http://dx.doi.org/10.5380/abp.v52i1.86607

Acta Biológica Paranaense

Inventories
(Inventários)

Commented list of diurnal mosquitoes (Diptera: Culicidae), collected between 2004 and 2006, in forested areas of the state of Paraná, southern Brazil

Lista comentada de mosquitos (Diptera: Culicidae) de hábito diurno, coletados no período entre 2004 e 2006, em áreas florestadas do estado do Paraná, sul do Brasil

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Received 06/30/2022 | Accepted 02/26/2023 | Published 03/09/2023 | Edited by Andrey Andrade

Abstract

This study was conducted to determine the composition and distribution of anthropophilic diurnal mosquitos in forest environments in the state of Paraná, southern Brazil. Mosquitoes were collected between April 2004 and June 2006, in the remnant forests of rural and urban areas of 37 municipalities. A total of 15 genera and 121 species, or groups

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of species. The largest number of species, or groups of species, belonged to *Wyeomyia* (32 species or morphospecies), followed by *Sabethes* (20), *Aedes* (15) and *Anopheles* (13) genera. The results are discussed and compared with other entomological surveys conducted in Paraná. Several species collected are potential vectors of infectious agents to humans..

Keywords: Atlantic Forest, Culicidae, Distribution, Forest fragments, List of species, Vector Ecology

Resumo

Este estudo foi conduzido para determinar a composição e distribuição de mosquitos antropofílicos de hábito diurno em ambientes florestais no estado do Paraná, sul do Brasil. Os mosquitos foram coletados entre abril de 2004 e junho de 2006, em remanescentes florestais de áreas rurais e urbanas de 37 municípios. No total foram coletados 15 gêneros e 121 espécies, ou grupos de espécies. A maioria das espécies, ou grupos de espécies, pertencia aos gêneros *Wyeomyia* (32 espécies ou morfoespécies), seguido por *Sabethes* (20), *Aedes* (15) e *Anopheles* (13). Os resultados são discutidos e comparados com outros levantamentos entomológicos realizados no Paraná. Várias espécies coletadas são vetores potenciais de agentes infecciosos para humanos.

Palavras-chave: Mata Atlântica, Culicidae, Distribuição, Fragmentos florestais, Lista de espécies, Ecologia de vetores

Introduction

Mosquitoes (Diptera: Culicidae) are widely distributed in forest environments, where some species have epidemiological importance in the transmission of infectious agents, whether these are viruses and nematodes, with their main vectors belonging to the Culicinae, or protozoa, such as those that cause malaria and whose vectors are several species of Anopheles. Despite the importance of mosquitoes as vectors, information on the distribution of many species is still incomplete (Forattini, 1995).

Efficient entomological surveillance, including the ability to identify risk areas for the transmission of infectious agents to humans, largely relies on having comprehensive information on the composition of the mosquito fauna of forest environments, and the distribution of these insects in different ecosystems (Gomes, 2002).

This study the main objective was to present a checklist of fauna of sylvatic mosquito with diurnal habits, as a result of entomological surveys carried out in different forest environments in Paraná state.

The methodology used in entomological surveys is detailed below, with description of the study area, methodology for mosquito collection, literature used to identify species and richness estimators. In the results, the list of mosquitoes occurring in different forested areas of the Atlantic Forest of Paraná, from the coastal region to the Paraná River, followed by a discussion of the main mosquito species identified.

Material and methods

Study Area

The study area is located in the state of Paraná, Tropic of Capricorn, between 26°10'S and 51° 10'W. The state is a 199,575 km^2 area in southern Brazil (Neotropical Region), composed of different landscapes. The climate is more tropical to the north, with warmer temperatures, and more temperate towards the south (Maack,1968; Müller, 1974; Nimer, 1977).

According to Maack (1968), the original vegetation in Paraná is characterized by two predominant types of environments, forests tropical and subtropical (subdivided into Dense Ombrophilous Forest - DO, Mixed Ombrophilous Forest - MO and Semidecidual Seasonal Forest - SS), and region of general fields - FI

(Figure 1). During the period of this study, the forest remnant corresponded to an area of 2,091,752.63 hectares, equivalent to 10.50% of the original vegetation cover (IPARDES, 2006). The study areas can be described as follows:

• Dense Ombrophilous Forest (DO) - Vegetation that occurs on the coast and in the region of Serra do Mar. Both are humid due to high rainfall rates. In the First Paraná Plateau the forest has characteristics of subtropical vegetation, forming a zone of transition;

• Mixed Ombrophilous Forest. Consisting of coniferous forest - *Araucaria angustifolia* Bertoloni) Kuntze, 1898, known as "Pinheiro do Paraná" - occupying humid subtropical climate at altitudes between 500 - 600 m;

• Fields. In the region of general fields predominate in the center-south region with extensive areas of grasses interspersed with riparian forests and isolated capons in the regions of Curitiba and Castro (Maracanã plateau). Cerrado areas, on the other hand, cover most of the territory in the municipalities of Sengés and Jaguariaíva;

• Semidecidual Seasonal Forest. Occurs where there is purple soil, located between the rivers Itararé, Paranapanema, Pirapó and Ivaí, extending to the mouth of the Piquiri River, west of Paraná.

