



Diversity analysis, distribution and abundance of mosquito (Diptera: Culicidae) assemblages at urban sector from southwestern Colombia

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Abstract

The Culicidae family (mosquitoes) has great relevance worldwide, due to its involvement in generating several diseases. The Department of Cauca in Colombia is characterized as a region with the influence of several vector-borne diseases. This study aims to analyze the ecological diversity and distribution of mosquitoes with potential transmitters of diseases in a particular urban area of the municipality of Santander de Quilichao. This is one of the first studies of its kind in this municipality. Mosquito collections were carried out during the rainy and dry seasons of 2022, between 17:00 to 19:00. Morphological keys were used for species identification. For the analysis of diversity comparison vs. sampling points, Simpson's index was used, a dendrogram, rarefaction curve, and non-metric multidimensional scaling (nMDS). In the statistical analysis of species-abundances, ANOVA was applied to determine if there were significant differences regarding abundance. A total of 1116 culicid specimens were collected. The 59.4% were mosquitoes of the species *Aedes aegypti*, 18.5% *Culex quinquefasciatus*, 18.2% *Aedes albopictus*, and 3.9% *Psorophora ferox*, being the rainy season important for their survival. ANOVA analysis showed that the mean abundance of *Ae. aegypti* was significantly different from the other species. This study is broadly consistent with other studies in the tropical American context where the abundance of Culicidae is more representative in the rainy season. The results suggest a wide presence of *Aedes* mosquitoes in natural and artificial habitats, showing the importance of establishing controls and permanent epidemiological surveillance in this region.

Keywords Culicidae · Mosquito diversity · Distribution · Abundance · Infectious diseases · Ecological study

Introduction

The Culicidae family (mosquitoes) has great relevance worldwide, due to the generation of several diseases (WHO 2020; Teltscher et al. 2021). This family has 41 genera and around 3,500 species (Cavalcante do Nascimento et al. 2018; Foster and Walker 2019). There are studies focused on the analysis of the richness, abundance, and distribution of this family in tropical areas, where climate and its variations are key to understanding its biology and the possible health implications in the context of environmental crisis (Boyer et al. 2020; Câmara et al. 2020; Naranjo-Díaz et al. 2020; Vieira et al. 2020; Adeniran et al. 2021; Akter et al. 2021; Gao et al. 2021; Omar et al. 2021; Talbot et al. 2021; Yee et al. 2021; Yeo et al. 2021; Bedoya-Rodríguez et al. 2022). Climate variations are a major factor in vector-borne disease (VBD) dynamics and mosquito abundance (Vieira et al. 2020; Caldwell et al. 2021). Consequently, these variations

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are related to climate change, favoring VBD (Dhimal et al. 2021; Francisco et al. 2021).

The Culicidae family has been studied worldwide. Particularly in South America: Brazil, Peru, and Colombia generated the highest number of cases of mosquito-borne disease in 2022, with 2,363,490, 72,851 and 69,497 cases, respectively (PAHO 2023). Brazil is considered the leading country for studies on hematophagous mosquito species (Melgarejo-Colmenares et al. 2022). In this country, ecological aspects related to climate variations and mosquito-borne viruses have been studied (Barrio-Nuevo et al. 2020; De Melo et al. 2021). Brazil has also conducted studies on mosquito diversity in different landscapes (Câmara et al. 2020; Ceretti-Junior et al. 2020) and its occurrence in natural and artificial habitats (Bastos et al. 2022). In Rio de Janeiro, studies analyzed how biotic and abiotic factors influence the abundance of *Aedes aegypti* (Linnaeus, 1762) in urban sectors (David et al. 2021; Orlandin et al. 2021). Likewise, they have studied the impact of yellow fever and other VBD in different environments, using different methods of capturing mosquitoes and evaluating their effectiveness (De Miranda et al. 2022; Stanzani et al. 2022).

In Argentina, analyses in *Ae. aegypti* allowed us to understand their adaptation and spread across the region. The authors improved knowledge about vector control due to its relationship with VBD such as dengue, Zika, chikungunya and yellow fever (Ruggerio et al. 2021). Also, characterizations of the mosquito (*Ae. aegypti*) populations in the warm and cold seasons were carried out (Visintin et al. 2022; Brivido et al. 2023). The population dynamics *Culex* and *Aedes* mosquitoes, climatic factors and environmental conditions of the habitats have determined their abundance and expansion in this region (Carbajo et al. 2019; Grech et al. 2019). In Peru, there are very few studies on the Culicidae family, some studies focus only on *Ae. aegypti* and the genera *Culex* and *Anopheles* (Ayala-Sulca et al. 2022). In Chile, *Culex quinquefasciatus* (Say, 1823) and *Aedes albopictus* (Skuse, 1894) have been studied for their relationship with Flaviviruses transmission (Cancino-Faure et al. 2023). Likewise, in Bolivia, this type of study made it possible to identify the different characteristics of genus *Flavivirus* present in the region (Orba et al. 2021). In Venezuela and Ecuador, the Culicidae family has been studied, allowing the analysis of its diversity, richness and abundance, in addition to generating inventories of the species of this family (Berti et al. 2019, 2021; Jacome et al. 2023). In addition, *Ae. albopictus* was recorded for the first time in the city of Guayaquil, Ecuador (Ponce et al. 2018).

