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ECOSYSTEMS

Ecological aspects of sand fly fauna (Diptera: Psychodidae, Phlebotominae) of Sumidouro District, State of Rio de Janeiro, Brazil

JOÃO RICARDO C. ALVES, CLEBER N. DO CARMO & RODRIGO C. MENEZES

Abstract: Aiming to compare and update the sand fly fauna of Portão de Pedra site, Sumidouro District, Rio de Janeiro State, Brazil, and considering the environmental changes occurred, the biology and ecology of the local sandfly species were examined five years later as a complementary study carried. Captures were made in the cave, surroundings of cave and forest of the region, from 6 p.m. to 6 a.m. Among the 2323 sandflies of eigth species of the *Lutzomyia* were captured: *L. gasparviannai*, *L. edwardsi*, *L. tupynambai*, *L. hirsuta*, *L. whitmani*, *L. migonei*, *L. intermedia, Lutzomyia*. sp and one species of the *Brumptomyia* Kind*: B. brumpti*. In 2009 and 2010 were collected 1756 samples from ten species of the former genus and two of the second. *L. gasparviannai* was predominant, in the three collection sites, in both periods. Five species implicated as vectors of *Leishmania*: *L. intermedia*, *L. whitmani*, *L. migonei*, *L. hirsuta* and *L. davisi* have been collected in the area. Poisson regression and ANOVA were used to perform statistical analysis of species most relevant. The record of *L. intermedia* and a case of American tegumentary leishmaniasis are relevant to the public health of municipality and of state of Rio de Janeiro.

Key words: cave, forest, sandfly, Sumidouro.

INTRODUCTION

Sand flies (Diptera, Psychodidae) serve as invertebrate hosts for protozoan species of the genus Leishmania Ross, 1903 (Kinetoplastida, Trypanosomatidae), which induce leishmaniasis in humans and other mammals (Ready 2013, Maroli et al. 2013, Cecílio et al. 2022). These protozoans are transmitted through the bites of female sandflies that are infected (Rangel & Lainson 2003).

In Brazil, a total of 275 sand fly species have been documented thus far, with some of them identified as proven or suspected vectors of leishmaniasis-causing agents (Shimabukuro et al. 2021). Aguiar & Vieira (2018) reported the presence of 125 species in the southeastern region and 65 species in the state of Rio de Janeiro (Carvalho et al. 2014), including six species that are considered vectors of Leishmania for both humans and mammals (Aguiar & Vieira 2018).

Following the emergence of American tegumentary leishmaniasis (ATL) cases in mountainous regions impacted by human activities in the state of Rio de Janeiro, investigations into the sand fly fauna and their ecological characteristics were initiated within these areas (Alves 2007, 2008, Carreira-Alves 2008, De Souza et al. 1995, Peres-Dias et al. 2016, Souza et al. 2002, 2003).

In January 2011, the occurrence of heavy precipitation in these mountainous regions, coupled with land utilization and human settlements involving excavation and embankment activities, preexisting rainfall

conditions, and erosion from rivers and rainwater, resulted in geological instability in the city of Sumidouro (SDEEIS 2011).

Between 2007 and 2017, a total of 31 cases of ATL were documented in Sumidouro and its neighboring municipalities (SINAN 2019), even though Sumidouro itself is not considered an endemic area for this disease. However, we received communication from a resident who claimed to have been diagnosed with ATL and treated by the Oswaldo Cruz Foundation in the same year, and this was corroborated by family members and acquaintances. Furthermore, physical evidence in the form of scars from the wounds (JRC Alves, personal communication) and the detection of *L. intermedia*, a vector of *Leishmania braziliensis*, was recorded for the first time in 2015 and 2016 (Martins et al. 1978, Carvalho et al. 2014).

This study focuses on the environmental transformations observed in the São Caetano neighborhood over a period of five years, with specific emphasis on alterations in biodiversity, population density, species predominance, and the presence of sand fly species known as vectors for Leishmania.

MATERIALS AND METHODS

Ethics statement

Sampling activities were conducted within a forested area, which included a cave, situated on private land. Prior consent was obtained to conduct the captures within this forested area and the cave, as evidenced by a consent statement.

Study area

The municipality of Sumidouro is situated in the mountainous region of the State of Rio de Janeiro, at a latitude of 22°02'59" south and a longitude of 42°40'29" west. It is located at an elevation of 355 meters and shares borders with the cities of Nova Friburgo, Teresópolis, Carmo, São José do Vale do Rio Preto, Sapucaia, and Duas Barras. With a total area of 397.6 square kilometers, it is positioned 174 kilometers away from Rio de Janeiro, the capital of the state (PMS 2019). (Figure 1)

The São Caetano district (22° 03'08" S and 42° 41'17" W) was established following the colonization of the Vale do Rio Paquequer region. The study area is situated at the São Caetano rock, which spans 2 kilometers in diameter and reaches a height of 500 meters. Composed of granite, the rock features vegetation covering