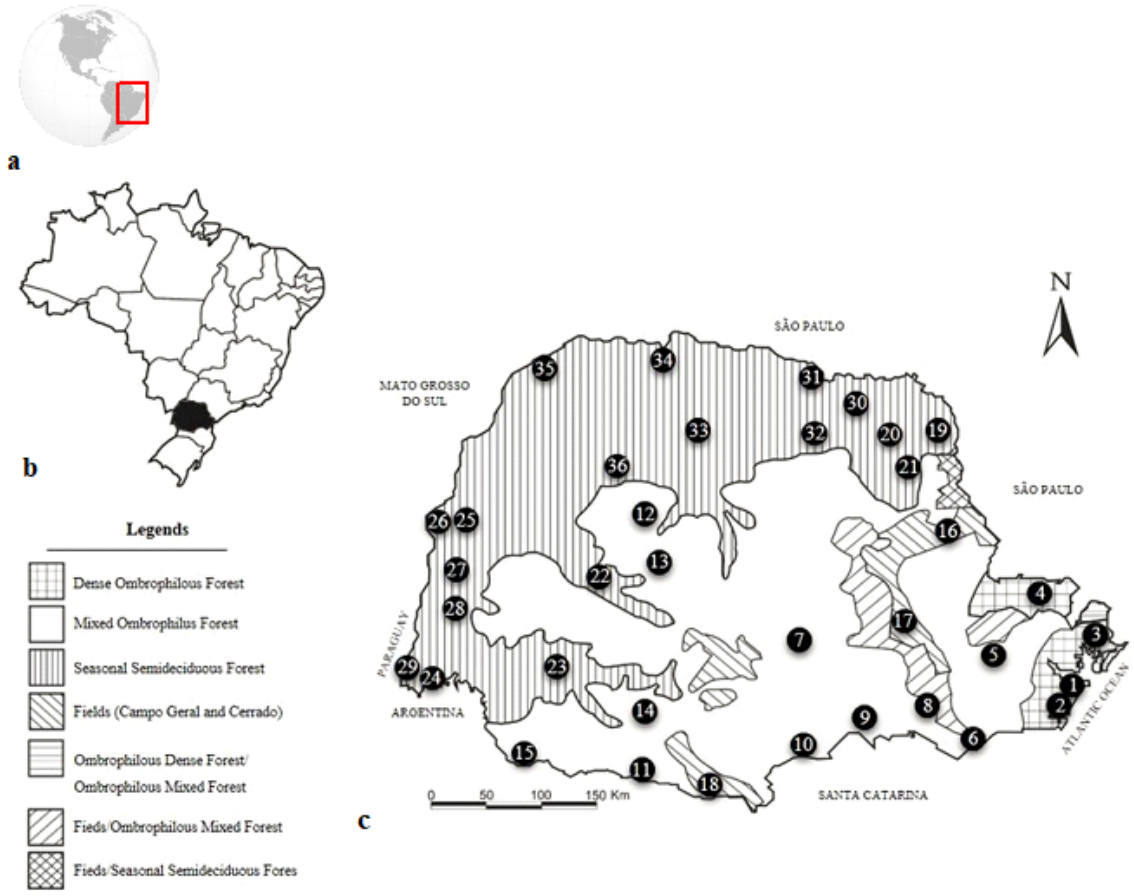

Figure 1. Original plant cover of the state of Paraná. Legends: 1 = Paranaguá, 2 = Matinhos, 3 = Guaraqueçaba, 4 = Adrianópolis, 5 = Almirante Tamandaré, 6 = Piên, 7 = Prudentópolis, 8 = Lapa, 9 = São Mateus do Sul, 10 = União da Vitória, 11 = Mariópolis, 12 = Campo Mourão, 13 = Roncador, 14 = Chopinzinho, 15 = Barracão, 16 = Jaguariaíva, 17 = Ponta Grossa, 118 = Palmas, 19 = Carlópolis and Joaquim Távora, 20 = Jundiaí do Sul, 21 = Tomazina, 22 = Campina da Lagoa, 23 = Três Barras do Paraná, 24 = Foz do Iguaçu – Fazenda Keller, 25 = Terra Roxa, 26 = Guaíra, 27 = Marechal Cândido Rondon, 28 = Diamante d'Oeste, 29 = Foz do Iguaçu – Refúgio Biológico, 30 = Cornélio Procópio and Santa Mariana, 31 = Sertaneja, 32 = Assaí, 33 = Maringá, 34 = Inajá, 35 = Porto Rico, 36 = Cianorte. Adapted from Maack, 1968.

Localization			Mosquito collection		
Area (acronym)	**County (Research Stations)**	**Geographical coordinates***	**Date**	**Total hours**	
				Ground	**Canopy**
Dense Ombrophilous Forest (DO)	Paranaguá (RS1)	25°32'45.2"S, 48°33'40.3"W	IX.20/21.2004, I.3-4.2005, IV.12/13.2004	18	18
	Matinhos (RS2)	25°48'03,5"S, 48°32'53.9"W	VII.30.2004, X.19.2004, VI.18.2004	18	0
	Guaraqueçaba (RS3)	25°13'16.8"S, 48°29'32.3"W	VII.27.2004, X.15.2004, VI.8.2004	18	0
	Adrianópolis (RS4)	24°40'56.3"S, 48°54'37.3"W	VIII.16.2004	6	0
Mixed Ombrophilous Forest (MO)	Almirante Tamandaré (RS5)	25°16'23.8"S, 49°18'21.7"W	VIII.18.2004, XI.9.2004	18	0
	Piên (RS6)	26°06'04.9"S, 49°24'16.4"W	XI.11.2004, V.5.2005	12	0
	Prudentópolis (RS7)	24°48'00.0"S, 51°14'00.0"W	VIII.12.2004, X.7.2004, IV.21.2005	18	18
	Lapa (RS8)	25°46'47.4"S, 49°41'56.6"W	VIII.11.2004, X.6.2004, I.19.2005, I.20.2005	24	0
	São Mateus do Sul (RS9)	25°51'20.0"S, 50°19'08.0"W	IX.29.2004, XI.18.2004, III.10.2005	18	18
	União da Vitória (RS10)	26°04'26.0"S, 51°12'42.0"W	VIII.10.2004, X.5.2004, I.18.2005, IV.19.2005	24	24
	Mariópolis (RS11)	26°16'08.0"S, 52°33'53.0"W	VIII.12.2004, XI.25.2004, III.3.2005, V.12.2005	24	24
	Campo Mourão (RS12)	24°07'23.5"S, 52°18'07.6"W	VII.25.2005, X.3.2005, II.6.2006, III.27.2006	24	24
	Roncador (RS13)	24°34'14.8"S, 52°16'08.6"W	VII.26.2005, X.4.2005, II.7.2006, VI.7.2006	18	18
	Chopinzinho (RS14)	25°56'06.7"S, 52°25'02.8"W	VIII.11.2004, IX.24.2004	24	24
	Barracão (RS15)	26°12'21.3"S, 53°29'08.9"W	VIII.13.2004, XI.26.2004, III.4.2005, V.13.2005	24	24
Fields (FI)	Jaguariaíva (RS16)	24°22'43.6"S, 49°39'38.0"W	VIII.1.2005, IX.27.2004, XI.17.2004, III.9.2005	24	24
	Ponta Grossa (RS17)	25°06'06.6"S, 50°09'53.1"W	IX.16.2004, XI.10.2004, V.4.2005	12	12
	Palmas (RS18)	26°27'58.0"S, 51°58'58.0"W	VIII.9.2004, X.4.2004, I.17.2005, IV.18.2005	24	24
Semidecidual Seasonal Forest (SS)	Carlópolis and Joaquim Távora (RS19)	23°29'47.7"S, 49°49'53.9"W	VIII.3.2005, X.1.2004, II.23.2005, III.15.2005	24	24
	Jundiaí do Sul (RS20)	23°25'17.1"S, 50°16'54.5"W	VIII.6.2004, VII.28.2005, II.22.2006	18	18
	Tomazina (RS21)	23°50'57.9"S, 49°57'36.1"W	VIII.4.2005, IX.30.2004, XI.19.2004, III.11.2005	24	24
	Campina da Lagoa (RS22)	24°30'58.6"S, 52°51'30.6"W	VII.27.2005, X.7.2005, II.8.2006, VI.8.2006	24	24
	Três Barras do Paraná (RS23)	25°26'22.0"S, 53°09'34.0"W	VIII.10.2004, XI.23.2004, III.1.2005, V.10.2005	24	24
	Foz do Iguaçu – Keller Farm (RS24)	25°36'26.0"S, 54°26'50.0"W	VII.12/13.2004, X.11/14.2004, I.10/11.2005, IV.12/13.2004	24	24
	Terra Roxa (RS25)	24°01'49.6"S, 54°05'29.8"W	VII.14/15.2004, XII.15/16.2004, I.26/27.2005, IV.22/28.2005	24	24
	Guaíra (RS26)	24°19'06.1"S, 54°10'08.0"W	VIII.5.2005, II.13.2006, VI.02.2006	18	18
	Marechal Cândido Rondon (RS27)	24°33'11.7"S, 54°00'41.6"W	VII.29.2005, II.10.2006, VI.1.2006	18	18
	Diamante do Oeste (RS28)	24°56'20.3"S, 54°01'52.1"W	VII.28.2005, II.9.2006, VI.9.2006	18	18
	Foz do Iguaçu - biological refuge (RS29)	25°26'38.7"S, 54°35'02.6"W	XI.9.2005, IV.11.2006	12	12
	Cornélio Procópio and Santa Mariana (RS30)	23°09'03.4"S, 50°34'17.8"W	VIII.3.2004, VII.27.2005, II.21.2005	18	18
	Sertaneja (RS31)	22°54'12.0"S, 50°48'24.5"W	VIII.4.2004, VII.26.2005, X.15.2004, I.26.2005	24	24
	Assaí (RS32)	23°22'01.9"S, 50°49'32.8"W	VIII.2.2004, X.11.2004, I.18.2005	18	18
	Maringá (RS33)	23°25'31.0"S, 51°55'56.3"W	VIII.15.2005, XII.20.2005, II.23.2005, V.6.2005	24	24
	Inajá (RS34)	22°39'25.8"S, 52°15'15.8"W	VII.7.2004, IX.28.2004, III.1.2005, IV.27.2004	24	24
	Porto Rico (RS35)	22°45'26.7"S, 53°17'24.0"W	IX.15.2004, X.26.2004	12	12
	Cianorte (RS36)	23°38'34.4"S, 52°36'35.6"W	VIII.16.2005, XI.24.2005, II.11.2005	24	24