In Colombia, the diversity of Culicidae mosquitoes shows a total of 324 species and 28 genera. In this country the presence of genera with medical importance such as *Aedes*, *Anopheles*, *Chagasia*, *Coquillettidia*, *Culex*, *Deinocerites*, *Haemagogus*, *Mansonia*, *Psorophora*, *Toxorinquitus* and

Wyeomyia was recorded (Rozo-Lopez and Mengual 2015). Particularly for the genus *Aedes*, there are results of its density associated to socioecological factors in urban sectors (Talbot et al. 2021). In addition, studies about incidence in the transmission of arboviruses among other VBDs have been carried out (Souza-Neto et al. 2019; Jones et al. 2020; Zerbo et al. 2020; Carrasquilla et al. 2021; Teltscher et al. 2021; Mantilla-Granados et al. 2022). Disease vectors are also being studied in several regions of the country. In the east, the dynamics of flavivirus transmission in mosquitoes has been studied (Martínez et al. 2023). In the Caribbean and northern Colombia there is a high incidence *Ae. aegypti* and reports *Ae. albopictus* (Cano-Pérez et al. 2022; Quimbayo et al. 2022; Atencia-Pineda et al. 2023). At present, this species is already present in 47% of the country, mostly in urban areas (Echeverry-Cárdenas et al. 2021).

In the department of Cauca in Colombia, the species of *Ae. aegypti*, *Ae. albopictus*, *Cx quinquefasciatus* and *Psorophora ferox* (de Humboldt, 1819) have been detected (Bedoya-Rodríguez et al. 2022; Marceló-Díaz et al. 2022). It is a region influenced by several VBD such as dengue, malaria, chikungunya, Zika and yellow fever (Secretaría de Salud 2022). Likewise, it is essential to consider the influence and variation in climatic factors and the loss of biodiversity as important conditioning factors that potentiate the generation and propagation of VBD (Attaullah et al. 2021; Williams et al. 2021). In this context, this study has great importance because it provides information on the ecology of mosquitoes in this region of great ecological and sociocultural heterogeneity. Thus, the purpose of this study was to analyze the diversity, distribution and abundance of mosquito assemblages (Diptera: Culicidae) in an urban sector of the municipality of Santander de Quilichao (Department of Cauca), located in southwestern Colombia.

Materials and methods

Study area

The municipality of Santander de Quilichao (3°00'29.7"N, 76°28'40.0"W), is located at the Department of Cauca, in the southwest of Colombia (Fig. 1). This region has a tropical deciduous woodland climate, with two seasons: rainy and dry, throughout the year (Gobernación del Cauca 2019). The municipality has an average warm temperature of 26 °C, which favors the proliferation of mosquitoes. The urban area population is near 52,684 people. The study area and the sampling points for the characterization, distribution and abundance of mosquitoes were randomly selected in the central western part of the municipality (area: 42,740 m²), which corresponds to approximately 0.5% of the city (AMSQ 2020). This area had the following conditions:

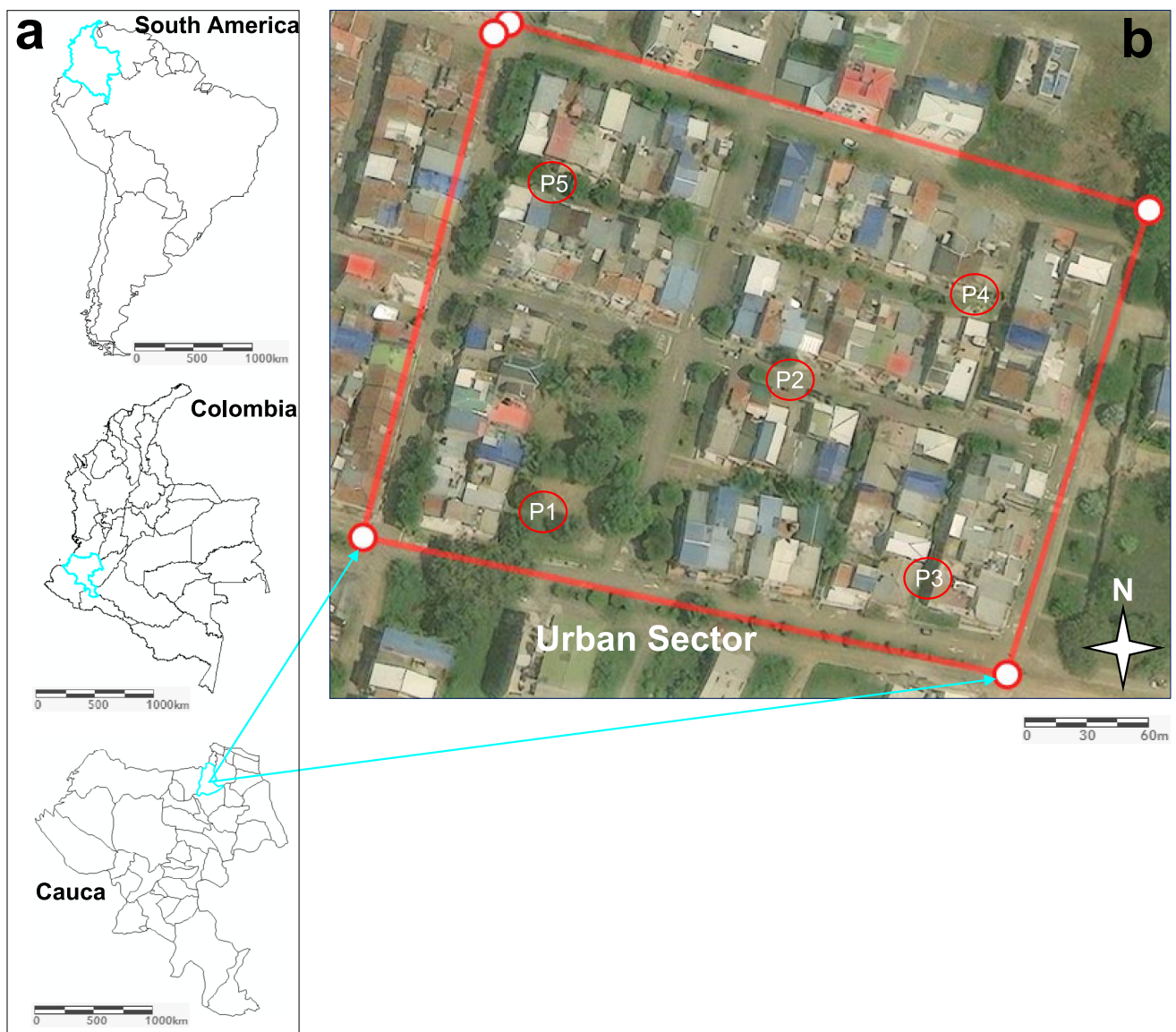


Fig. 1 **a** Location of the municipality of Santander de Quilichao in the department of Cauca, Colombia. **b** Geographical location of the study area, with the five sampling points (P1, P2, P3, P4 and P5) in the municipality of Santander de Quilichao. Generated using ArcGis

security situation, easy accessibility, reports of the presence of mosquitoes that transmit VBD and the existence of favorable habitats for their development (Chakravarty and Gupta 2023). Four nearby sampling points were selected since the mosquito's flight and dispersion capacity is normally 50 to 100 m (Sinti-Hesse et al. 2019). The point 1 (P1) is characterized by vegetation cover and a children's recreation area with the presence of houses, gardens, leafy trees, grasses and shrubs. Points 2, 3, 4 and 5 (P2, P3, P4 and P5) have homogeneous characteristics with the presence of built-up areas, gardens and some trees. Mosquito collections were carried out in four months, during part of the rainy and dry seasons (Boyer et al. 2020; Câmara et al.

2020; Bedoya-Rodríguez et al. 2022), between April—May and June—July 2022, respectively.

Mosquito capture and identification

Ae. aegypti, *Ae. albopictus*, *Cx. quinquefasciatus* were studied, since they have a greater capacity to transmit diseases in the department of Cauca (Marceló-Díaz et al. 2022), and *Ps. ferox* related to the Venezuelan equine encephalitis virus (Foster and Walker 2019). The sampling was performed weekly (Romiti et al. 2022; Delgado-Serra et al. 2021; Kumar et al. 2021) between 17:00 and 19:00 (Orlandín et al. 2021). The capture of adults was carried out with an entomological net (area: 42,740 m²) (Cunha et al. 2020; Farag

et al. 2021; Guarido et al. 2021; Mantilla-Granados et al. 2022; Mucci et al. 2022) and the larvae with a ladle and aquatic pipette (Ali et al. 2021). Adults were sacrificed by freezing (Rahman et al. 2021a) and larvae using 80% ethanol (Deblauwe et al. 2022). Morphological identification of species was conducted using taxonomic keys (Cavalcante do Nascimento et al. 2018; Foster and Walker 2019; Nava and Debboun 2020; Rueda 2020a, b, c), using a stereoscope and a Canon professional camera (Lorenz and Suesdek 2020) (Fig. 2). Furthermore, the web was consulted in order to identify mosquitoes that presented certain taxonomic challenges. The distribution of mosquitoes was mapped using ArcGIS software.

Data analysis

Since the municipal health secretary has no analysis of diversity indexes or monitoring of the mosquitoes, it is hoped that this study will provide recent inputs to continue studying the behavior of the mosquitoes. For the analysis of diversity vs. sampling points, Simpson's index was used (Ceretti-Junior et al. 2020; Guarido et al. 2021). A dendrogram, rarefaction curve (Lee et al. 2020; Bedoya-Rodríguez et al. 2022) and non-metric multidimensional scaling (nMDS) were constructed; all of these focused on the Bray–Curtis similarity, which analyzes species abundances (Juma et al. 2021;

Yeo et al. 2021) and the similarity between sampling sites. The analyses were conducted using Past statistical software version 4.05 (Mucci et al. 2022). The species abundance data were normalized and analyzed using the Kolmogorov–Smirnov test (De Melo et al. 2021). Analysis of variance (ANOVA) was applied to study the comparative effects of different mosquito species and their abundances (Câmara et al. 2020). In addition, a post hoc test was conducted using Tukey's method ($p < 0.05$), to determine if there were significant differences with respect to abundances by zones. A significance level of 5% was employed, and the data were analyzed using the statistical software IBM SPSS Statistics v25 and Minitab v19.