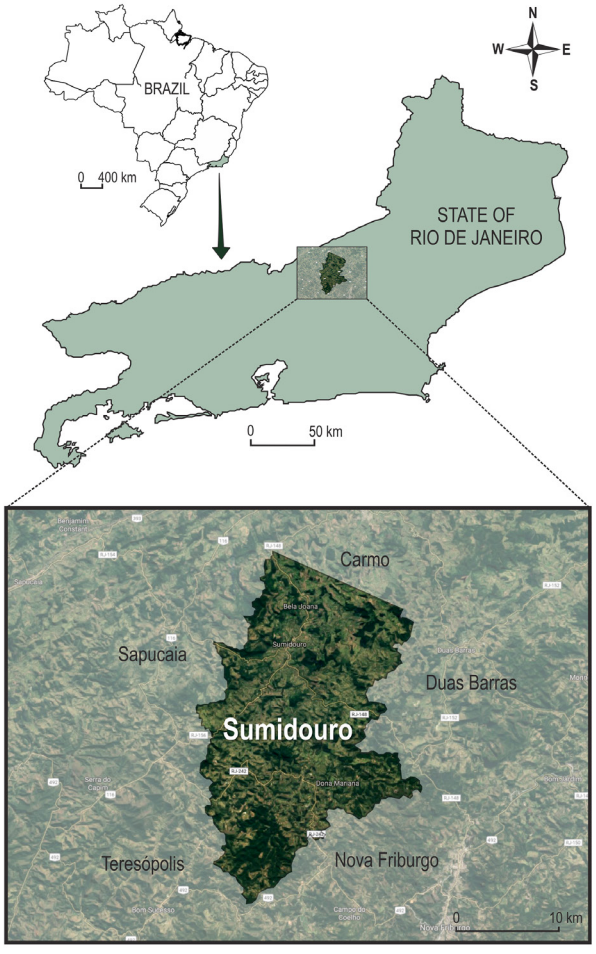

Figure 1. Geographic location of the city of Sumidouro, latitude 22º02'59" south and longitude 42º40'29" west, in the mountain region of the state of Rio de Janeiro, RJ, Brazil.

its summit, while the surrounding area is characterized by typical forest vegetation. It is located 3 kilometers away from the city center. The collections were conducted within a cave named "São Caetano," its vicinity, and a forest in the locality known as "Portão de Pedra," situated 1 kilometer from São Caetano (Figure 2).

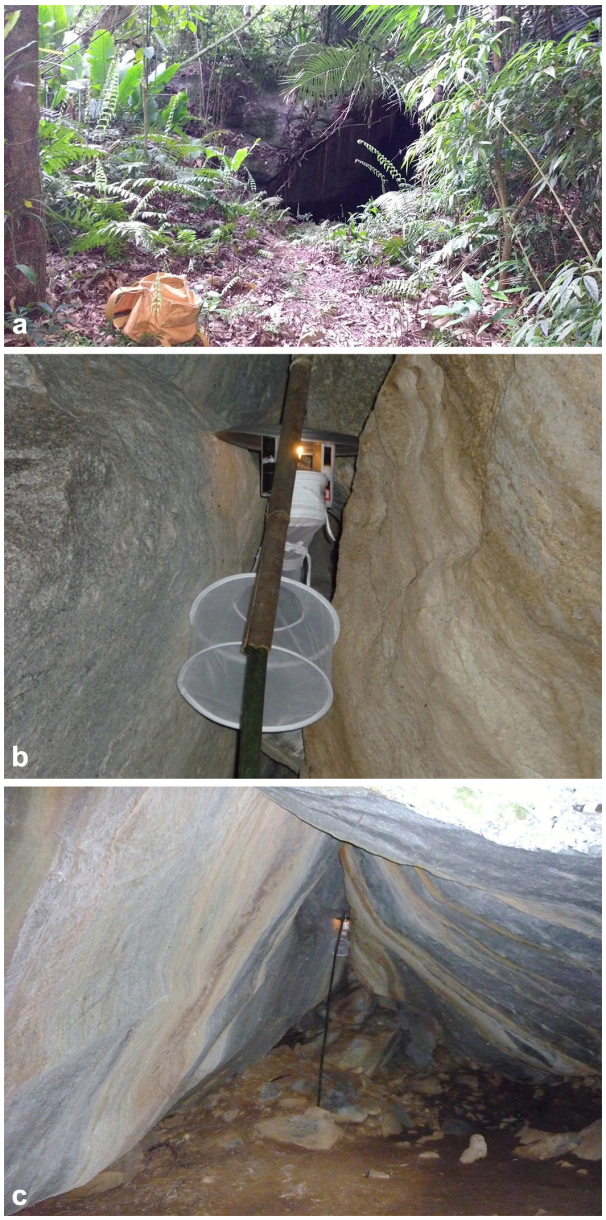

Figure 2. Entrance of the cave, near the base of São Caetano Rock, where the phlebotomine sand fly collections were made (a). CDC-type light trap between the rocks inside the cave (b). In detail, CDC-type light trap, between the rocks inside the cave (c). Photos of: Alves, JRC.

