Sand flies (Diptera, Psychodidae, Phlebotominae) from Central Amazonia and four new records for the Amazonas state, Brazil

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ABSTRACT. Sand flies from Central Amazonia and four new records for the Amazonas state, Brazil. A survey was conducted in May and June 2008 to study the fauna of insects in Central Amazonia, Brazil. As part of the survey, we report here that sixty species of phlebotomine were identified, totaling 13,712 specimens from 13 genera. The collection sites were located at the border between the states of Pará and Amazonas, comprising three municipalities from the Amazonas state (Borba, Maués, and Nhamundá). Malaise, CDC and Shannon traps were used to collect the insects. Most of the sand flies were collected by CDC traps (89.5%), while Malaise and Shannon traps collected 7% and 3.5%, respectively. The most abundant genera, representing 97.1% of the total sand flies identified were: *Trichopygomyia* Barretto, 1962 (47.6%), *Psathyromyia* Barretto, 1962 (17.9%), *Psychodopygus* Mangabeira, 1941 (17.5%) and *Trichophoromyia* Barretto, 1962 (14.3%). The genera with the largest number of species identified were: *Psychodopygus* (14), *Psathyromyia* (10), *Evandromyia* Mangabeira, 1941 (7), *Trichophoromyia* (5) and *Trichopygomyia* (5). The most abundant species was *Trichopygomyia trichopyga* (Floch & Abonnenc, 1945), which represented 29% of the total sand flies identified. Here we also report new records for four species in the Amazonas state: *Ps. complexus* (Mangabeira, 1941), *Ps. llanosmartinsi* Fraiha & Ward, 1980, *Ty. pinna* (Feliciangeli, Ramirez-Pérez & Ramirez, 1989), and *Th. readyi* (Ryan, 1986). The results of this study provide new, additional information on the distribution of sand flies in the Amazon and increase the number of species in the Amazonas state from 127 to 131.

KEYWORDS. Amazon, inventory; medical entomology; phlebotomine sand flies.

RESUMO. Flebotomíneos da Amazônia Central e quatro novos registros para o estado do Amazonas, Brasil. Um levantamento foi conduzido em maio e junho de 2008 para estudar a fauna de insetos da Amazônia Central, Brasil. Como parte desta pesquisa, foram registradas 60 espécies de um total de 13.712 espécimes pertencentes a 13 gêneros. Os locais de coleta localizaram-se na fronteira dos estados do Pará e do Amazonas, incluindo três municípios do estado do Amazonas (Borba, Maués e Nhamundá). Armadilhas do tipo Malaise, CDC e Shannon foram utilizadas para coletar os insetos. A maioria dos flebotomíneos foi coletada em armadilhas CDC (89,5%), enquanto que as armadilhas Malaise e de Shannon coletaram 7% e 3,5%, respectivamente. Os gêneros mais abundantes, representando 97,1% do total de flebotomíneos identificados foram: *Trichopygomyia* Barretto, 1962 (47,6%), *Psathyromyia* Barretto, 1962 (17,9%), *Psychodopygus* Mangabeira, 1941 (17,5%) e *Trichophoromyia* Barretto, 1962 (14,3%). Os gêneros com o maior número de espécies identificadas foram *Psychodopygus* (14), *Psathyromyia* (10), *Evandromyia* Mangabeira, 1941 (7), *Trichophoromyia* (5) e *Trichopygomyia* (5). A espécie mais abundante foi *Trichopygomyia trichopyga* (Floch & Abonnenc, 1945) a qual representou 29% do total de flebotomíneos identificados. Também são registradas quatro novas espécies para o estado do Amazonas: *Ps. complexus* (Mangabeira, 1941), *Ps. llanosmartinsi* Fraiha & Ward, 1980, *Ty. pinna* (Feliciangeli, Ramirez-Pérez & Ramirez, 1989), e *Th. readyi* (Ryan, 1986). Os resultados deste estudo fornecem informações novas e adicionais sobre a distribuição de flebotomíneos da Amazônia e aumenta o número de espécies no estado do Amazonas de 127 para 131.

PALAVRAS-CHAVE. Amazônia, inventário; entomologia médica; flebotomíneos.