Results

A total of 1,116 Culicidae were collected and identified. A total of 680 specimens were captured during the rainy season, in comparison to 436 specimens captured during the dry season. The mean abundance of species was higher in the rainy season. In addition, points P1 and P4 showed the highest presence of adult mosquitoes and were the main breeding sites for larvae (Table 1). The majority of the specimens ($n = 663$) were identified as *Ae. aegypti* (59.4%), followed by *Cx. quinquefasciatus* (18.5%), *Ae. albopictus*

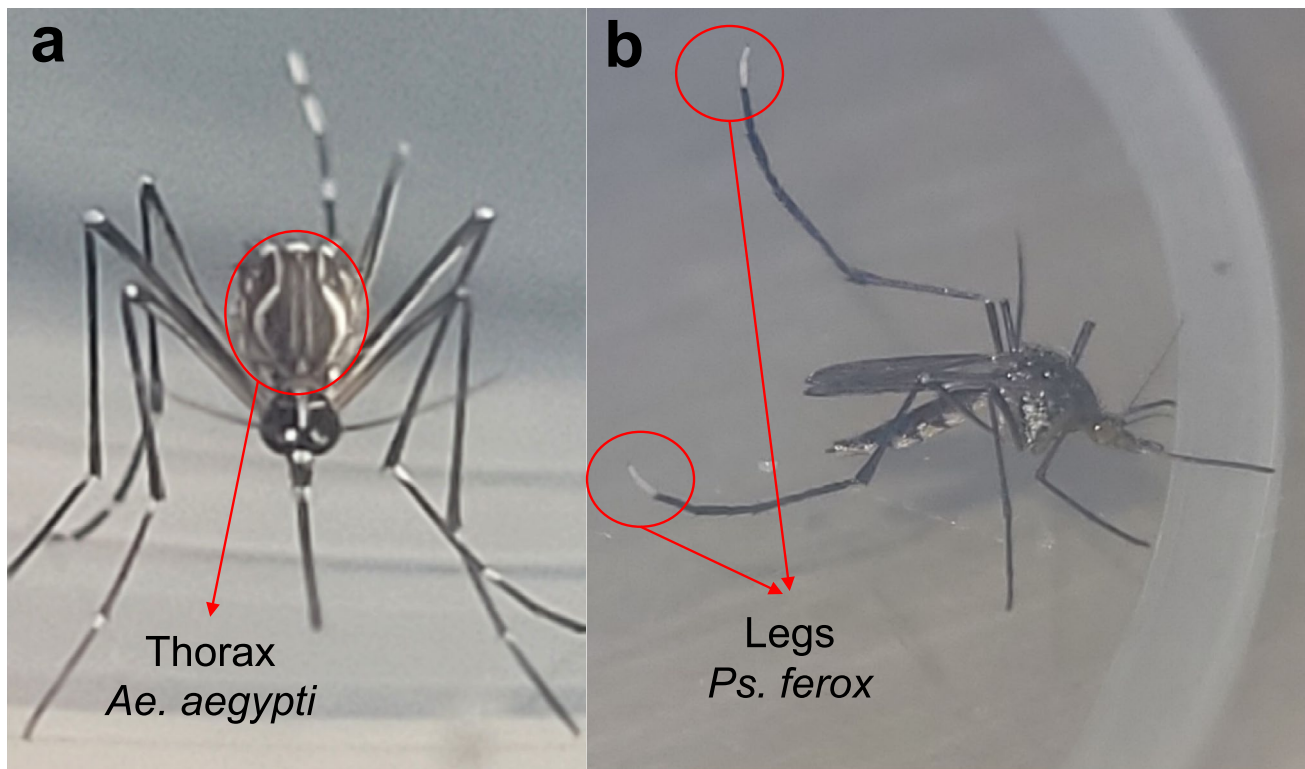


Fig. 2 a *Ae. aegypti* thorax: with silvery lyre-shaped scales, b *Ps. ferox* legs: with pale scales (Foster and Walker 2019; Rueda 2020b)

Table 1 Number of mosquito adult and larvae specimens collected at five sampling points (P1, P2, P3, P4 and P5) in the urban sector during rainy and dry seasons in Santander de Quilichao, Cauca, Colombia

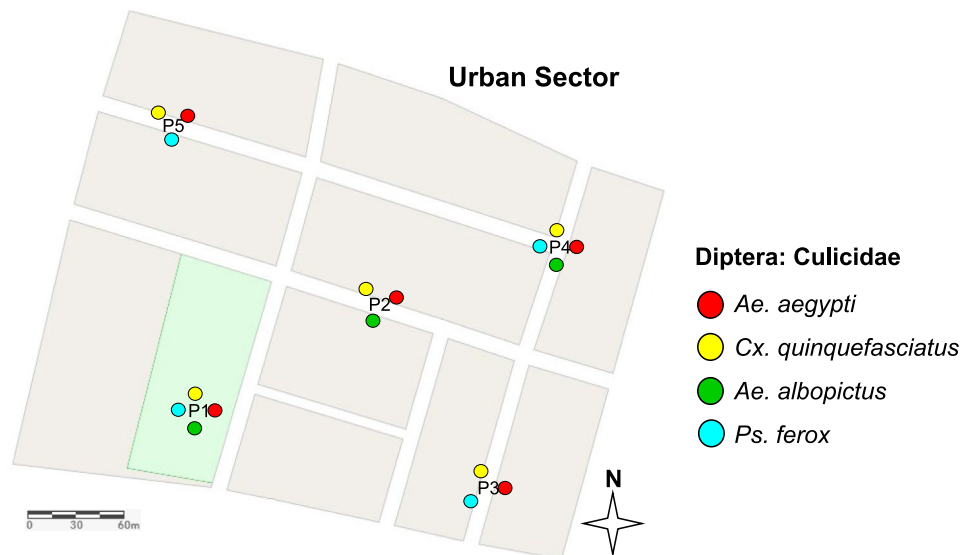
Season	Species	P1		P2		P3		P4		P5		Total	Mean
		Adults	Larvae	Adults	Larvae	Adults	Larvae	Adults	Larvae	Adults	Larvae		
Rainy	<i>Ae. aegypti</i>	47	58	34	21	36	37	57	33	41	39	403	80.6
	<i>Cx. quinquefasciatus</i>	14	6	10	3	22	4	27	11	25	3	125	25.0
	<i>Ae. albopictus</i>	29	11	12	15	0	0	39	19	0	0	125	25.0
	<i>Ps. ferox</i>	5	1	0	0	3	0	8	2	7	1	27	5.4
Dry	<i>Ae. aegypti</i>	54	25	24	9	38	7	43	13	27	20	260	52.0
	<i>Cx. quinquefasciatus</i>	21	2	9	1	8	6	14	3	16	2	82	16.4
	<i>Ae. albopictus</i>	17	9	11	2	0	0	26	13	0	0	78	15.6
	<i>Ps. ferox</i>	3	0	0	0	2	0	6	0	5	0	16	3.2
	Total	302		151		163		314		186		1116	27.9

