degrees of abundance normally occur. The present study corroborates this assertion, as the richness of sandflies in forest areas was greater than in anthropogenic areas (intradomicile and

peridomicile). Likewise, richness was greater in the more conserved forest fragments than in the more degraded ones. The greater species richness in the local forest areas suggests that in these environments there are still appropriate ecotopes for sandflies to establish their breeding sites and shelters. In the same way, it must still have a food source for males and females, enough to maintain the populations of the different species.

The main pressure factors on continental species are related to the consequences of agricultural activities, whether due to fragmentation and decreased habitat quality in areas where activity is consolidated or the continuous process of habitat loss where activity is expanding. The reduction of natural forest habitats by deforestation restricts the ecotopes for vertebrates, mainly the large ones [22]. In this perspective, Rebêlo et al. (2019) [3] speculated that if the size of the populations of these vertebrates decreases and many may disappear, this process ends up affecting sandflies. After all, sandflies are hematophagous and these vertebrates constitute their source of blood food.

The impact of deforestation and land cover degradation can change the abundance rank of sandflies. Abundant species in conserved forests may become rare in altered forests and vice versa [3]. The reduction of habitats can stimulate the gradual migration of vectors to nearby populations due to deforestation and fires. Due to the opportunities generated in this new anthropogenic environment (availability of shelter and food in backyards and even inside houses), sandflies can achieve great development, as demonstrated by numerous works [23-25].

Species of sandflies originally from forests maintain contact with peridomiciles, due to the proximity between these wild and anthropogenic environments (in rural and periurban areas). In the present study, many species found in forest areas occurred in anthropogenic environments. This proportion increases the more degraded the area is [3]. So much so that in Senador La Rocque and Governador Nunes Freire, where forest areas were more degraded, the richness of sandflies increased in peridomestic and indoor areas, unlike Santa Luzia, where the richness was comparatively greater in the forest area.

Despite the great richness of sand fly species in peridomiciles and even inside houses, not all taxa are adapted to these new environments. This statement is based on the fact that over the years these taxa have occurred in low density, as observed in the municipalities studied. However, those species whose males and females abundantly frequent peridomiciles may derive from autochthonous populations, that is, those that reproduce and proliferate in the peridomicile itself. In this case, the predominance of females may favor the transmission of the etiological agent of leishmaniasis that may be introduced by synanthropic animals, such as rodents [26].

The other species that contributed very few individuals, sometimes of only one of the sexes, are considered as occasional visitors to the anthropogenic environment. The question is that the proximity of the villages to the forest areas and the high degree of degradation of these, contribute to this contact of the wild vector with the peridomestic environment, with the possibility of entering human habitations.

The greater abundance of sandflies in peridomiciles suggests that in these environments there is a greater concentration of hosts than forest fragments for sandflies to perform the blood meal. Domestic animals present in abundance become the main sources of blood for female sandflies that need to reproduce. The respective shelters of these animals may constitute the appropriate ecotopes to shelter both females and males, since these were also found in abundance. Animal shelters can also constitute the places for the formation of aggregates of males to search for females for copulation.

In the present study, a large number of specimens of *L. longipalpis*, *E. evandroi*, *N. whitmani* and *B. flaviscutellata* frequenting peridomiciles. The first three species tend to be opportunistic in these environments, being attracted mainly by chickens, pigs, dogs and horses, used as hosts for the blood meal [6, 24, 25].

The attraction of these species to domestic animals increases the risk of infection for residents of areas with sand fly infestation [27, 28]. These vectors have already been found contaminated with DNA fragments of pathogens that cause leishmaniasis in successive studies using molecular methods. *L. longipalpis*, the vector of *L. infantum* causing visceral leishmaniasis is permissive for *L. braziliensis*, *L. shawi*, *L. amazonensis*, *L. lainsoni* and *L. mexicana*, causing tegumentary leishmaniasis; while *Ny. whitmani* vector of *L. braziliensis* is permissive for *L. infantum* [7, 8]. Even though it is rarer in peridomiciles, *B. flaviscutellata* the vector of *L. amazonensis* [29] was

found with traces of *Leishmania* DNA [7]. As if that were not enough, other sand fly species found in the present study, which are not considered competent vectors of *Leishmania*, were also found with DNA fragments from these parasites. It was the case with *E. lenti* (carrying *L. infantum*). *E. evandroi* (*L. lainsoni*), *S. sordellii* (*L. infantum*) [6-8], *E. termitophila* (*L. infantum* and *L. guyanensis*), *M. trinidadensis* (*L. infantum/L. braziliensis*). It is possible that some species do not function as vectors, only become infected from the same hosts used by competent vectors.

5. CONCLUSION

Given the above, it is concluded that there was variation in the richness and abundance of sand fly species between the different forest environments and human settlements. Sand fly richness was higher in areas whose forest was moderately degraded when compared to very and completely degraded environments. However, the abundance increased in peridomiciles, the more degraded the forest fragment was. The abundance was greater in peridomiciles due to the presence of domestic animals and their shelters. Activities that cause deforestation modify the vegetation cover and, consequently, affect the structure of wild sand fly communities. The reduction of forests due to the advance of agriculture and livestock has been causing a decrease in the components of the sandfly community in natural environments; while the establishment of rural settlements close to degraded forest areas has enabled the adaptation of sand fly species to these new anthropized environments. As a consequence, leishmaniasis affects human populations and domestic animals. So, phlebotomine sand flies can function as indicators of diversity and environmental changes in the transmission area of tegumentary leishmaniasis.

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