Phlebotomine sand flies are small dipteran insects of great importance to public health because they are responsible for transmission of *Leishmania* species, bacteria and viruses to humans and non-human animals (Rangel & Lainson 2003). In Amazonas state, there are 127 known species of sand flies, representing approximately 56% of the number of species recorded for Brazil (Galati 2003a). The diversity of sand flies in the Amazon may be underestimated because the extent, and duration of flooding in the state prevent access to "terra-firme", locations in which sand flies are most common (Barrett *et al.* 1996).

In spite of the few studies on dipteran diversity and biogeography, it is expected that the greatest diversity of flies reside in the tropics (Brown 2005; Amorim 2009). The Neotropical region is predicted to hold the majority of dipteran species, a pattern is that also found in other groups such as

birds and butterflies (Robbins & Opler 1997), as well as many other groups (Gentry 1988). Still, dipteran insects remain poorly studied in this region.

The Conference of the Parties of the Convention on Biological Diversity last held in 2010 in Nagoya, Japan, made public a protocol to regulate access to genetic resources and it included bioprospecting, associated research and taxonomic studies as a means to implement the protocol (Nagoya Protocol 2011). As previously pointed by Barrett *et al.* (1996), sand flies can be useful tools for bioprospection, and as indicators of biodiversity, because they are easily collected and transported in ethanol to the laboratory, and their taxonomy is relatively well known with several different identification keys to species level available (Forattini 1973; Ryan 1986; Young & Duncan 1994; Galati 2003b; Shimabukuro *et al.* 2010). Also, knowledge about the distribution of sand flies can enable inferences about the distribution of other species with known interactions, such as the vertebrate hosts they feed upon and the kinetoplastid parasites they transmit (Cranston 2005; Barrett *et al.* 1996).

The main objective of this work was to study the sand fly fauna in "terra-firme" areas located in three municipalities of the state of Amazonas. This study was conducted as part of the project "Amazonas: Diversidade de insetos ao longo de suas fronteiras" to map and describe the biodiversity of insects and provide a better understanding of insect species diversity in the region.

MATERIAL AND METHODS

Data on the collection sites, rivers, geographical coordinates, types of traps used, and dates of expeditions, are reported in Table I. The collection sites were located on the border between the states of Pará and Amazonas, comprising three municipalities from the state of Amazonas: Borba, Maués, and Nhamundá (Fig. 1). Borba is located east of Manaus, in the Madeira river region. The population is estimated at 34,452 inhabitants, and the total area of the municipality is 44,252 km² (IBGE 2010). Maués is located in the region of the Middle Amazonas river between the Madeira and Tapajós rivers. The total population of Maués is 51,847 inhabitants, and it has a total area of 39,990 km² (IBGE 2010), while the main economic activity in the region is guaraná plantations. Nhamundá is located in the lower Amazonas river region; it comprises 18,278 inhabitants and a total area of 14,106 km² (IBGE 2010). The climate for the three municipalities is *Af* (Equatorial climate) of the Koeppen classification, and the vegetation in the collection sites is alluvial rain forest highly influenced by the pluvial regime of the Amazon region. The map was produced using SimpleMppr (Shorthouse 2010).

Fig. 1. Map of the Amazonas state with the collection sites at the three municipalities (numbered) studied in May and June 2008: 1. Borba; 2. Maués; 3. Nhamundá.

The collections were carried out in May and June 2008. The insects were collected in undisturbed remote primary "*terra-firme*" forest habitats, which can only be accessed by boat and foot. The collection areas were accessed by river boat, through the Nhamundá and Abacaxis rivers and their tributaries. Three different types of traps were used for the collections: Malaise, Shannon, and CDC light traps. In Borba, collections were carried out for two days with Malaise traps and two nights with CDC traps, these traps were set at three different collection sites: Picada Pirarara, Picada Borba and Paxiuba. In Maués, collections were carried out for four days with Malaise traps and four nights with CDC traps that were set at Picada Pirarara, Pau Rosa National Forest (FLONA Pau Rosa) and Pacamiri. In Nhamundá, collections were carried out for six days with Malaise traps, six nights with CDC traps and one night with white Shannon traps, the traps were set at two collection sites: Igarapé Areia and Cuipiranga/Aburi Lake. Although Malaise traps are not commonly used to capture phlebotomines, it is widely used to collect other dipterans and a variety of other flying insects; it consists of a trap for the interception of flying insects and does not require someone to carry out the collections.