Specimen collection

In 2009 and 2010, and later in 2015 and 2016, sand fly captures were conducted using CDC light traps, specifically the HP model. The trapping activities were carried out twice a month, resulting in a total of 24 hours of collection time per month. The consistent methodology was maintained throughout the two-year collection period. Three light traps were deployed, with one placed within the forested area, another positioned in the surrounding vicinity, and a third one situated inside the cave. The traps were operational from 6 p.m. until 6 a.m. the following morning, ensuring a comprehensive sampling effort during both periods.

To assess the phlebotomine sand fly fauna profile in light of the environmental changes caused by the heavy rainfall event on January 12, 2011, additional captures were conducted at the same site. These supplementary collections aimed to establish a correlation between the biodiversity, abundance of these insects, and the potential vectors of leishmaniasis.

Phlebotomine sand flies that were captured were carefully aspirated using manual suction catchers. Subsequently, they were subjected to a brief period of low-temperature exposure for approximately 10 minutes. Following this, the sand flies were transferred to cylindrical tubes containing 70% alcohol, ensuring proper labeling with the corresponding collection information. These specimens were then submitted to the Diptera Laboratory, specifically the Phlebotomine Sector of the Fundação Oswaldo Cruz, where they underwent sorting, arrangement, and identification processes.

The climatic variables, including temperature and relative humidity of the air, were obtained from the National Institute of Meteorology,

specifically the 6th District of Meteorology. These data were sourced from the Observation and Applied Meteorology Section (SEOMA), located in Parque Nacional da Serra dos Órgãos, in the city of Teresópolis, Rio de Janeiro.

The sand flies were subjected to the clarifying process and mounted using the technique described by Young & Perkins (1984), with modifications as outlined by Aguiar (1993). Species identification within the Lutzomyia França, 1924 and Brumptomyia França & Parrot, 1921 generally followed the guidelines provided by Young & Duncan (1994) and Forattini (1973), respectively.

The collected specimens were deposited in the Entomological Laboratory of the Oswaldo Cruz Institute, which is part of the Oswaldo Cruz Foundation.

Statistical analysis

For the analysis of the abundance and spatial distribution of phlebotomine sand flies at a specific site, the Index of Species Abundance (ISA) and the Standardized Index of Species Abundance (SISA) were employed, following the methodology proposed by Roberts & Hsi (1979).

The ISA was calculated using Microsoft Excel 2013 (Microsoft Corp., Redmond, WA, USA), and the resulting values were subsequently converted to a range between 0 and 1 to obtain the SISA. The conversion was carried out using the following equations:

$$ISA = (a + RJ) / k$$

$$SISA = (c - ISA) / (c-1)$$ where: K = capture number

a = value obtained by multiplying the number of the species absence (NAE) in k captures per c.

c = value of the highest position of the species in k captures plus 1.

RJ = sum of classifications in each species

For the results obtained in the research on the influence of temperature (C º) and relative humidity of air (RHA) on the phlebotomine fauna, in both periods, the Poisson Regression was used. Meanwhile, the ANOVA procedure was performed to compare the SISA results for *L. gasparviannai*, *L. edwardsi*, and *L. tupynambai*.

RESULTS

From June 2009 to May 2010, a total of 1,756 sandflies were captured at the Portão de Pedra site. These sand flies belonged to 14 different species, with 10 species belonging to the Lutzomyia genus: *L. gasparviannai* (Martins, Godoy & Silva, 1962), *L. edwardsi* (Mangabeira, 1946), *L. tupynambai* (Mangabeira, 1942b), *L. hirsuta hirsuta* (Mangabeira, 1942b), *L. whitmani* (Antunes & Coutinho, 1939), *L. davisi* (Root, 1934), *L. migonei* (France, 1920), *L. microps* (Mangabeira, 1942a), *L. cortelezzii* (Brethés, 1923) and *L. quinquefer* (Dyar, 1929). Additionally, there were two species of the Brumptomyia genus: *Brumptomyia brumpti* (Larrouse, 1920) and *B. guimaraesi* (Coutinho & Barreto, 1941a) (Table I).

From March 2015 to February 2016, a total of 2,323 phlebotomine sand flies were captured at Sítio Portão da Pedra. These sand flies belonged to nine different species, with seven species belonging to the Lutzomyia genus: *L. gasparviannai*, *L. edwardsi*, *L. tupynambai*, *L.* hirsuta, *L. whitmani*, *L. migonei* and *L. intermedia*. Additionally, there was one species from the Brumptomyia genus: *Brumptomyia brumpti* (Table I).

The results of the Poisson regression analysis revealed that, when comparing the temperatures (°C) of the collection periods 2009/2010 and

Table I. Total genders of sandflies captured with light traps (CDC) in the cave, surrounding and forest, in the three collection, from June 2009 to May 2010 and from March 2015 to February 2016, at sítio Portão de Pedra, Municipality of Sumidouro, State of Rio de Janeiro, Brasil.