↑Table 1. Description of the study areas according to their primitive characteristics, geographic coordinates, mosquito collection dates and total collection hours on the ground and in the canopy of trees, state of Paraná, from April 2004 to June 2006.

Mosquitoes were collected in remnant forests, with typical characteristics of each of these original plant formations, in the rural and urban areas of 36 municipalities of Paraná, being considered two more municipalities for presenting contiguous forest (about 10% of the 399 existing municipalities), between April 2004 to June 2006. More details on the location of the Research Stations (RS) and mosquito collection are shown in Table 1.

Methodology for collecting

The data for this study were extracted from the entomological surveillance program of the State Department of Health of Paraná, which used the collection technique by human attraction, aiming to know the fauna of mosquitoes with an anthropophilic tendency and of importance in the transmission of arboviruses. When possible, four collections were carried out in each Research Station, one in each season of the year. In the research stations selected, two different strata were established for mosquito collecting: ground level and tree canopy. Collecting occurred simultaneously at the ground level and canopy, at 60-min intervals between 9 am and 3 pm (from 10 am to 4 pm during the summer), with the intention of collecting species with an essentially diurnal habit. In six localities mosquitoes were only collected at the ground level.

Collections at the tree tops were conducted between 10 and 15 m from the soil, considering the average height of the dominant trees in each research station: installation of tubular scaffold - consisting of tower with crossbeams and diagonals joined by rosettes, same model used in civil construction; portable platforms - consists of a metallic base composed of four-walled tubes, with corners supported by four chains that are connected to the parapet and converge at 1.20 m of this structure, using, as support, two reels with three pulleys each and a 20 mm nylon rope (Ferreira, 2005); sleeping net - installed on the tree tops, with support for the ropes on the branches spanning 3 to 3.5 meters. Access by means of a rope ladder or vertical climbing using appropriate climbing gear; wooden platforms - platform nestled between the branches to avoid damage to the tree, access by rope ladders; climb - Climbing using 15 m long rope ladders made of wooden steps and electrician-type safety equipment (Figure 2a-e). Some of these mosquito collection techniques were innovative, being indicated in a guide from the Ministry of Health, for capturing vectors in the wild (MS/SVS/DVDT, 2014).

Ground level samples were collected over a transect with 18 focal points separated by 10 m. Their central point was positioned about 30 m from the tree selected for collection at the forest canopy. The collector remained for 20 minutes at each focal point of the transect (Figure 2f).

For collecting, protected human attraction strategies (trousers and long-sleeved shirts and thick fabric, black soccer socks, ivanhoe garment and protective gloves) were used to avoid exposing the researchers to infection. All researchers involved in the study had been previously vaccinated against yellow fever.

Female mosquitoes were collected with the aid of a net and killed in a jar containing chloroform, at the moment they tried to bite the researcher. The collected mosquitoes were packaged and transported to the laboratory in labeled plastic containers.

Taxonomic identification and vouchers

Mosquitoes were identified to species whenever possible. For the identification of the mosquitoes collected, the descriptions and taxonomic keys of Lane (1953a, b), Galindo et al. (1954), Forattini (1962; 1965a, b; 2002), Bram (1967), Gorhan et al. (1967),

Zavortink (1973), Arnell (1976), Linthicum (1980), Consoli and Lourenço-de-Oliveira (1994) were used. The taxonomic nomenclature and classification of Harbach (2013) were adopted for sabetine mosquitoes. Aedini nomenclature follows Wilkerson et al. (2015).

Vouchers were deposited in the Entomological Collection Padre Jesus Santiago Moure (DZUP), in the Laboratory of Medical and Veterinary Entomology, Federal University of Paraná. The taxonomist responsible for identifying was Allan Martins da Silva.

Figure 2. Methods of collecting mosquitoes by human attraction, carried out by researchers at the ground level and the tree canopy in forested areas of the state of Paraná, from April 2004 to June 2006. Legend: a) installation of tubular scaffold; b) portable platforms; c) sleeping nets; d) wooden platforms; e) climbing using rope ladders; f) human attraction.

Distribution and similarity analysis

The list of species and morphospecies of wild mosquitoes occurring in Paraná in the various types of vegetation cover is presented in a presence/absence table.

The relationship between the accumulated number of mosquito species and the research stations was ascertained using the "collector curve" and sampling sufficiency was used to demonstrate that the asymptote was reached (Cain, 1938).