The insects were kept in 70% alcohol. In the laboratory, the insects were processed according to the clarification method described by Young & Duncan (1994), and their identification was performed using the keys by Young & Duncan (1994) and Galati (2003b). A sample consisting of 5% of the specimens was mounted on microscope slides with Canada balm, the remaining sample was kept in alcohol 70% and all will be deposited in the Collections of Invertebrates from the Instituto Nacional de Pesquisas da Amazônia. The classification of the species follows Galati (2003a), and the abbreviation of the generic names Marcondes (2007).

RESULTS

A total of 13,712 sand flies were collected, belonging to 60 species from 13 genera (Tables II-IV). Nine female specimens from the genus *Trichophoromyia* could not be identified to species level, since some species are morphologically indistinguishable.

The largest number of sand flies was collected at the municipality of Nhamundá (91%): were from Igarapé Areia (39%)

and Cuipiranga/Aburi Lake regions (61%) within this municipality. The remaining sand flies collected were from Borba (5.2%) and Maués (3.8%). In the municipality of Borba, 22 species belonging to the subtribes Lutzomyiina and Psychodopygina were recorded (Table II). In Maués, 27 species were recorded belonging to the subtribes Brumptomyiina, Lutzomyiina and Psychodopygina (Table III). Nhamundá recorded the largest number of species (55) belonging to the subtribes Sergentomyiina, Brumptomyiina, Lutzomyiina and Psychodopygina (Table IV).

Table I. Localities, traps, and dates for collection of sand flies in Amazonas state.

Municipality	Rivers	Collection sites	Geographic coordinates	Collection dates	Traps	Collectors
Borba	Abacaxis	Picada Pirarara	05°15'09"S, 58°41'52"W	May 27–29, 2008	Malaise	Rafael, JA *et al.*
Borba	Abacaxis[a]	Picada Borba	05°13'19"S, 58°41'22"W	May 27–28, 2008	CDC	Hutchings, RSG *et al.*
Borba	Abacaxis[a]	Paxiuba	04°29'00"S, 58°34'14"W	June 3–4, 2008	CDC	Hutchings, RSG *et al.*
Maués	Abacaxis[b]	Picada Pirarara	05°15'09"S, 58°41'52"W	May 26–27, 2008	CDC	Hutchings, RSG *et al.*
Maués	Abacaxis	Picada Pirarara	05°15'09"S, 58°41'52"W	May 27–29, 2008	Malaise	Rafael, JA *et al.*
Maués	Abacaxis	FLONA Pau Rosa	05°15'09"S, 58°41'52"W	May 26–28, 2008	Malaise	Rafael, JA *et al.*
Maués	Abacaxis	Pacamiri	04°35'49"S, 58°13'14"W	May 30–31, 2008	CDC	Hutchings, RSG *et al.*
Maués	Abacaxis	Pacamiri	04°35'49"S, 58°13'14"W	May 30–31, 2008	Malaise	Rafael, JA *et al.*
Maués	Abacaxis	Pacamiri	04°35'49"S, 58°13'14"W	May 31–June 1, 2008	CDC	Hutchings, RSG *et al.*
Maués	Abacaxis	Pacamiri	04°35'49"S, 58°13'14"W	May 30–31, 2008	CDC	Hutchings, RSG *et al.*
Nhamundá	Nhamundá	Cuipiranga, Aburi Lake	01°53'58"S, 57°00'25"W	May 17–20, 2008	Malaise	Rafael, JA *et al.*
Nhamundá	Nhamundá[b]	Cuipiranga, Aburi Lake	01°53'42"S, 57°03'25"W	May 20–22, 2008	CDC	Hutchings, RSG *et al.*
Nhamundá	Nhamundá[b]	Igarapé Areia	01°35'18"S, 57°37'32"W	May 16–20, 2008	CDC	Hutchings, RSG *et al.*
Nhamundá	Nhamundá[b]	Igarapé Areia	01°35'22"S, 57°37'06"W	May 18, 2008	Shannon	Hutchings, RSG *et al.*
Nhamundá	Nhamundá	Igarapé Areia	01°35'18"S, 57°37'32"W	May 17–23, 2008	Malaise	Rafael, JA *et al.*

[a] left margin of the river, [b] right margin of the river.