			Collections from 2009 to 2010						
Species	**Cave**			**Surrounding**			**Forest**		
	Males	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total[1]**
L. gasparviannai	211	461	672	81	172	253	112	144	256
L. edwardsi	37	114	151	5	88	93	25	21	46
L. tupynambai	30	129	159	4	23	27	9	6	15
L. hirsuta	2	7	9	1	10	11	9	2	11
L. whitmani	2	6	8	-	4	4	-	12	12
B. brumpti	2	2	4	-	-	-	1	-	1
L. migonei	1	2	3	-	2	2	-	-	-
L. quinquefer	-	2	2	-	-	-	-	-	-
L. microps	2	-	2	-	-	-	-	-	-
L. cortelezzii	1	1	2	-	-	-	-	-	-
L. sp.	1	-	1	-	1	1	-	3	3
L. davisi	-	-	-	-	2	2	-	3	3
B. guimaraesi	-	-	-	1	-	1	-	-	-
B. sp	-	-	-	-	2	2	-	-	-
Cumulative[2]	**289**	**724**	**1013**	**92**	**304**	**396**	**156**	**191**	**347**
				Collections from 2015 to 2016.					
Species	**Cave**			**Surrounding**			**Forest**		
	Males	**Females**	**Total**	**Males**	**Females**	**Total**	**Males**	**Females**	**Total[1]**
L. gasparviannai	427	347	774	62	84	146	92	85	177
L. tupynambai	113	319	432	22	117	139	7	36	43
L. edwardsi	37	356	393	29	87	116	2	34	36
L. sp.	3	18	21	-	1	1	-	-	-
L. hirsuta	-	17	17	1	7	8	1	1	2
B. brumpti	6	-	6	-	-	-	1	-	1
L. migonei	-	3	3	1	-	1	-	-	-
L. whitmani	-	3	3	-	-	-	1	2	3
L. intermedia	-	-	-	1	-	1	-	-	-
Cumulative[2]	**586**	**1063**	**1649**	**116**	**296**	**412**	**104**	**158**	**262**

[1]=Is the enumeration of male and female sandflies collected at a designated sampling site during specific temporal intervals.
[2]=Is the cumulative count encompassing males, females, and the overall count from a designated collection site during a specified temporal period.

2015/2016, there were no statistically significant differences for *L. gasparviannai* (p-value = 0.328) and *L. edwardsi* (p-value = 0.685). However, for *L. tupynambai*, a significant statistical difference was observed (p-value < 0.01), indicating an opposite behavior between the variable and the species.

When considering the relative humidity of the air (%) and using the same statistical method and periods, all three species (*L. gasparviannai*, *L. edwardsi*, and *L. tupynambai*) exhibited statistically significant differences (p-value < 0.01).

DISCUSSION

Considering the three sites of collection, cave, surrounding and forest, we highlight that *Lutzomyia gasparviannai* predominated over all species, types and collection sites, with 67.2% of females and 73.4% of males of this species collected in the São Caetano cave. *L. tupynambai* was the second most frequent species, with 67.5% of females and 79.6% of males captured in the cave, followed by *L. edwardsi* with and 74.6% of females and 54.4% of males of this species in the cave.

L. tupynambai presented a greater difference in males frequency in relation *to L. gasparviannai* and *L. edwardsi*, which does not confirm Rodrigues et al. (2013). These authors, in their collection with CDC light trap, captured more females of *L. tupynambai* than males. According to the literature, there is no record of *L. gasparviannai* in cave, what is corroborated by Alves et al. (2011), Barata et al. (2008, 2012), Campos et al. (2017), Carvalho et al. (2014), Dutra-Rêgo et al. (2022), Galati (2003), Galati et al. (2010). For *L. tupynambai*, Aguiar & Vieira (2018) point armadillo burros, other types of wild animal burrows, tree trunks, tubular roots and marginal areas, while *for L. gasparviannai* only the forest without defined location. The high frequency of males is relevant, since it is known that a considerable population of males at a given location suggests the existence of breeding sites of these sandflies (Alves 2007, Brazil & Brazil 2003). Therefore, the caves may be a favorable environment for oviposition of, *L. gasparviannai* and *L. tupynambai* consequently, the perpetuation of this species due to the sudden changes that have taken place over time.

Considering the Standardized Species Abundance Index (SISA), *L. gasparviannai* presented the highest abundance in both periods, the highest in the 2009/2010 (0.708) and the lowest in 2015/2016 (0.656); however, in absolute values, they were more significant in this study (774 sandflies) than in the previous study (672 specimens), thus showing the relevance of SISA indices, because a more defined distribution suggests the need to control and prevent leishmaniasis at the site.

Lutzomyia edwardsi presented a more homogeneous spatial distribution in 2015/2016, with 0.490 and a previous record of 0.316, which demonstrates a better and more efficient adaptation than the population of ten years ago (Table II). Galati et al. (2010) in State São Paulo, collected *L. edwardsi* with 0.353, and it was the sixth of the ranking, with an absolute value of 48 sandflies considering the cave. We can see that there was a more harmonic adaptation in the research carried out in this study. In both periods, the species was the third of the ranking, and the spatial distribution was more uniform, even after the environmental changes that occurred in the region. In 2015/2016, a further 242 specimens of a total of 544, almost half, were collected. (Table II). These results confirms Campos et al. (2017), who in night gathering in caves and surroundings in the municipality of Pains, state Minas Gerais, registered *L. edwardsi* as the third most abundant (11%) and present

Table II. Quantitative comparison of total, frequency, Standardized Index of Species Abundance (SISA) and the total Ranking of phlebotomines captured with CDC model light trap placed in the cave, surroundings and Forest, from June 2009 to May 2010, and from March 2015 to February 2016, at Sítio Portão de Pedra, in the city of Sumidouro, state of Rio de Janeiro, Brazil.