The original vegetation areas were classified by Cluster Analysis. Paired samples (number of pairs - 1) were compared using the Jaccard similarity index, where zero means "no similarity" and 1 "total similarity" (Jaccard, 1908).

Similarity between landscape areas was measured from the data stored in a Microsoft Office Excel 2010 spreadsheet and analyzed in the Paleontological Statistics (PAST) program, Software Package for Education and Data Analysis, version 1.88 (Hammer et al., 2001).

Results

In total, 119 collections were made at the ground level and 103 at the tree canopy, 720 and 618 hours, respectively. The tendency for the curves to stabilize confirmed that the number of collected samples was sufficient to demonstrate the diversity of the anthropophilic wild mosquito fauna at the 36 research stations. A hypothetical 10% increase in the number of collections would reflect an increase in the cumulative number of 12 species, which would represent 10% of the total mosquito species identified, demonstrating that the asymptote was reached (Figure 3). Therefore, the increase in the numbers of species occurrence was equal to the average, represented by the total number of species found, divided by the total number of collections. The R-square regression parameter was close to "one", R^2 = 0.8895, indicating a strong relationship between the two variables.

The results indicated that the sylvatic fauna of diurnal mosquitoes was diverse in the forests of Paraná. A total of 15 genera and 121 anthropophilic species

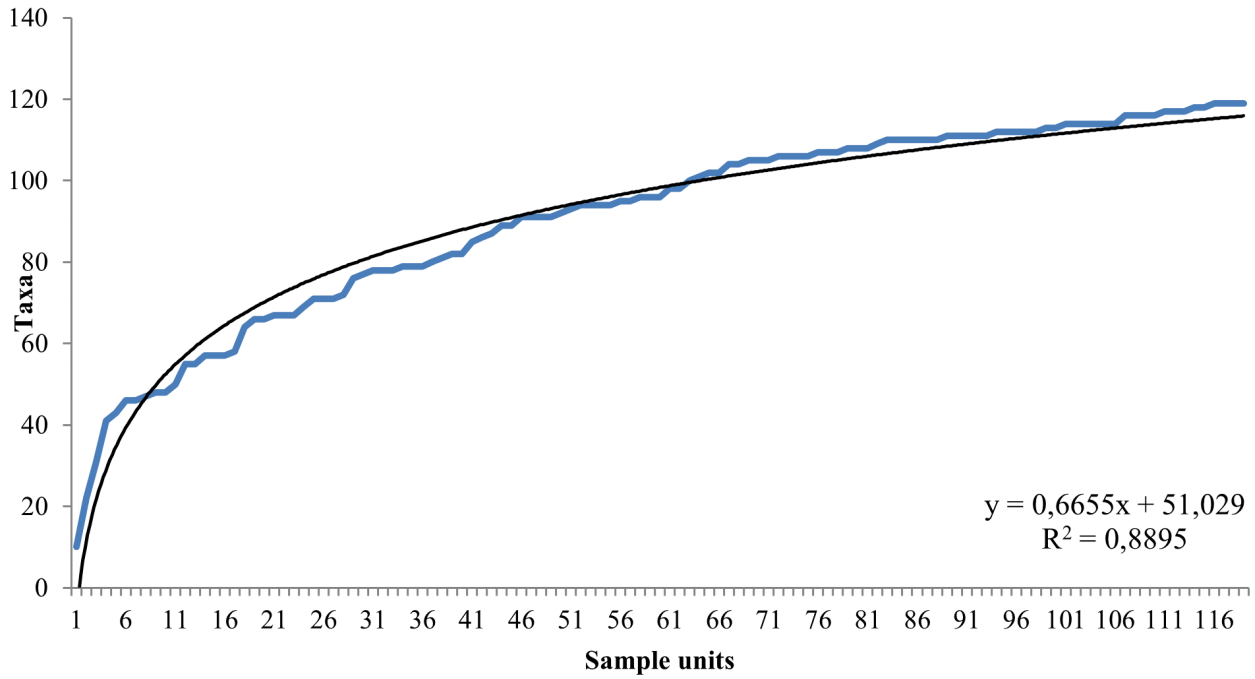

Figure 3. Collector curve for dihurnal mosquitoes collected from the wild (ground and canopy levels), state of Paraná, from April 2004 to June 2006. Legends: (blue) = Number of species and group of species (taxa) accumulated; (black) = Logarithmic trend line.

or groups of species (taxa) were found. The most frequent subfamily in samples was Culicinae, totaling 99% of the specimens collected. In this subfamily, the Sabethini were the most numerous, totaling 50% of the specimens collected, and the other tribes represented 49% of the total. The most diverse genus was *Wyeomyia* (31 species), followed by *Sabethes* (21 species), *Aedes* (15 species) and *Anopheles* (13 species) (Table 2).

The greatest richness of wild mosquito species was observed in the areas covered with Semidecidual Seasonal Forest (α = 79). In the areas of Dense Ombrophilous Forest and Mixed Ombrophilous Forest, species richness was similar, (α = 50) and (α = 48), respectively. The lowest species diversity was observed in the Campos (α = 27) areas (Table 2).

Most mosquito taxa occurred in only one type of forest, with 65 (56.0%) taxa, or two forest types, with 25 (21.6%) taxa. Among the populations of mosquitoes that showed the highest distribution, 15 (12.9%) taxa occurred in three forest areas and 11 (9.5%) were recorded in the four types of vegetation cover surveyed (Table 2).

The proportion of species and morphospecies shared between the four types of original vegetation was 74% (Jaccard = 0.7352), demonstrating similarity between the analyzed groups.

Discussion

The mosquito survey in the remnant and secondary forests of the state of Paraná provided data on the composition and distribution of species, including places where no previous surveys had been conducted, like the Fields regions of the municipalities of Jaguariaíva and Palmas. This study was the first attempt to systematically collect wild adult mosquitoes that have diurnal habits.

The number of species (91) and species groups (30) found in our data demonstrates that the mosquito fauna occurring in Paraná is quite significant. In the Sabethes, for example, 16 species and four groups of species were collected, out of the 28 species of this genus that occur in Brazil (WRBU, 2022).

Before the present study, few articles listed the mosquito fauna occurring in the state of Paraná. The first entomological studies in Paraná were part of a survey of the anopheline fauna in areas where malaria was endemic in 1949 and 1950. It resulted in a list with 26 species of Anophelini distributed in two genera, *Anopheles* and *Chagasia* (Rachou & Ricciardi, 1951). Although our study focused on diurnal mosquitoes, species of *Anopheles* were also collected, some of them transmitters of plasmodia that cause malaria in humans, such as *An. (Nys.) darlingi*, *An. (Ker.) cruzii* e *An. (Ker.) bellator*.