(18.2%), and *Ps. ferox* (3.9%). The most abundant species was *Ae. aegypti* for both climatic seasons (dry and wet) in all sampling points. *Cx. quinquefasciatus* was identified at all five sampling points, exhibiting the greatest richness and abundance at points P1 and P4 (Fig. 3).

As previously stated, *Ae. aegypti* was detected at all five sampling points, P1 (60.9%, $n = 184$), P2 (58.3%, $n = 88$), P3 (72.4%, $n = 118$), P4 (46.5%, $n = 146$) y P5 (68.3%, $n = 127$). *Cx. quinquefasciatus* was captured at all points, but with lower abundances, P1 (14.2%, $n = 43$), P2 (15.2%, $n = 23$), P3 (24.5%, $n = 40$), P4 (17.5%, $n = 55$) y P5 (24.7%, $n = 46$). *Ae. albopictus* was captured in three points, P1 (21.8%, $n = 66$), P2 (26.5%, $n = 40$) y P4 (30.9%, $n = 97$). Additionally, *Ps. ferox* was identified in four locations, though in smaller quantities than the other species. The numbers were as follows: P1 (3.0%, $n = 9$), P3 (3.0%, $n = 5$), P4 (5.0%, $n = 16$), and P5 (7.0%, $n = 13$).

In P3, the dominance of *Ae. aegypti* (58.5%) over the other species is high. Consequently, the diversity analysis using Simpson's index was low (41.5%). P4 showed a significantly higher diversity according to Simpson's index of 65.5% (Fig. 4a). On the other hand, the rarefaction curve shows that the sampling points with the highest richness were located in P4 and the lowest in P3 (Fig. 4b). The dendrogram showed a higher similarity between points P3 and P5 with 93%, followed by P1 and P4 with 63% (Fig. 4c). The nMDS showed that P3 and P5 had a high degree of similarity in both climatic seasons. Similarly, P1 and P4 showed a strong correlation during the rainy season, whereas P1 and P2 showed a lack of similarity during the dry season, with no points clustering together. The abundance of mosquitoes in the dry season was found to be similar at P2 and P4, and thus these points were determined to be in close proximity according to the dendrogram analysis (Fig. 4d).

Fig. 3 Map of the urban sector in Santander de Quilichao, Cauca, showing the distribution of Culicidae found in the study points