Species	Total	%[1]	SISA[2]	Ranking[3]	Total	%	SISA	Ranking
	Cave 2009 - 2010				Cave 2015 - 2016			
L.gasparviannai	672	66.3	0.708	1	774	46.9	0.656	1
L. tupynambai	159	15.7	0.476	2	432	26.2	0.508	2
L. edwardsi	151	14.9	0.316	3	393	23.8	0.490	3
L. hirsuta	9	0.9	0.122	4	17	1.0	0.021	6
L. whitmani	8	0.8	0.080	5	3	0.2	0.015	7
B. brumpti	4	0.4	0.049	6	6	0.4	0.025	5
L. migonei	3	0.3	0.042	7	3	0.2	0.010	8
L.sp.	1	0.1	0.017	10	21	1.3	0.072	4
L. microps	2	0.2	0.035	8	-	-	-	-
L. quinquefer	2	0.2	0.035	8	-	-	-	-
L. cortelezzii	2	0.2	0.028	9	-	-	-	-
Cumulative	**1013**	**100.0**			**1649**	**100.0**		
Species	**Surroundings 2009 - 2010**				**Surroundings 2015 - 2016**			
L. gasparviannai	253	63.9	0.523	1	146	35.4	0.595	1
L. edwardsi	93	23.5	0.384	2	116	28.2	0.463	3
L. tupynambai	27	6.8	0.245	3	139	33.7	0.488	2
L. hirsuta	11	2.8	0.120	4	8	1.9	0.083	4
L. whitmani	4	1.0	0.056	5	-	-	-	-
L. davisi	2	0.5	0.046	6	-	-	-	-
L. migonei	2	0.5	0.028	7	1	0.2	0.017	5
B. sp.	2	0.5	0.023	8	-	-	-	-
L. sp.	1	0.3	0.019	9	1	0.2	0.012	6
B. guimaraesis	1	0.3	0.009	10	-	-	-	-
L. intermedia	-	-	-	-	1	0.2	0.017	5
Cumulative	**396**	**100.0**			**412**	**100.0**		
Species	**Forest 2009 - 2010**				**Forest 2015 - 2016**			
L. gasparviannai	256	73.8	0.529	1	177	67.6	0.594	1
L. edwardsi	46	13.3	0.350	2	36	13.7	0.214	2
L. tupynambai	15	4.3	0.125	3	43	16.4	0.188	3
L. whitmani	12	3.5	0.108	4	3	1.1	0.083	4
L. hirsuta	11	3.2	0.088	6	2	0.8	0.083	4
L. davisi	3	0.9	0.063	5	-	-	-	-
L. sp.	3	0.9	0.050	8	-	-	-	-
B. brumpti	1	0.3	0.029	7	1	0.4	0.015	5
Cumulative	**347**	**100.0**			**262**	**100.0**		

[1]= Represents the percentage of the aggregate collected at a specific collection site relative to the overall species collection total.

[2]=Constitutes an index assessing the spatial distribution and frequency of a species within a designated area. The maximum attainable value is 1.

[3]= Signifies the positioning of the species based on its Standardized Index of Species Abundance (SISA) concerning other species collected within the same scrutinized area.

in three cavernous environments. These authors collected 133 specimens in the cave, 105 females and 28 males, and 30 specimens in the surrounding area, 25 females and 5 males. In view of the quantitative aspects, it is noted that *L. edwardsi* was the most present in the cave and its surroundings, with more specimens collected than in the research carried out by Galati et al. (2010) and Campos et al. (2017). The fact that in the municipality of Pains, the area studied suffers anthropic activity of mining, calcination and agriculture, may be contributing to the reduction of this fauna.

In 2015 and 2016, the monthly frequency of *L. gasparviannai* had its highest peak in October (168), and it was decreasing until January, when it started to rise, showing a drop in March, recovering later and stabilizing in the cold and dry period from June to August, when 33.9% of the sandflies were collected, while in the other months this percentage was of 27.1%. In 2009 and 2010, the most adequate season was the hot and humid months, with 54.1% of the sandflies collected, with peak in March (240), the female (191) being responsible for 75.6% of this total. In March, the highest relative humidity occurred, which was 98%. It is known that the higher the moisture in the air, the more sandflies appear in nature (Aguiar & Medeiros 2003) (Table III).

Table III. Frequency, Standardized Index of Species Abundance (SISA) and the total of phlebotomines captured with CDC model light trap placed in the cave, surroundings, and Forest, in the cold and dry season, warm and humid season, from March 2015 to February 2016, at Sítio Portão de Pedra, in the city of Sumidouro, state of Rio de Janeiro, Brazil.