Subsequently, Müller et al. (2008) compiled a list of 78 species in the genera *Aedes*, *Psorophora*, *Mansonia*, *Limatus*, *Sabethes*, *Wyeomyia*, *Uranotaenia* and *Toxorhynchites*, which had been listed by previous authors, in addition to three new records for Paraná. More recently, Silva et al. (2021) updated the list of anopheline species occurring in the state of Paraná, with distribution by municipality and location where they were collected.

Considerations about the two main mosquito tribes identified in this study are presented below, with special attention paid to percentage and distribution in different types of vegetation cover in Paraná.

Aedini

The tribe Aedini consists of ten genera, of which *Aedes*, *Psorophora* and *Haemagogus*, are widely distributed in the Neotropical Region (WRBU, 2022). The predominantly diurnal activity and preference for human blood has made it possible to collect a large number of individuals of *Aedes* and *Psorophora*.

Aedes (Ochlerotatus) scapularis was found in secondary forest at different levels of vegetation complexity. At some focal points, for instance Mata São Francisco State Park, municipalities of Cornélio Procópio and Santa Mariana, the characteristics of the vegetation were close to the original vegetation of the Semideciduous Seasonal Forest. Finding these mosquitoes in a forest adjacent to Iguaçu National

Table 2. Distribution of species and morphospecies of mosquitoes (females) by type of original vegetation cover, state of Paraná, from April 2004 to June 2006. Legend: (X) = present, (-) = absent, according to the collecting methodology used and the type of vegetation cover surveyed. ([1]) Original vegetation: (DO) = Dense Ombrophilous Forest; (MO) = Mixed Ombrophilous Forest; (SS) = Seasonal Semideciduous Forest; (FI) = Fields. ([2]) Mosquito populations with different morphotypes. ([3]) (spp.) = identification not determined.

Species	**Original vegetation ([1])**			
	DO	**MO**	**SS**	**FI**
Anophelinae				
Anopheles (Anopheles) fluminensis Root, 1927	X	-	X	-
Anopheles (Kerteszia) bellator Dyar and Knab, 1906	X	-	-	-
Anopheles (Kerteszia) cruzii Dyar and Knab, 1908	X	X	-	-
Anopheles (Nyssorhynchus) darlingi Root, 1926	-	-	X	-
Anopheles (Nyssorhynchus) evansae (Brethes, 1926)	-	-	X	-
Anopheles (Nyssorhynchus) galvaoi Causey, Deane & Deane, 1943	-	-	X	-
Anopheles (Nyssorhynchus) lutzii Cruz, 1901	-	X	X	-
Anopheles (Nyssorhynchus) parvus (Chagas, 1907)	-	-	X	-
Anopheles (Nyssorhynchus) rangeli Gabaldon, Cova Garcia & Lopez, 1940	-	-	X	-
Anopheles (Nyssorhynchus) strodei Root, 1926	-	-	X	-
Culicinae				
Aedini				
Aedes (Ochlerotatus) crinifer (Theobald, 1903)	-	-	X	X
Aedes (Georgecraigius) fluviatilis (Lutz, 1904 In: Bourroul, 1904)	-	-	-	X
Aedes (Ochlerotatus) fulvus (Wiedemann, 1828) ([2])	-	-	X	-
Aedes (Ochlerotatus) scapularis (Rondani, 1848)	X	X	X	X
Aedes (Protomacleaya) terrens (Walker, 1856)	-	X	X	X
Aedes (Sallumia) hortator Dyar and Knab, 1907	X	-	-	-
Aedes (Stegomyia) aegypti (Linnaeus, 1762)	-	-	X	-
Aedes (Stegomyia) albopictus (Skuse, 1895)	X	-	X	X
Haemagogus (Conopostegus) leucocelaenus (Dyar and Shannon, 1924)	-	X	X	X
Psorophora (Grabhamia) cingulata (Fabricius, 1805)	X	-	-	-
Psorophora (Janthinosoma) albigenu (Peryassú, 1908) ([3])	X	X	X	X
Psorophora (Janthinosoma) albipes (Theobald, 1907)	-	X	X	-
Psorophora (Janthinosoma) champerico (Dyar and Knab, 1906)	-	-	X	-
Psorophora (Janthinosoma) discrucians (Walker, 1856)	-	X	X	-
Psorophora (Janthinosoma) ferox (Von Humboldt, 1819)	X	X	X	X
Psorophora (Janthinosoma) lutzii (Theobald, 1901)	X	-	-	-
Culicini				
Culex (Aedinus) amazonensis (Lutz, 1905)	X	-	X	-
Culex (Culex) declarator Dyar and Knab, 1906	-	-	-	X
Culex (Culex) nigripalpus Theobald, 1901	-	-	X	-
Culex (Melanoconion) ribeirensis Forattini and Sallum, 1985	X	-	X	-
Culex (Melanoconion) sacchettae Sirivanakarn and Jacob, 1981	X	-	-	-
Culex (Melanoconion) spissipes (Theobald, 1903)	-	-	X	-
Mansoniini				
Coquillettidia (Rhynchotaenia) albicosta (Peryassú, 1908)	-	-	X	-

Table 2. Cont.