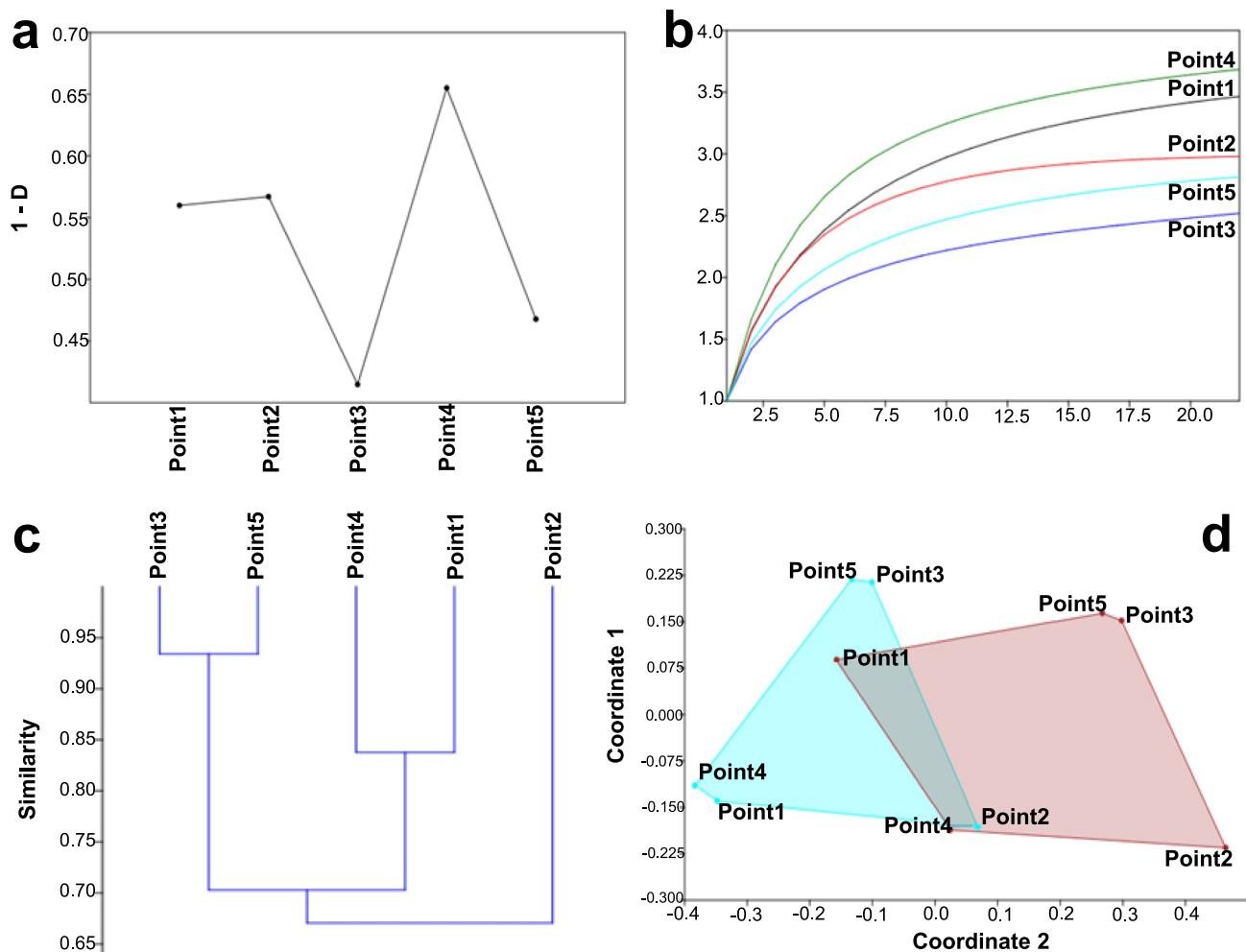


Fig. 4 Multivariate analysis between sampling points vs. abundances. **a** Simpson's index, **b** rarefaction curve, **c** dendrogram and **d** nMDS. Blue and brown color for rainy and dry season, respectively

Table 2 ANOVA analysis ($p < 0.05$) comparing the abundance of mosquito species collected during two season (dry and rainy) in five different sampling points in an urban sector of Santander de Quilichao, Cauca, Colombia

Source of variation	Degrees of freedom (df)	Sum of squares (SS)	Quadratic mean (QM)	Statistic F	Significance p -value
Species	7	23874	3410.6	16.00	0.000
Error	32	6822	213.2		
Total	39	30696			

The mean abundance of all mosquito species showed significant differences between species (Table 2). Tukey's method groups species and if they do not share a letter (A, B and C) they are significantly different. For example, *Ae. aegypti* in the wet season do not share the same grouping as the other species and are therefore significantly different.

However, the wet and dry season *Ae. aegypti* groups share the letter A, which shows no significant differences between them. Similarly, group B, formed by *Ae. aegypti* in the dry season, *Cx. quinquefasciatus* and *Ae. albopictus* in the wet season, showed no significant differences. The data for the species included in group C indicate that there are no significant differences in abundance (Table 3).

Discussion

This is a pioneering study carried out in the south-western region of Colombia, specifically in the department of Cauca. The study revealed the presence of four species of mosquitoes (Culicidae) in the specific urban area of Santander de Quilichao. These results can be replicated in other areas of the municipality. This sector was chosen because of its favorable security situation, accessibility and reports from

Table 3 Clustering of mosquito species abundances in rainy and dry season, in the five sampling points (N), in using Tukey's method and a confidence of 95%

Species	N	Mean	Grouping
<i>Ae. aegypti</i> (Rainy season)	5	80.60	A
<i>Ae. aegypti</i> (Dry season)	5	52.00	A B
<i>Cx. quinquefasciatus</i> (Rainy season)	5	25.00	B C
<i>Ae. albopictus</i> (Rainy season)	5	25.0	B C
<i>Cx. quinquefasciatus</i> (Dry season)	5	16.40	C
<i>Ae. albopictus</i> (Dry season)	5	15.60	C
<i>Ps. ferox</i> (Rainy season)	5	5.40	C
<i>Ps. ferox</i> (Dry season)	5	3.20	C