Table II. Species of sand flies collected in the municipality of Borba, Amazonas state, Brazil.

Subtribe	Genus	Species	Borba – Abacaxis river						Total
			Picada Pirarara		Picada Borba		Paxiuba		
			Malaise		CDC		CDC		
			M	F	M	F	M	F	
Lutzomyiina	*Sciopemyia*§	*S. servulolimai*	–	–	–	–	1	1	2
		S. sordellii	–	–	–	1	–	–	1
	Trichopygomyia§	*T. longispina*	–	–	1	–	–	–	1
		T. rondoniensis	–	–	4	2	1	–	7
	Evandromyia§	*E. saulensis*	–	–	–	–	–	1	1
		E. williamsi	–	–	–	–	–	1	1
Psychodopygina	*Psathyromyia*§	*P. abunaensis*	–	–	–	1	–	–	1
		P. aragaoi	–	–	14	10	3	2	29
		P. barrettoi barrettoi	–	–	5	1	–	–	6
	Viannamyia	*V. furcata*	–	–	–	1	–	–	1
		V. tuberculata	–	–	–	–	–	3	3
	Bichromomyia§	*B. flaviscutellata*	–	8	–	–	1	–	9
		B. olmeca nociva	1	1	–	–	–	–	2
	Psychodopygus	*P. ayrozai*	–	–	1	–	–	–	1
		P. claustrei	2	–	–	–	1	1	4
		*P. complexus**	1	–	1	–	1	1	4
		P. corossoniensis	–	–	5	–	–	–	5
		P. davisi	–	–	1	–	–	1	2
		P. geniculatus	–	1	–	1	–	–	2
	Trichophoromyia	*T. octavioi*	4	7	64	57	–	–	132
		*T. readyi**	–	–	–	–	1	–	1
		T. ubiquitalis	26	51	335	85	1	–	498
Total M/F			34	68	426	156	8	10	
Total			102	590	21	713			

* New record for Amazonas state. § Genera with species that are exclusive to the Brazilian Amazon.

The most abundant genera were *Trichopygomyia* Barretto, 1962 (47.6%), *Psathyromyia* Barretto, 1962 (17.9%), *Psychodopygus* Mangabeira, 1941 (17.5%) and *Trichophoromyia* Barretto, 1962 (14.3%). It is interesting to note that 97.1% of all the specimens collected belong to these four genera. *Psathyromyia* and *Psychodopygus* recorded both the greatest abundance and species richness, while *Trichopygomyia* and *Trichophoromyia* were represented by only 5 species each. The most abundant species were: *Trichopygomyia trichopyga* (Floch & Abonnenc 1945) (29%), *Ty. pinna* (Feliciangeli, Ramírez-Pérez & Ramirez, 1989) (18.5%), *Trichophoromyia ubiquitalis* (Mangabeira, 1942) (11%), *Psathyromyia dreisbachi* (Causey & Damasceno, 1945) (9.6%), *Psychodopygus davisi* (Root, 1934) (8.6%) and *Psathyromyia aragaoi* (Costa-Lima, 1932) (7%). These six species corresponded to 83.7% of the total number of sand flies collected. When we combine the number of specimens for all 27 species with less than 10 individuals each, they only account for 0.9% of the specimens collected. The remaining 15.4% of the specimens were represented by 27 species with between 11 to 305 individuals.

The following genera had the largest number of species collected: *Psychodopygus* (14), *Psathyromyia* (10) and *Evandromyia* Mangabeira, 1941 (7), which accounted for more than half of the total number of identified species. The most abundant species in the genus *Psychodopygus* were: *Ps. davisi* (8.6%), *Ps. geniculatus* (Mangabeira, 1941) (2.2%), and *Ps. corossoniensis* (Le Pont & Pajot, 1978) (1.8%). In the genus *Psathyromyia*, the most abundant species were: *Pa. dreisbachi* (9.6%), and *Pa. aragaoi* (7%). The genus *Evandromyia* was represented by only 35 (0.25%) specimens distributed among the seven species.

Approximately 90% of the sand flies were collected in CDC traps, while 7% and 3% were collected in Malaise and Shannon traps, respectively. Only one species was exclusively collected by Shannon trap: *Pa. dendrophyla* (Mangabeira, 1942); three species were exclusively collected by Malaise traps: *Brumptomyia pentacantha* (Barretto, 1947), *Evandromyia*

Table III. Species of sand flies collected in the municipality of Maués, Amazonas state, Brazil.