Coquillettidia (Rhynchotaenia) fasciolata (Lynch Arribálzaga, 1891)	-	-	X	-
Coquillettidia (Rhynchotaenia) hermanoi (Lane and Coutinho, 1940)	-	-	X	-
Coquillettidia (Rhynchotaenia) venezuelensis (Theobald, 1912)	X	-	X	-
Mansonia (Mansonia) amazonensis (Theobald, 1901)	-	-	X	-
Mansonia (Mansonia) humeralis Dyar and Knab, 1916	-	-	X	-
Mansonia (Mansonia) indubitans Dyar and Shannon, 1925	X	-	X	X
Mansonia (Mansonia) titillans (Walker, 1848)	X	X	X	-
Sabethini				
Limatus durhamii Theobald, 1901	X	X	X	X
Limatus flavisetosus Oliveira Castro, 1935	X	-	-	-
Limatus pseudomethysticus (Bonne-Wepster and Bonne, 1920)	X	-	-	-
Onirion personatum (Lutz, 1904)	-	X	-	-
Runchomyia (Runchomyia) cerqueirai (Stone, 1944)	X	-	-	-
Runchomyia (Runchomyia) reversa (Lane and Cerqueira, 1942)	X	X	-	X
Runchomyia (Runchomyia) theobaldi (Lane and Cerqueira, 1942)	X	-	-	-
Sabethes (Peytonulus) aurescens (Lutz, 1905)	X	X	X	X
Sabethes (Peytonulus) identicus Dyar and Knab, 1907	-	X	X	-
Sabethes (Peytonulus) shannoni (Lane & Cerqueira, 1942)	X	-	-	-
Sabethes (Peytonulus) soperi Lane and Cerqueira, 1942	X	X	-	-
Sabethes (Peytonulus) whitmani Lane and Cerqueira, 1942	X	-	-	-
Sabethes (Sabethes) albiprivus Theobald, 1903 (2)	X	X	X	X
Sabethes (Sabethes) belisarioi Neiva, 1908	-	X	X	-
Sabethes (Sabethes) purpureus (Theobald, 1907)	-	-	X	X
Sabethes (Sabethes) cerqueirai Nascimento-Pereira et al., 2021	-	-	X	-
Sabethes (Sabethinus) melanonymphe Dyar, 1924	-	X	X	-
Sabethes (Sabethinus) xhyphydes Harbach, 1994	-	X	X	-
Sabethes (Sabethoides) conditus Moses, Howard and Harbach, 2000	-	-	X	-
Sabethes (Sabethoides) glaucodaemon (Dyar and Shannon, 1925)	-	-	X	-
Sabethes (Sabethoides) tridentatus Cerqueira, 1961	X	X	X	-
Shannoniana fluviatilis (Theobald, 1903)	-	X	X	-
Trichoprosopon compressum Lutz, 1905	-	X	X	-
Trichoprosopon digitatum (Rondani, 1848)	X	-	-	-
Wyeomyia (Davismyia) petrocchiae (Shannon and Del Ponte, 1928)	-	X	X	X
Wyeomyia (Miamyia) limai Lane and Cerqueira, 1942	-	X	X	X
Wyeomyia (Miamyia) oblita (Lutz, 1904)	-	X	-	-
Wyeomyia (Miamyia) sabethea Lane and Cerqueira, 1942	-	X	-	-
Wyeomyia (Phoniomyia) davisi (Lane and Cerqueira, 1942)	X	-	-	-
Wyeomyia (Phoniomyia) fuscipes Edwards, 1922	-	X	-	-
Wyeomyia (Phoniomyia) galvaoi (Correa and Ramalho, 1956)	X	X	-	-
Wyeomyia (Phoniomyia) incaudata (Root, 1928)	X	-	-	-
Wyeomyia (Phoniomyia) lopesi (Correa and Ramalho, 1956)	X	-	-	-
Wyeomyia (Phoniomyia) muehlensi Petrocchi, 1927	-	-	X	-
Wyeomyia (Phoniomyia) pilicauda Root, 1928	-	X	-	-
Wyeomyia (Phoniomyia) quasilongirostris (Theobald, 1907)	X	X	X	X
Wyeomyia (Prosopolepis) confusa (Lutz, 1905)	X	-	X	-
Wyeomyia (Triamyia) aporonoma Dyar and Knab, 1906	X	X	-	-

Table 2. Cont.

Wyeomyia (Wyeomyia) arthrostigma (Lutz, 1905)	-	X	X	-
Wyeomyia (Wyeomyia) medioalbipes Lutz, 1904	-	X	X	-
Wyeomyia (Wyeomyia) scotinomus (Dyar and Knab, 1907)	-	-	X	-
Wyeomyia occulta Bonne-Wepster and Bonne, 1919	X	X	X	X
Wyeomyia serratoria (Dyar and Nuñez Tovar, 1927)	-	-	X	-
Wyeomyia undulata Del Ponte and Cerqueira, 1938	-	-	X	-
Morphospecies	**Original vegetation (1)**			
	DO	**MO**	**SS**	**FI**
Anophelinae				
Anopheles (Anopheles) mediopunctatus/costai	X	-	-	-
Anopheles (Nyssorhynchus) oswaldoi sensu lato (s.l.)	-	-	X	-
Anopheles (Nyssorhynchus) triannulatus s.l.	-	X	X	-
Chagasia fajardoi/rozeboomi	-	X	X	X
spp. (3)	X	-	-	-
Culicinae				
Aedini				
Aedes (Ochlerotatus) confer crinifer	-	X	-	-
Aedes (Howardina) cf. fulvithorax	-	-	X	-
Aedes (Ochlerotatus) cf. fluviatilis	X	-	-	-
Aedes (Ochlerotatus) serratus/aenigmaticus	X	X	X	X
Aedes (Ochlerotatus) serratus/nubilus	X	X	X	-
Haemagogus (Haemagogus) janthinomys/capricorni	-	-	X	-
Psorophora (Janthinosoma) near fiebrigi	-	-	X	-
Culicini				
Culex (Culex) bidens/mollis/lygrus	-	-	X	-
Culex (Culex) coronator complex	X	X	X	-
Mansoniini				
Coquillettidia (Rhynchotaenia) chrysonotum/albifera	X	X	X	X
Sabethini				
Sabethes (Peytonulus) undosos/fabrici	-	-	X	-
Sabethes (Peytonulus) undosos/fabrici/ignotus	-	X	X	X
Sabethes (Sabethes) nr. belisarioi	-	-	X	-
Sabethes (Sabethes) sp. Form	X	X	-	X
Sabethes (Sabethes) cf. gymnothorax	-	-	X	-
Sabethes (Sabethes) sp. Belisarioi group	-	-	X	-
Trichoprosopon pallidiventer/castroi/simile	X	X	X	-
Wyeomyia (Decamyia) felicia/pampeithes	-	-	-	X
Wyeomyia (Miamyia) cf. limai	X	X	X	X
Wyeomyia (Phoniomyia) cf. fuscipes	-	X	-	-
Wyeomyia (Phoniomyia) nr. longirostris	X	-	-	-
Wyeomyia (Phoniomyia) nr. quasilongirostris	X	-	-	-
Wyeomyia (Phoniomyia) nr. splendida	X	-	-	-
Wyeomyia (Spilonympha) mystes/finlayi	X	-	-	-
Wyeomyia (Wyeomyia) nr. scotinomus	-	X	-	X
Wyeomyia cf. serratoria	-	-	X	-
spp. (including five morphotypes) ([3])	X	X	X	X

Park corroborates previous suspicions that these are mosquitoes of preferably wild biotopes (Guimarães et al., 2003).

In the area of Mixed Ombrophilous Forest (MO), *Ae. (Och.) scapularis* was found in residual forests where conifers and broad - leaved trees from 12 to 15 meters high predominate (*Araucaria*). The most important vestiges of this type of vegetation are found in the southwest of Paraná, represented by the research locality at municipality of Barracão (RS15).

Despite the fact that there are several literature records of *Ae. (Och.) scapularis* in the forested areas (Davis, 1945; Causey & Santos, 1949; Rachou et al., 1955; Guimarães & Arlé, 1984; Lourenço-de-Oliveira, 1984; Forattini et al., 1986a, b), anthropic changes in the natural environment favor this species, which has affinities with human domestic environments (Forattini et al., 1995). In the north of the state of Paraná, Silva & Menezes (1996) reported the finding of immature forms of this species colonizing abandoned artificial breeding sites on the edge of the forest. Other studies carried out in areas of Seasonal Semideciduous Forest in Paraná showed that *Ae. (Och.) scapularis* is one of the most frequent species, mainly in altered forest fragments (Consolim et al., 1993; Teodoro et al., 1994; Tubaki et al., 1999).