Species	Collection Sites	Dry and Cold			Warm and Humid		
		Total[1]	%[2]	SISA	Total	%	SISA
L. edwardsi	Cave	47	14.2	0.444	128	27.4	0.667
	Cave Surrounding	33	28.7	0.528	13	21.3	0.125
	Forest	9	9.2	0.083	12	16.2	0.278
L. gasparviannai	Cave	221	66.6	0.833	231	49.4	0.750
	Cave Surrounding	66	57.4	0.800	11	18.0	0.250
	Forest	85	86.7	1.000	57	77.0	0.667
L. hirsuta	Cave Surrounding	3	2.6	0.222	4	6.6	0.167
	Forest	2	2.0	0.167	-	-	-
L. migonei	Cave	-	-	-	3	0.6	0.058
L. sp.	Cave	-	-	-	3	0.6	0.063
L. tupynambai	Cave	64	19.3	0.544	100	21.4	0.583
	Cave Surrounding	13	11.3	0.500	33	54.1	0.167
	Forest	-	-	-	4	5.4	0.333
L. whitmani	Cave	-	-	-	3	0.6	0.042
	Forest	2	2.0	0.167	1	1.4	0.056
Cumulative		**545**			**603**		

[1]= Denote the agregatte count of species collected at each designated collection site during both the cold and dry, as well as the hot and humid periods in the studied area for the years 2015 and 2016.
[2]=Represents the percentage of the total species count amassed at the identical collection site, pertaining to both the cold and dry, and warm and humid periods, within the years 2015 and 2016.

L. edwardsi had its peak in October (145), it was null in November, recovering in March. In the hot and humid period, it represented 28.7%, with the lowest collection in May (18), from June to August, ranged from 25 to 33 sandflies, being higher in September (34), accounting for 22.7% of the sandflies collected. These data suggest a higher activity of this species in the warmer period and in humid places.

L. tupynambai registered the highest peak among the three species, which occurred in October (225). In absolute values, in October there was the highest peak among males (195), while for females (37) it was in September (Fig. 3). In 2009 and 2010, the most adequate season was the hot and humid months, with 69.8% of the sandflies collected, with peak in March (106), and females (85) accounted for 80.1% of this total, and males with 19.8%.

In the cave in 2009 and 2010, 12 species were collected, 10 of the genus *Lutzomyia* and two of the genus *Brumptomyia*. In 2015 and 2016, eight species were collected, seven of which were of the genus *Lutzomyia* and one of the genus *Brumptomyia*. There was a decrease in species diversity in the first genus, but *B. brumpti* occurred in both periods, confirming Aguiar & Vieira (2018), who pointed to the cave with one of the main habitats of this species; however, the amount of specimens collected in this period was low, suggesting that there is a small population in the studied environment. These results does not corroborate Alves (2008) and Carreira-Alves (2008), who in a study conducted in the municipality of Carmo, found that 33% of the sandflies captured in the forest belonged to the genus *Brumptomyia*, confirming their savage behavior, as already observed by other authors (Aguiar & Medeiros 2003, Fraiha & Shaw 1970).

According to Aguiar & Vilela (1987), the food preferences of the sandflies are a predominant factor, directly influencing their dispersion. All