Subtribe	Genus	Species	Maués – Abacaxis river										Total
			Picada Pirarara				FLONA Pau Rosa		Pacamiri				
			CDC		Malaise		Malaise		CDC		Malaise		
			M	F	M	F	M	F	M	F	M	F	
Brumptomyiina	*Brumptomyia*	*B. pintoi*		2	–	–	–	–	–	1	–	–	3
Lutzomyiina	*Sciopemyia*§	*S. servulolimai*	1	2						1	–	–	4
	Trichopygomyia§	*T. longispina*	–	–	–	–	–	–	2	–	–	–	2
		*T. pinna**	2	–	–	–	–	–	–	–	–	–	2
		T. rondoniensis	2	2	–	–	–	–	–	–	–	–	4
		T. trichopyga	1	–	–	–	–	–	1	–	–	–	2
Psychodopygina	*Psathyromyia*§	*P. abunaensis*	1	–	–	–	–	–	–	–	–	–	1
		P. aragaoi	11	3	–	–	–	–	12	3	–	1	30
		P. dreisbachi	–	–	–	–	–	–	–	1	–	–	1
		P. inflata	4	6	–	–	–	–	–	–	–	–	10
		P. lutziana	–	–	–	–	–	–	–	1	–	–	1
		P. runoides	–	–	–	–	1	–	9	3	–	–	13
	Viannamyia	*V. tuberculata*	–	2	–	–	–	–	–	2	–	–	4
	Bichromomyia§	*B. flaviscutellata*	–	–	–	1	–	–	–	–	–	1	2
	Psychodopygus	*P. ayrozai*	–	2	–	–	–	–	–	7	–	–	9
		P. bispinosus	2	14	–	–	–	–	–	1	–	–	17
		P. carrerai	1	2	–	–	–	–	–	–	–	–	3
		P. chagasi	10	16	–	1	–	4	–	1	–	2	34
		P. claustrei	–	–	–	–	–	–	–	1	1	–	2
		*P. complexus**	3	4	1	–	–	–	1	–	–	–	9
		P. corossoniensis	1	24	–	–	–	–	–	2	1	1	29
		P. davisi	2	34	–	1	–	–	–	–	–	–	37
		P. geniculatus	2	34	–	–	–	–	–	1	–	–	37
		P. squamiventris	–	–	–	–	–	1	–	–	–	–	1
	Trichophoromyia	*T. octavioi*	–	–	–	–	–	–	16	6	3	1	26
		*T. readyi**	1	1	1	2	–	–	–	–	–	–	5
		T. ubiquitalis	108	23	2	4	2	–	80	12	2	5	238
			152	171	4	9	3	5	121	43	7	11	
Total			323		13		8		164		18		526

* New record for Amazonas state. §Genera with species that are exclusive to the Brazilian Amazon.

Table IV. Species of sand flies collected in the municipality of Nhamundá, Amazonas state, Brazil.