In the region of Açungui, on the Paraná side of Vale do Rio Ribeira, *Ae. (Och.) scapularis* and *Ps. (Jan.) ferox* were the species collected in secondary forest areas. In the same region, but in the state of São Paulo, Forattini et al. (1995) demonstrated that this species prevailed in open cultivated areas and in residential environments. Anjos and Navarro-Silva (2008) also observed the predominance of this species in an environment altered by humans, at an area of the First Paraná Plateau between Dense Ombrophilous Forest (DO) and the Mixed Ombrophilous Forest (MO).

In the coast of Paraná *Ae. (Och.) scapularis* was the most collected species of Aedini, similar to the results of other studies carried out in the littoral regions of the state of São Paulo, where this species shows a marked preference for human habitations (Forattini et al., 1986b, 1987, 1989; Forattini & Gomes, 1988). However, the species was less frequent in the samples collected in the Atlantic Forest of Serra do Mar. The same observation was made in another study carried out in the region (Santos-Neto & Lozovei, 2008). But in the region of general fields, where grasses predominate, *Ae. (Och.) scapularis* was collected in riparian forests and isolated canyons, being one of the most frequent species in the research station located in the municipality of Palmas. This was the first report of the species in the region.

Aedes (Ochlerotatus) serratus/aenigmaticus was the most frequent group among the Aedini, representing 9.1% of the total mosquitoes, being collected mainly in the research stations of the areas of general fields, Mixed Ombrophilous (MO) Rainforest of Subtropical Wetland and Semidecidual Seasonal Forest (SS). Out of the two species that comprise this group, only *Aedes (Ochlerotatus) serratus* (Theobald, 1901) has already been recorded from Paraná, both on the coast and at the interior (Tissot & Navarro-Silva, 2008; Müller et al., 2008).

The present study, besides *Ae. (Och.) serratus*, other species of Serratus Group were identified from females. They almost or completely lack longitudinal stripe on the scutum. *Aedes (Ochlerotatus) serratus* was collected only at research stations located on the coast, while *Ae. (Och.) serratus/nubilus* was collected at several research stations located Mixed Ombrophilous Forest (MO) and Seasonal Semideciduous Forest (SS), in the interior of the state of Paraná. This group of species is quite variable with regards to the presence or absence the pale longitudinal stripe on the scutum. According to Belkin et al. (1970), this band is a reliable and unique feature in *Ae. (Och.) serratus*, which can be used to identify this species. It is therefore possible that records of *Ae. (Och.) serratus* in the interior of Paraná correspond to *Aedes (Ochlerotatus) nubilus* Theobald, 1903.

Psorophora (Janthinosoma) ferox was the second species in number of individuals, representing 8.6% of the total collected. This species was widely distributed of Campos Gerais (FI), Ombrophilous Mixed Forest (MO) of Subtropical Zone and Semideciduous

Tropical Forest zones (SS). Still, the species was more common in the municipality of Inajá, in the semideciduous seasonal forest area, in the municipality of Chopinzinho, in the Mixed Ombrophilous Forest (MO) area, and in the coastal municipalities, in the Dense Ombrophilous Forest (DO) area in coastal municipalities.

In others surveys of the mosquito fauna in the extreme west of Paraná, *Ps. (Jan.) ferox* was collected on the banks of Itaipu Lake and Iguaçu National Park, in a semideciduous seasonal forest area, which still holds much of its original characteristic (Consolim et al., 1993; Guimarães et al., 2003). In other studies, *Ps. (Jan.) ferox* was recorded in altered natural environments of the First Paraná Plateau, between Dense Ombrophilous Forest (DO) and Mixed Ombrophilous Forest (MO) and in the Seasonal Semideciduous Forest (SS) (Teodoro et al., 1994; Tubaki et al., 1999; Anjos & Navarro-Silva, 2008)

Finding *Ps. (Jan.) ferox* in several types of natural environments may be related to the dispersion capacity of this species among forest fragments (Forattini, 2002). One should also consider the fact that females of this mosquito deposit their eggs in places situated in forested areas, which may in part explain the strong presence of mosquito in forest environments at various stages of conservation.

The locations of research sites in more anthropized areas, often with a large number of temporary soil breeding sites (lagoons, swamps and wetlands), which are directly influenced by the rains and underground water levels, may have contributed contributed to the abundance of these species of Aedini. Dorvillé (1996) separated mosquitos into different levels of anthropic bioindicators, and classified *Ae. (Och.) scapularis* and *Ps. (Jan.) ferox* as indicators of a high degree of anthropization.

The distribution and behavior of *Ae. (Och.) scapularis*, *Ae. (Och.) serratus/aenigmaticus* and *Ps. (Jan.) ferox* in Paraná are probably associated with the distribution of their breeding grounds. The localities where these species were identified are in areas of rivers and plains with very gentle slope, allowing extensive breeding sites to form in the soil and favoring the proliferation of these species.

Sabethini

The Sabethini include a large number of species, distributed in 14 genera, of which nine are Neotropical (WRBU, 2022). According to Judd (1996), the American species are divided into two morphological groups: 1) *Trichoprosopon*, including *Isostomyia, Johnbelkinia, Runchomyia, Shannoniana* and *Trichoprosopon*; 2) *Sabethes*, including *Sabethes, Wyeomyia, Onirion, Limatus* and *Phoniomyia*.

This study, species of the two Sabethini groups were collected. The genera S*abethes, Trichoprosopon* and *Wyeomyia* were the most numerous. *Sabethes (Peytonulus) aurescens* was the most frequent species among the sabetines, accounting for 12.6% of the total collected. It occurs mainly in the Mixed Ombrophilous Forest (MO), where it is the most numerous in the research station located in the municipality of União da Vitória.

Even though *Sa. (Pey.) aurescens* was a frequent species in the forest environments of Paraná, little is known about the behavior and vector capacity of this mosquito. The frequency of individuals collected at the focal points can be explained by the fact that females ovulate throughout the year (Müller et al., 2009).

The immature forms of *Sa. (Pey.) aurescens* are frequently found in various types of bamboos, which provide microhabitats with different levels of organic matter and where predatory mosquito species also occur (Lozovei & Luz, 1976; Lozovei, 1998, 2001; Marcondes & Mafra, 2003; Marcondes et al., 2006; Zequi & Lopes, 2001; Müller et al., 2009).