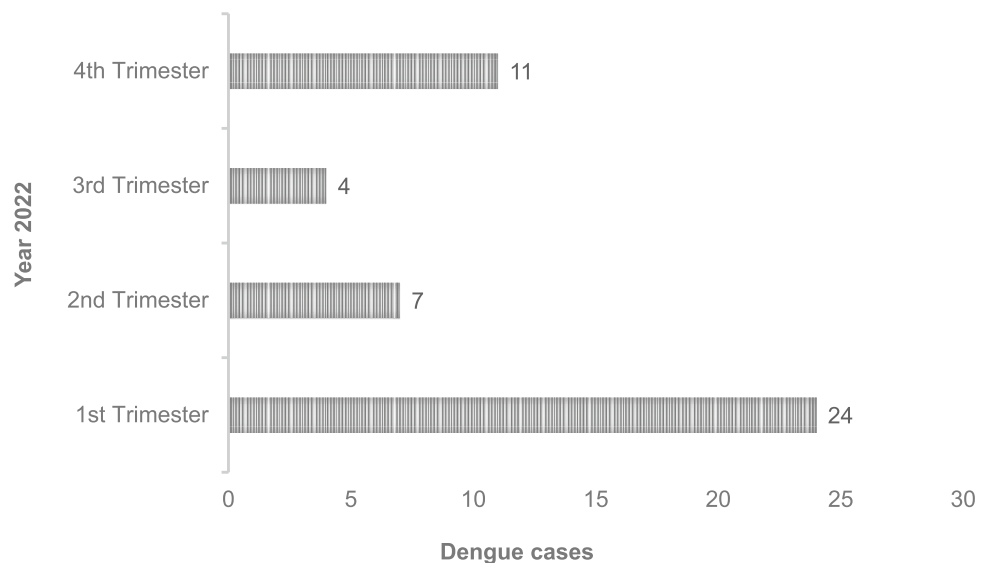
the local community on the presence of mosquitoes transmitting VBD. In addition, the area provides suitable habitats for their development. The results showed a robust correlation between the two seasons studied and the ecological distribution patterns of the different mosquito populations studied. Mosquitoes do not have a wide range of distribution from birth to death; they move only a few meters and do not cover a large enough area. Accordingly, the focus of efforts should be on the distribution of these neighborhoods (Sinti-Hesse et al. 2019). Therefore, the results of this study are in line with those of other research projects that have confirmed the high abundance of Culicidae during the rainy season (Bedoya-Rodríguez et al. 2022; De Melo et al. 2021; Omar et al. 2021; Maquart et al. 2021).

The reproduction of this insect depends on water. Similarly, the tropical dry forest climate is conducive to the proliferation of mosquitoes due to its relatively stable annual thermal conditions. It is clear that elevated temperatures are advantageous for these organisms, which lack physiological

thermoregulation mechanisms. These ecophysiological conditions contribute to the prevalence of VBDs in tropical latitudes (Verhulst et al. 2020; De Melo et al. 2021). For example, the epidemiological presence of dengue fever in the department of Cauca has led to the implementation of measures to ensure the safety of the population. This disease is the second most common after malaria (INS 2023). In particular, statistical data from the department show the impact of VBD in the municipality of Santander de Quilichao, which is consistent with the results of this ecological study. It is noteworthy that the number of dengue cases in the second trimester exceeded those in the third trimester of 2022 (Fig. 5). This observation coincides with the greater abundance of mosquitoes collected during the rainy season compared to the dry season. Furthermore, the Culicidae family, particularly the *Aedes* species, have been identified as vectors directly associated with dengue. Their role in the transmission of the disease has been studied in different urban areas of Colombia (Carrasquilla et al. 2021; Talbot et al. 2021).

The study reported the presence of two *Aedes* species with the potential to transmit VBD. A review of epidemiological data provided by the Secretaria de Salud (2022) showed that 130,400 cases of VBD were reported between 2015 and 2019. Malaria accounted for 69% of cases, dengue 16.9% and other VBDs 14.1%. During the first three months of 2022, Santander de Quilichao had the highest incidence of VBD, with 24 cases of dengue reported. The incidence rate of severe dengue fever represents a significant risk to the population of this municipality (Secretaria de Salud 2022). The cases reported in the second trimester (7 cases), third trimester (4 cases), and fourth trimester (11 cases) of that year demonstrated the importance of conducting studies

Fig. 5 Dengue cases presented by trimester in Santander de Quilichao, Cauca, Colombia during 2022. Based on data from the INS (2022)



on the ecology and abundance of mosquitoes (INS 2022) (Fig. 5).

It is well documented that both natural and man-made habitats are conducive to the development of mosquitoes. The present study, carried out in an urban environment with a considerable amount of green space and minimal development, is considered to be an important factor contributing to the prevalence of Culicidae. Indeed, these factors may contribute to the formation of stagnant water bodies without natural predators. Conversely, the presence of humans and inadequate management practices to prevent the proliferation of mosquitoes facilitate their development and provide a relatively high resource for their hematophagous activity, which is essential for the acquisition of areas for their reproduction (Foster and Walker 2019). The results of this study show that *Ae. aegypti* is the species with the highest richness in urban sectors, a conclusion that is consistent with the results of previous studies by Câmara et al. (2020), Juma et al. (2021) and Rahman et al. (2021b). The results were confirmed by multivariate analyses, including nMDS, ANOVA and rarefaction curves, which showed significant correlations between mosquito abundance and sampling locations. This finding is consistent with results from studies conducted in other countries. These studies have confirmed that *Ae. aegypti* has developed a high level of adaptive capacity, which has had a significant impact on its evolution in urban environments. As a result, this species has been able to establish and colonize a wide range of biomes, competing with other Culicidae species (Juma et al. 2021; Deblauwe et al. 2022).