Subtribe	Genus	Species	Nhamundá – Nhamundá river										Total
			Igarapé Areia						Cuipiranga/Aburi Lake				
			CDC		Malaise		Shannon		CDC		Malaise		
			M	F	M	F	M	F	M	F	M	F	
Sergentomyiina	*Micropygomyia*§	*M. pilosa*	–	1	–	–	–	–	–	–	–	–	1
		M. rorotaensis	2	7	–	1	3	1	–	2	–	–	16
Brumptomyiina	*Brumptomyia*	*B. pentacantha*	–	–	2	1	–	–	–	–	–	–	3
		B. pintoi	6	14	1	–	–	–	3	4	–	–	28
Lutzomyiina	*Sciopemyia*§	*S. nematoducta*£	1	3	–	–	–	–	7	10	–	–	21
		S. pennyi£	–	–	–	–	–	–	2	–	–	–	2
		S. sordellii	1	3	–	–	–	–	1	8	–	–	13
	Pintomyia§	*P. pacae*	–	–	2	–	–	–	–	–	–	–	2
	Pressatia§	*P. triacantha*	–	–	–	–	–	–	1	2	–	–	3
		P. trispinosa	5	6	–	–	–	–	–	–	–	–	11
	Trichopygomyia§	*T. longispina*	1	–	–	–	–	–	–	–	–	–	1
		*T. pinna**	–	4	79	–	–	1	1,629	817	1	–	2,531
		T. ratcliffei£	1	–	–	–	1	–	–	–	–	–	2
		T. trichopyga	444	291	1	2	43	35	1,671	1,492	–	–	3,979
	Evandromyia§	*E. infraspinosa*	–	–	1	–	–	–	–	–	–	–	1
		E. inpai	1	1	2	2	1	–	–	1	–	–	8
		E. monstruosa	–	–	1	3	–	–	–	5	–	–	9
		E. saulensis	–	1	–	1	–	1	–	–	–	–	3
		E. sericea	–	1	–	–	–	–	1	2	–	–	4
		E. tarapacaensis	–	–	1	1	–	–	–	5	–	–	7
		E. williamsi	–	–	–	–	–	–	–	1	–	–	1
Psychodopygina	*Psathyromyia*§	*P. abunaensis*	14	3	3	2	–	–	4	–	–	–	26
		P. aragaoi	74	41	26	50	–	4	492	218	–	–	905
		P. barrettoi barretoi	12		1	–	1	–	4	1	–	–	19
		P. cuzquena	4	2	–	–	–	–	–	–	–	–	6
		P. dendrophyla	–	–	–	–	1	1	–	–	–	–	2
		P. dreisbachi	629	419	42	19	143	52	3	7	–	–	1,314
		P. inflata	17	18	2	2	1	–	15	17	–	–	72
		P. lutziana	1	1	–	–	–	–	–	–	–	–	2
		P. runoides	9	8	–	–	–	–	–	–	–	–	17
		P. shannoni	–	1	–	–	–	–	5	1	–	–	7
	Viannamyia	*V. tuberculata*	–	1	–	1	–	–	–	–	–	–	2
	Bichromomyia§	*B. flaviscutellata*	7	11	29	50	1	2		2	–	–	102
		B. olmeca nociva	–	14	10	21	–	6	6	26	–	–	83
	Psychodopygus	*P. amazonensis*	–	4	–	6	1	–	9	4	–	–	24
		P. ayrozai	–	14	–	2	–	–	4	22	–	–	42
		P. bispinosus	2	31	18	28	1	16	–	24	–	–	120
		P. chagasi	1	3	–	–	–	–	–	–	–	–	4
		P. claustrei	3	1	1	8	–	–	12	5	–	–	30
		P. corossoniensis	3	126	8	38	–	17	2	27	–	–	221
		P. davisi	108	388	50	84	45	57	53	354	–	–	1,139
		P. geniculatus	–	77	–	24	–	6	1	158	–	–	266
		P. hirsutus	6	8	2	1	1	3	16	37	–	–	74
		*P. llanosmartinsi**	–	9	–	2	–	–	–	–	–	–	11
		P. paraensis	1	5	1	3	–	1	–	–	–	–	11
		P. squamiventris	15	49	128	12	3	10	4	17	–	–	238
	Nyssomyia§	*N. anduzei*	–	1	1	2	–	–	–	2	–	–	6
		N. antunesi	1	3	–	–	1	–	–	–	–	–	5
		N. richardwardi	–	1	–	–	–	–	–	–	–	–	1
		N. umbratilis	–	7	–	5	1	3	–	2	–	–	18

Continue

Table IV. Continued.

Subtribe	Genus	Species	Nhamundá – Nhamundá river										Total
			Igarapé Areia						Cuipiranga/Aburi Lake				
			CDC		Malaise		Shannon		CDC		Malaise		
			M	F	M	F	M	F	M	F	M	F	
	Trichophoromyia	*T. eurypyga*	72	78	10	18	2	3	–	–	–	–	183
		T. octavioi	6	–	–	–	–	–	–	–	–	–	6
		*T. readyi**	3	–	–	–	–	–	–	–	–	–	3
		T. ruii	31	14	3	5	–	–	24	10	–	–	87
		T. sp.	–	9	–	–	–	–	–	–	–	–	9
		T. ubiquitalis	303	72	2	5	–	–	282	108	–	–	772
			1,784	1,751	427	399	250	219	4,251	3,391	1		
Total			3,535		826		469		7,642		1		12,473