In Paraná, immatures of *Sa. (Pey.) aurescens* have been found in different types of vegetation: Mixed Ombrophilous Forest (Lozovei & Luz, 1976; Lozovei, 1998); Dense Ombrophilous Forest (Lozovei, 1998, 2001); and Seasonal Semideciduous Forest (Requi & Lopes, 2001). In the First Paraná Plateau, in an area where the Dense Ombrophilous Forest (DO) and the Mixed Ombrophilous Forest (MO) encounter one

another, adults of *Sa. (Pey.) aurescens* were collected in shelters in the forest soil (Anjos & Navarro-Silva, 2008).

Despite many findings of larvae and adults of S*a. (Pey.) aurescens* in shelters in the Ombrophilous Forest, no specimens were collected using human attraction at the research stations located on the coastal range and on the edge of Serra do Mar.

Sabethes (Sabethes) albiprivus was the second species of Sabethini in number of individuals (5.7% of the specimens). It was collected at 25 research stations (69.4%), especially in areas of Mixed Ombrophilous Forest (MO) and Seasonal Semidecidual Forest (SS), on Third Paraná Plateau. In Paraná, this species had been recorded only in 2003, in a study on the incidence of Culicidae in four different locations of the Iguaçu National Park, in a semideciduous seasonal forest area, where it showed a marked tendency to occupy wild (more pristine) areas (Guimarães et al., 2003).

This mosquito was collected in different forest typologies and different successional stages, including residual and secondary forest areas. The vegetation in some of these areas is close to the original vegetation, for instance, areas next to the Iguaçu National Park (municipalitie Foz do Iguaçu - Keller Farm), Mata São Francisco State Park (municipalities of Cornélio Procópio and Santa Mariana) and Capela Farm (municipalities of Carlópolis and Joaquim Távora). However, it was also collected in Parque do Ingá, urban forest in the city of Maringá.

Although in this study *Sa. (Sab.) albiprivus* is being treated as a single valid species, during the identification process we observed color variation from the analysis of the morphological characteristics of females collected from the soil and the canopies of trees, in different forest environments of the state. Molecular studies have shown that there may be two species living in sympatry in the west of the state of São Paulo (Pedro et al., 2008). Westphal-Ferreira and Navarro-Silva (2016), who used part of the *Sa. (Sab.) albiprivus* collected in the present study, found two groups with different color variations using near infrared spectroscopy and microstructure of the scales.

Trichoprosopon pallidiventer/castroi/simile (cryptic species) was collected in four landscape areas of Paraná, being more frequent in mixed Ombrophilous Forest areas, mainly in temperate regions. This morphospecies was also collected in some areas of the Semideciduous Seasonal Forest, in the Humid Subtropical Zone and on the coast, where few specimens were found in the municipalities of Paranaguá and Matinhos. In Paraná, *Trichoprosopon pallidiventer* (Lutz 1905) was recorded in a forest fragment in the urban area of Londrina (Zequi & Lopes, 2001), and at the Serra do Mar region and the First Paraná Plateau (Lozovei, 1998, 2001; Anjos & Navarro-Silva, 2008; Santos-Neto & Lozovei, 2008). *Trichoprosopon simile* Lane and Cerqueira, 1942 was found at the Iguaçu National Park, extreme west of Paraná (Guimarães et al., 2003). The record of this group of species of Sabethini in 15 municipalities of the 37 surveyed in Paraná is new, since *Tr. pallidiventer, Tr.castroi* and *Tr.simile* had not been found before in areas of Mixed Ombrophilous Forest.

The species of *Wyeomyia* were more frequent at the research stations located on the coast of Paraná. *Wyeomyia (Phoniomyia) galvaoi* was collected from four research stations, three of which were located in the Dense Ombrophilous Forest, on the edge of Serra do Mar and on the coast. In the municipality of Matinhos this species predominated over the other species of mosquitoes. However, in the Mixed Ombrophilous Forest (MO) area, only one specimen was collected, in the town of Boa Vista, in the municipality of Piên. This result corroborates another study conducted in the same area, where only one specimen was collected (Bonna & Navarro-Silva, 2008). *Wyeomyia (Miamyia) cf. limai* was collected in 14 municipalities distributed in five types of original vegetation of Paraná, predominating in the research stations in areas of Mixed Ombrophilous Forest and Semidecidual Seasonal Forest of the Humid Subtropical Zone, with distribution similar the morphospecies of *Trichoprosopon*.

Trichoprosopon pallidiventer/castroi/simile, Wy. (Pho.) galvaoi e *Wy. (Mia.) cf. limai* had different

distribution patterns in the state of Paraná. Some environmental characteristics such as the presence of preferred breeding sites may be important for the predominance of these species. For example, Guimarães et al. (2003) observed that the frequency of Tr. pallidiventer in forested areas could be associated with the large breeding sites in the soil.

The species of *Wyeomyia* colonize natural containers. For example, the distribution of *Wy. (Pho.) galvaoi* is markedly associated with the areas of Atlantic Forest where bromeliads occur. The distribution of *Wy. (Mia.) limai*, in contrast, depends on the occurrence of bamboos (Lozovei, 1998, 2001; Zequi & Lopes, 2001; Lopes, 2002).

This study also revealed the presence of species of sabetini in remnant forests that had not yet been found in the south of the country as *Wy. (Wyo.) scotinomus*, *Sa. (Sab.) cerqueirai* (renamed from *Sa. shannoni*, per Nascimento-Pereira et al., 2021), *Sa. (Sbo.) conditus*, *Wy. occulta, Sa. (Pey.) shannoni* (= *Wy. shannoni* synonymy, according Nascimento-Pereira et al., 2021), *Wy. undulata,* and in of Paraná state like *Sa. (Pey.) whitmani*, *Sa. (Sob.) glaucodaemon, Sa. (Sob.) tridentatus, Wy. (Mia.) sabethea, Wy. (Pho.) fuscipes, Wy. serratoria*, previously presented by Silva et al. (2019). Also the discovery of *Cx. (Mel.) spissipes* in the Semideciduous Seasonal Forest of the Paraná River Basin (Silva et al., 2017).

After this brief list of the diurnal anthropophilic mosquito fauna, occurring in forest environments in the state of Paraná, an article will follow on the epidemiological importance of these findings and the risk areas for the transmission of arboviruses through the analysis of entomological indicators.

Acknowledgements

We thank Dr. Natal Jataí de Camargo and the team from the Paraná State Health Department, who made this study possible. We also thank the entomology technicians of the Ministry of Health, assigned to SESA-PR, for collecting the mosquitoes. The teacher Dr. Maria Anice Mureb Sallum, from the Faculty of Public Health, University of São Paulo, for confirming the identification of the species.

This article is part of a Ph.D. dissertation by Allan Martins da Silva. Wild mosquitoes (Diptera: Culicidae) and potential areas of occurrence of arboviruses in the state of Paraná. Graduate program in biological sciences, entomology, Universidade Federal do Paraná.

In memory of Alvir Swiderski and Silvestre Marques de Moura.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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