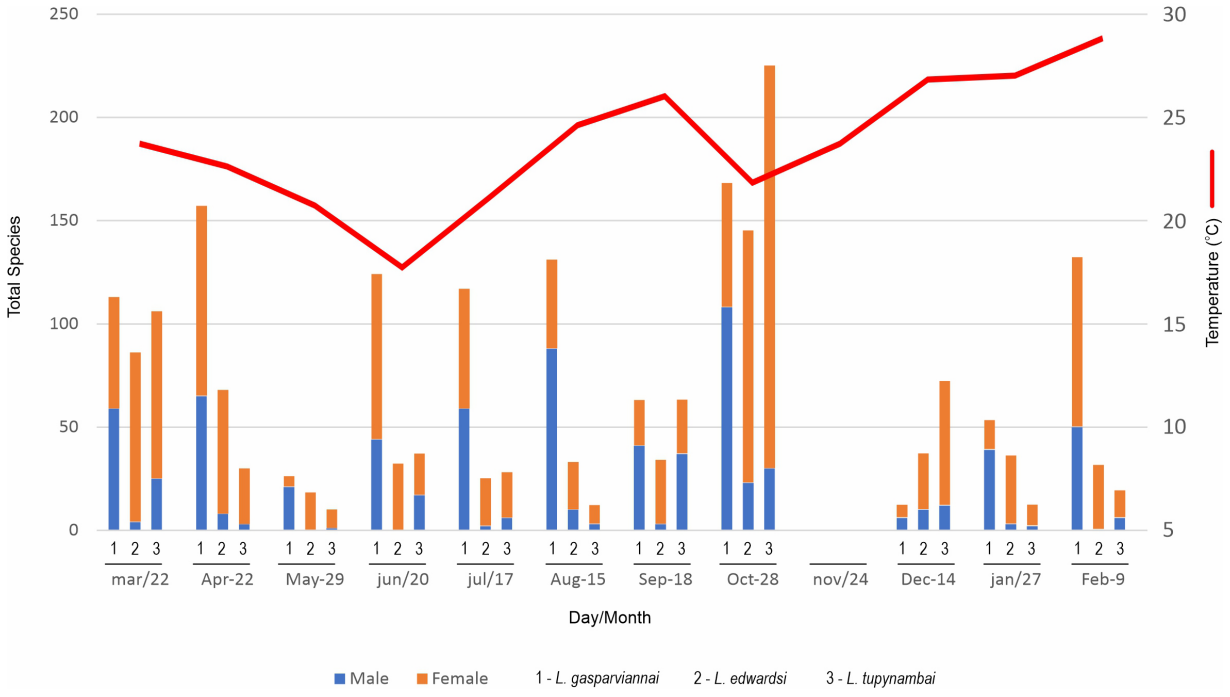

Figure 3. Monthly distributions of the total of *L. gasparviannai*, *L. tupynambai* and *L. edwardsi* captured with CDC model light trap, compared with the temperature (T), from March 2015 to February 2016, at Sítio Portão de Pedra, in the city of Sumidouro, Rio de Janeiro, Brazil.

species of the genus *Brumptomyia* suck the blood of Dasypodidae, always being found in burrows of these animals and only accidentally outside them (Aguiar & Medeiros 2003, Alves 2007). This fact suggest the existence of armadillos in the cave and adjacencies in this study, thus confirming the importance of knowing the feeding preference of sandflies in the survey of their fauna.

Despite the geographical distribution of the fauna of sandflies of *Brumptomyia,* the species *B. brumpti* was not registered for the states of Rio de Janeiro and Espírito Santo by Aguiar & Medeiros (2003), and was later mentioned in the state of Rio de Janeiro for the cities of: Petrópolis, by Souza et al. (2005), Carmo, by Carreira-Alves (2008), Rio de Janeiro, by Gouveia et al. (2012), Carvalho et al. (2014) and Cantagalo, by Peres-Dias et al. (2016). Campos et al. (2017), carrying out the study of sandflies fauna in caves in the municipality of Pains, state of Minas Gerais, did not record the meeting of females of *B. brumpti*, at the same time that he recorded the collection of 5 males in the cave and 14 in the vicinity of the cave. This result confirms the finding of Galati (2003) in researching the cavernous fauna of Serra da Bodoquena in Mato Grosso do Sul. Aguiar & Vieira (2018) who do not point this species to the state of Goiás, Central-West region of Brazil.

According to Carvalho et al. (2014) this is the second record of *B. brumpti*, *B. cardosoi* and *B. guimaraesi* to the mountain region of the state of Rio de Janeiro, being the first one done by Souza et al. (2002, 2005). We emphasize that *B. avellari* and *B. nitzulescui* were first cited in the municipality of Carmo and in the mountain region of this state by Carreira-Alves (2008), showing that of the eight species of the genus *Brumptomyia*, five had already been registered in the state of Rio de Janeiro. In this study, this diversity corresponds to 25% of the fauna known in this state.

Lutzomyia (Psychodopygus) *hirsuta* (Mangabeira, 1942) was collected in the three collection points, being larger in the cave with 17 specimens and smaller in the forest with only two specimens, in 2015-2016. This is the third time that *L. hirsuta* is registered in the mountain region of the state of Rio de Janeiro and was mentioned in the municipality of Carmo by Carreira-Alves (2008) and 57 years ago by Martins et al. (1962, 1978) in the city of Petrópolis. The observation in two distinct ecosystems, forest and cave, in both periods, shows their adaptation to the studied region. The detection of *L. hirsuta* in this study is relevant in view of the fact that in 1985, Rangel et al. (1985) isolated *Leishmania* (*Viannia*) *braziliensis* in *L. hirsuta* collected in a forest near the city of Além Paraíba, state of Minas Gerais. In addition, Gil et al. (2003) found *L. davisi* and *L. hirsuta* infected with *Leishmania* (*Viannia*) *naiffi* in the state of Rondônia.

In 2009 and 2010*, L. whitmani* was collected at the forest, cave and four in the surrounding area, representing 1.4% of the species collected. In 2015 and 2016, three specimens were collected in the cave and three in the forest with a very low frequency (0.3%). Females were predominant and only one male was collected (Table III). Aguiar & Vieira (2018) pointed out in their study that *L. whitmani* can be found on the internal and external walls of the human household, and in domestic animal facilities (chicken house, pigsty, barnyard etc.). These data are relevant because Ready et al. (2018) confirmed *L. whitmani* and *L. intermedia* as vectors of *Leishmania* (*Viannia*) *braziliensis* for the Northeast and Southeast regions, and the first for the Midwest of Brazil. They also confirmed that they found *L. whitmani* infected with *Leishmania* (*Viannia*) *guyanensis* and *Leishmania* (*Viannia) shawi* in the Amazon.

In the two periods of this study, *L. migonei* was present in the cave and its surroundings, with only three specimens in each of the periods researched. Aguiar & Vieira (2018) do not point caves as one of the main habitats of this species. These data suggest that the existing population, both in the cave and its surroundings, is low.

In 2009 and 2010, *L. cortelezzii, L. microps* and *L. quinquefer* were collected only in the cave, *L. davisi, L. whitmani* and *B. guimaraesi* in the surroundings, and *L. davisi* in the forest, and in 2015 and 2016, *L. intermedia* was collected in the surrounding area. The species *L. davisi*, *L. cortelezzii*, *L. microps*, *L. quinquefer*, *L. intermedia* and *B. guimaraesi* were collected only once in the two periods researched, with low frequency. Therefore, it is not possible to make a correlation between periods, because there is no parameter for this (Table lV).