*New record for Amazonas state.
£Species only known to occur in the state of Amazonas.
§Genera with species that are exclusive to the Brazilian Amazon.

infraspinosa (Mangabeira, 1941) and *Pintomyia pacae* (Floch & Abonnenc, 1943); and 15 species were exclusively collected by CDC traps: *Micropygomyia pilosa* (Damasceno & Causey, 1944), *Evandromyia williamsi* (Damasceno, Causey & Arouck, 1945), *Sciopemyia nematoducta* (Young & Arias, 1984), *Sc. pennyi* (Arias & Freitas, 1981), *Sc. servulolimai* (Damasceno & Causey, 1945), *Sc. sordellii* (Shannon & Del Ponte,1927), *Pressatia triancantha* (Mangabeira, 1942), *Pr. trispinosa* (Mangabeira, 1942), *Ty. longispina (*Mangabeira, 1942), *Ty. rondoniensis* (Martins, Falcão & Silva, 1965), *Pa. cuzquena* (Martins, Llanos & Silva, 1975), *Pa. lutziana* (Costa-Lima, 1932), *Pa. shannoni* (Dyar, 1929), *Nyssomyia richardwardi* (Ready & Fraiha, 1981), *Thrichophoromyia ruii* (Arias & Young, 1982). The efficiency and/or the difference in the number of specimens collected between the three kinds of traps, and the three locations, could not be tested because different numbers of traps were operated for different numbers of hours in the three localities.

Here we also report new records for four species in the state of Amazonas: *Ps. complexus* (Mangabeira, 1941) collected in Borba, *Ps. llanosmartinsi* Fraiha & Ward, 1980 collected in Nhamundá, *Ty. pinna* (Feliciangeli, Ramirez-Pérez & Ramirez, 1989) collected in both Maués and Nhamundá, and *Th. readyi* (Ryan, 1986) collected in all three of the studied areas (Borba, Maués, Nhamundá).

DISCUSSION

The 60 species of sand flies identified during one week of May and June in 2008 represent over 27% of the total number of sand flies species reported for South America, and 38% of what is known for the Brazilian Amazon (Galati 2003a), showing that the Amazon holds a great diversity of sand flies species and more studies in different areas are necessary to provide adequate knowledge on the distribution of sand flies in the Amazon. Our results show a sand fly fauna composition from primary "terra-firme" forest located in three municipalities at the eastern border of Amazonas state that are considered as low risk area for deforestation (Sales *et al.* 2011).

These results are different when compared to other studies carried out in the state, which describe sand flies from areas showing different degrees of anthropic activities that are characteristic of ACL transmission. Previous works published on the sand fly fauna collected in the state of Amazonas using various strategies reported three genera as the most abundant: *Nyssomyia* Barretto, 1962, *Psychodopygus* and *Trichophoromyia* (Barrett *et al.* 1996; Castellón *et al.* 2000; Dias-Lima *et al.* 2002; Feitosa & Castellón 2006; Silva *et al.* 2007; Guerra *et al.* 2006). Two other common genera found by these studies were *Psathyromyia* (Barrett *et al.* 1996) and *Trichopygomyia* (Silva *et al.* 2007). Unlike these previous studies, our results showed the largest abundance of specimens in the genera *Trichopygomyia*, *Psathyromyia, Psychodopygus* and *Trichophoromyia,* respectively, and this fact is due to one or two highly abundant species in each of these genera (*Ty. trichopyga, Ty. pinna, Pa. dreisbachi, Pa. aragaoi*, *Ps. davisi* and *Th. ubiquitalis*). The low abundance of the genus *Nyssomyia* (0.21%) differs from the results previously found by the authors mentioned above. The low number of *Nyssomyia* specimens collected in the present work might be explained by different sampling strategies (Malaise and Shannon traps), and also differences in the environment. It is worth mentioning that *Nyssomyia* species were only found in Nhamundá, where the biggest collection effort was made. Studies on the vertical stratification of sand flies in Central Amazonia showed that *Ny. umbratilis* (Ward & Fraiha, 1977) and *Ny. anduzei* (Rozeboom, 1942) occur at different heights in tree canopies during the night where the sloth (*Choloepus didactylus* (Linnaeus, 1758) and the anteater (*Tamandua tetradactyla* (Linnaeus, 1758)), their main hosts, are found (Lainson *et al.* 1981; Lainson 1983; Ready *et al.* 1986). However, these sand fly species are found resting at the base of tree trunks during the day and may bite humans if disturbed (Ready *et al.* 1986; Castellón *et al.* 1994; Dias-Lima 2002). They are the most abundant species when