Notably, mosquitoes have historically been considered as the first arthropod associated with the intermediate host of parasites (Foster and Walker 2019). In particular, the *Ae. aegypti* species is of African origin and has spread globally in the tropics through commercial and human transport (Bennett et al. 2016; Campos et al. 2020). In this study, *Ae. aegypti* and *Cx. quinquefasciatus* were the most abundant species at the five sampling sites, demonstrating their remarkable adaptive capacity at the reproductive level. These species show a preference for artificial habitats such as discarded tires and natural habitats in the case of tree holes (Juma et al. 2021; Deblauwe et al. 2022). The research conducted by Farag et al. (2021) in Qatar is consistent with the results of our study. The habitats in which *Cx. quinquefasciatus* can develop were comparable to those sampled in the present study. However, in the case of *Ae. aegypti*, the researchers found that desert climatic conditions influence the presence of this species in urban areas. The risk of disease transmission by this vector is therefore low. This evidence suggests that tropical and subtropical climates are conducive to the reproduction of *Aedes*, whereas in desert climates it is virtually absent. Conversely, *Aedes* is a mosquito with a high capacity for disease transmission, as

evidenced by numerous studies of VBD worldwide (Silva et al. 2020; Semenza and Paz 2021). Similarly, Colombia has experienced outbreaks of dengue fever with high mortality rates, as shown by research by Gutierrez-Barbosa et al. (2020).

The third most abundant culicid in this study was *Ae. albopictus*, which together with *Ae. aegypti* are the most important vectors of VBDs of public health concern, including dengue, Zika, chikungunya and yellow fever (Câmara et al. 2020; Lowe et al. 2021; Shin and Jung 2021; WHO 2020). It is therefore imperative that these vectors are controlled in the region. Muñoz et al. (2021) showed a correlation between the El Niño phenomenon and an increase in dengue cases. A variety of strategies have been developed to intervene and control disease vectors. One effective vector control strategy is the use of *Wolbachia* bacteria. Infection of *Aedes* with these bacteria reduces its ability to transmit disease, as the bacteria inhibit the reproduction of the virus (Lee et al. 2020; Nirmani et al. 2021). In addition, the use of insecticides should be avoided. Consistent and widespread use of insecticides has led to the development of resistance in certain *Ae. aegypti* populations, resulting in evolutionary resistance to insecticides. It is therefore essential to develop alternative vector control strategies (Boyer et al. 2022). However, such interventions have not yet been implemented in the municipality of Santander de Quilichao.

Conversely, the results of the research indicate that the sampled points 1 and 4 have comparable diversity and abundance of mosquitoes, as well as similar physical characteristics. Site 1 is characterized by the presence of a recreational area with vegetation, whereas Site 4 is an inbuilt sector with an abundance of vegetation. This type of space provides a wide variety of locations that are conducive to the development of mosquitoes (Hernandez-Colina et al. 2021). While the influence of the landscape is undoubtedly a significant factor in the presence of mosquitoes, it is important to consider the impact of climatic variables such as rainfall, temperature and humidity. These factors, taken together, influence the impact of mosquitoes in the regions (Francisco et al. 2021). In this regard, the rainy season has an influence on the abundance of mosquitoes, which is reflected in the increase of optimal places, both natural and artificial, for their development (Maquart et al. 2021). The influence of the dry season (from June to August) in the department of Cauca was characterized by a relatively low level of rainfall (Gobernación del Cauca 2019), which appeared to favor the presence of the species under study. Such variations are thought to be related to the Niña phenomenon (Muñoz et al. 2021). It is evident that rainfall occurred in July 2022, which contributed to the presence of mosquitoes (IDEAM 2022).

On the other hand, the least common species was *Ps. ferox*. This suggests that the species may be lacking optimal environments and habitats conducive to reproduction.

However, it is important to note that their diet is not only dependent on mammals, but also on birds (Ramalho-Ortigao and Gubler 2020), which are a common feature of the study area. It could be argued that the species in question are more abundant in environments where human presence is not a significant factor. However, in the context of our study, this species showed a higher abundance during the rainy season. This finding is consistent with the observations of Orlandin et al. (2021), who also reported positive sampling of the species in environments with high rainfall. The species was also present during the dry season, albeit in low numbers. This finding supports the hypothesis that the species may have the ability to withstand climatic transitions (Ceretti-Junior et al. 2020).

The phenomenon of climate change, coupled with the biodiversity crisis that has led to the disappearance of certain species and ecosystems, and exacerbated by human activities, has been shown to facilitate the spread of VBDs (Williams et al. 2021). These impacts reflect an increase in the number of species that transmit infectious diseases, which in turn necessitates the implementation of more effective vector control measures in both urban and rural settings. This work provides an important basis for the initiation of entomological studies in the Cauca region. The results of this study will help the health sector to improve preventive vector control practices, thereby reducing the risk to the community through a better understanding of the ecology of these species.

In conclusion, our work provides pertinent information on the diversity of Culicidae mosquitoes, which are of significant public health interest. It is of great importance that future studies take into account factors such as socio-demographic characteristics of the population, vector capacity, genetic diversity and how they influence the abundance of mosquitoes. Likewise, it is also imperative to conduct studies that examine community knowledge, attitudes and practices regarding mosquitoes and VBDs. It is therefore crucial to encourage the general public to participate in vector control education initiatives in the home environment.

Abbreviations VBD: Vector-borne diseases; *nMDS*: non-metric multidimensional scaling

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Authors' contributions FJBR designed and conceptualized the study. FJBR collected data. FJBR analyzed the data and wrote the manuscript. CEGF and JSRP reviewed the content of the manuscript, made comments and observations. FJBR incorporated comments and edits of co-authors. The authors have read and approved the manuscript.

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Declarations

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