The literature points out that in the collections with a light trap of the CDC type in the forest, the frequency of *L. intermedia* is low, which corroborates the finding of this study (Alves 2007). Considering that there were two cases of tegumentary leishmaniasis in the area and that this species has been scientifically incriminated as a vector of *Leishmania* (*Viannia*) *braziliensis*, these facts demonstrate that there is a potential for transmission in the studied area.

Table IV. Quantitative comparison of total phlebotomines captured with CDC model light trap placed in the cave, surroundings and Forest, from June 2009 to May 2010, and from March 2015 to February 2016, at Sítio Portão de Pedra, in the city of Sumidouro, state of Rio de Janeiro, Brazil.

Species	Total[1]	2009/10	%[2]	2015/16	%[2]	Grand Total (%)[3]
L. gasparviannai	2278	1181	51.8	1097	48.2	55.8
L. edwardsi	835	290	34.7	545	65.3	20.5
L. tupynambai	815	201	24.7	614	75.3	20.0
L. hirsuta	58	31	53.4	27	46.6	1.4
L. whitmani	30	24	80.0	6	20.0	0.7
L. sp	27	5	18.5	22	81.5	0.7
B. brumpti	12	5	41.7	7	58.3	0.3
L. migonei	9	5	55.6	4	44.4	0.2
L. davisi	5	5	100.0	-	-	0.1
L. cortelezzii	2	2	100.0	-	-	0.0
L. microps	2	2	100.0	-	-	0.0
L. quinquefer	2	2	100.0	-	-	0.0
B. sp.	2	2	100.0	-	-	0.0
L. intermedia	1	-	-	1	100.0	0.0
B. guimaraesi	1	1	100.0	-	-	0.0
Cumulative	**4079**	**1756**		**2323**		

[1]= Represents the aggregate count of species collected during the periods 2009/2010 and 2015/2016.
[2]= Signifies the percentage of specimens collected for a particular species in the years 2009/2010 and 2015/2016 relative to the overall total.
[3]= Denotes the percentage of the total species count in relation to the comprehensive species collection total across both periods.

CONCLUSIONS

Only future studies to be conducted in the mountainous region of the state of Rio de Janeiro will be able to provide a definitive understanding of the sand fly fauna, particularly regarding the mentioned species.

It has been observed that the environmental changes have influenced the dispersal and distribution of the phlebotomine sand fly fauna in both the São Caetano cave and the forest ecosystem. These changes created ecological conditions that favor the proliferation of populations that are more resilient to extreme weather events.

As a result, it was noticed that in 2015 and 2016, the phlebotomine sand fly fauna exhibited higher population numbers but reduced species diversity. Notably, the presence of *L. intermedia*, *L.* whitmani, and *L. migonei* known vectors of Leishmania was detected, albeit in small populations. The recorded 31 cases of American tegumentary leishmaniasis (ATL) from 2007 to 2017, encompassing Sumidouro and its surrounding areas, coupled with the identification of these three species, underscores the significance of these findings. This calls for increased attention from health authorities in the mountain region regarding surveillance and control measures targeting leishmaniasis vectors.

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JOÃO RICARDO C. ALVES[1,2]
https://orcid.org/0000/0001-5885-6758

CLEBER N. DO CARMO[3]
https://orcid.org/0000-0003-4165-2198

RODRIGO C. MENEZES[4]
https://orcid.org/0000-0003-1853-3449

[1]Fundação Oswaldo Cruz, Instituto Oswaldo Cruz, Laboratório de Entomologia, Castelo Mourisco, Avenida Brasil, 4365, Manguinhos, 21041-210 Rio de Janeiro, RJ, Brazil

[2]Programa de Pós- Graduação em Biologia Animal, Universidade Federal Rural do Rio de Janeiro, Rodovia BR 465, Km 7, Campus Universitário Zona Rural, 23851-970 Seropédica, RJ, Brazil

[3]Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rua Leopoldo Bulhões, 1480/807, Manguinhos, 21041-210 Rio de Janeiro, RJ, Brazil

[4]Fundação Oswaldo Cruz, Instituto Nacional de Infectologia Evandro Chagas, Laboratório de Pesquisa Clínica em Dermatozoonoses em Animais Domésticos, Avenida Brasil, 4365, Manguinhos, 21041-210 Rio de Janeiro, RJ, Brazil

Correspondence to: **João Ricardo Carreira Alves**
E-mail: chamberlaim@ioc.fiocruz.br

Author contributions

Conceptualization, Data curation, Validation, Visualization, Writing – review & editing: João Ricardo Carreira Alves, Rodrigo Caldas Menezes. Formal analysis: João Ricardo Carreira Alves, Rodrigo Caldas Menezes, Cleber Nascimento do Carmo. Funding acquisition, Investigation, Project administration Resources, Writing – original draft: João Ricardo Carreira Alves. Supervision: Rodrigo Caldas Menezes.

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