sampling the base of tree trunks during the day is carried out (Dias-Lima *et al.* 2002; Guerra *et al.* 2006). In addition, the sand fly fauna composition might change due to environmental changes caused by human activities (Ready *et al.* 1986). Azevedo *et al.* (2002) found different abundances of *Psychodopygus* (higher in primary forest) and *Nyssomyia* (higher in anthropic areas) in the municipality of Peixoto Azevedo, Mato Grosso state, Brazil.

The genera *Trichopygomyia*, *Psychodopygus* and *Trichophoromyia* are very diverse in the Amazon, with more species recorded for this region than for any other area in the Neotropical region (Galati 2003a; Castellón 2009).

The genus *Trichopygomyia* is poorly known, but its species are distributed throughout the Amazon. Arias *et al.* (1983) published a review on this group and stated that the species belonging to this genus seem to share similar ecological niches, being associated with armadillos and other burrowing animals. Given the epidemiological importance of armadillos as reservoirs of *Leishmania braziliensis* "sensu lato" (Lainson *et al.* 1979), the role of this group of sand flies as possible vectors remains to be determined.

The genus *Psathyromyia* comprises a large taxon with many species occurring in the Amazon. In the Neotropical region, this genus seems to be of little medical and/or veterinary importance, but *Pa. shannoni* has been implicated in the transmission of vesicular stomatitis virus (VSV), a disease of cattle and sheep in the United States of America (Comer *et al.* 1991, 1994).

The genus *Psychodopygus* is considered a genus of medical interest, since it includes species incriminated or suspected of being vectors of American cutaneous leishmaniasis (ACL) agents (Grimaldi *et al.* 1991). It has more species distributed in the Amazon than in other biotopes in South America. The species *Ps. davisi* has been described as anthropophilic (Castellón *et al.* 1994; Luz *et al.* 2000) and has been one of the most abundant species collected in other studies (Castellón *et al.* 2000; Dias-Lima *et al.* 2002; Feitosa & Castellón 2006; Guerra *et al.* 2006). The species *Ps. hirsutus* (Mangabeira, 1942), *Ps. ayrozai* (Barretto & Coutinho, 1940), and *Ps. geniculatus* (Mangabeira, 1941) also occur in other regions of Brazil, and have been found infected with *Leishmania* (Rangel *et al.* 1985). However, it is only in the Amazon that *Psychodopygus* species are associated with ACL transmission and can be important vectors in both enzootic and zoonotic cycles.

Trichophoromyia ubiquitalis is widely distributed throughout the Amazon, and it has been described as an anthropophilic species, and incriminated as a vector of *Leishmania* (*Viannia*) *lainsoni* Silveira, Shaw, Braga & Ishikawa, 1987 (Silveira *et al.* 1991; Lainson *et al.* 1992). Females of most species of *Trichophoromyia* cannot be distinguished based on morphology and little is known about the bio-ecology of most species in this genus, while their role as potential vectors of ACL agent is unclear.

The importance of faunistic inventories is shown by the present work, in which, during only one week of insect collections, carried out in a primary forest area, four new records of species were found to occur in the Amazonas state. *Trichopygomyia pinna* has been described from Venezuela, while in Brazil this species has only previously been recorded in Roraima state. *Trichophoromyia readyi* has only been reported from its type-locality, in Pará state. The species *Ps. llanosmartinsi* was recorded in Rondônia and Pará states, and *Ps. complexus* was recorded in Pará, Rondônia, Mato Grosso and Pernambuco states (Galati 2003a; Castellón 2009). The four records for Amazonas state presented here add new information on the distribution of sand flies in the Amazon and increase the number of species in the state of Amazonas from 127 to 131.

Faunistic descriptions and inventories are important tools to plan conservation strategies and, in the case of medically important species, these tools might contribute to the understanding of the epidemiology of vector-borne diseases. In addition, faunistic surveys of Neotropical Diptera can contribute to the establishment of a future basis for comprehensive knowledge of phylogenetic relationships, biogeography, and the ecological roles of these flies (Brown 2005).

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