



# Diversity of endophilic mosquitoes in three local government areas of Kano State, Northwest Nigeria

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## Abstract

Nigeria hosts a high diversity of mosquito species, with over 100 recorded, primarily from genera like *Anopheles*, *Culex*, *Aedes* and *Mansonia*. Kano State urban-rural mix supports diverse mosquito habitats such as stagnant water, irrigation canals, urban puddles and open drainages. This study assesses the diversity of endophilic mosquito species in some rural, semi-urban and urban areas of Kano State, including Babban Gura in Makoda Local Government Area (LGA), Unguwar Fulani in Wudil LGA, and Darmanawa in Tarauni LGA respectively. Mosquitoes were collected using the Pyrethrum spray collection method once in a month from each site over twelve-month period, from August 2023 to July 2024. The collected mosquitoes were identified morphologically using reported taxonomic guides. Density, species richness, Shannon's index, and Simpson's index were employed to evaluate the diversity of the identified mosquitoes. A total of 2,521 mosquitoes were collected, representing 21 species across 6 genera. The highest number of mosquito species was collected from Darmanawa, followed by Unguwar Fulani. *Culex pipiens* was a frequently species while *Culex quinquefasciatus* and *Anopheles gambiae* were common species. Endophilic mosquitoes exhibited greater diversity in May, June, and January particularly in Babban Gura during the dry season. However, highest species richness was recorded in January while no species richness was recorded in September, November and June. The high diversity indices of Shannon and Simpson recorded in the study pointed out that most of the species were represented and randomly sampled.

**Keywords:** Diversity, endophilic, Kano, mosquitoes, species,

## Introduction

Endophilic mosquitoes diversity, epidemiologically amplifies their public health impact, with over 700 million people affected annually by mosquito-borne diseases. The proximity of endophilic mosquitoes to humans increases the risk of disease transmission, as they are often more likely to bite humans compared to exophilic species, which rest outdoors<sup>1</sup>. Alterations in biology, population or geographic range of disease vectors can lead the emergence and spread of new diseases in rural, semi-rural and urban areas<sup>2</sup>.

Mosquitoes displayed fluctuation in size annually, as such they are extremely temporal dynamics<sup>3,4</sup>. Seasonality is among the factors that influenced the behaviour, abundance, spatio-temporal distribution and population dynamics of mosquito species<sup>5</sup>. Investigating mosquito population dynamics portray a task for ecologist because seasonal process which is controlled by climate is difficult to predict and understand and can create intricate population variation in mosquitoes<sup>6,7</sup>. The key factors of population dynamic include temperature, rainfall, humidity and land use these factors separately in mixture with anthropogenic activities decide the dynamics of local mosquito population. While these drivers are intricate, they may be of greater or lesser significance subject on the location<sup>8,9</sup>. Mosquito population drops in the dry season owing to high temperatures

and lack of breeding places. In Nigeria, wet and dry season alternating with each other, are the two seasons in a year, each with different features of meteorological weather parameters<sup>10</sup>.

Various *An.* spp. can adjust to the change in climatic conditions, dry or cold habitually by entering diapause<sup>11,12</sup>. The diapause of mosquitoes and proposed the re-invasion of mosquitoes may occur from elsewhere<sup>13</sup>. *Anopheles coluzzii* showed evidence of dormancy and the review of mosquito dormancy and diapause maintained that eleven species of *Anopheles* demonstrated diapause<sup>12</sup>.

In environment, it is not well-defined where anophelines rest throughout hot and dry states, it appears that a few can survive between leaves of trees and shrubs<sup>14</sup>. In Nigeria, some studies on mosquito reported only some of these indices, such as Irikannu *et al.*<sup>15</sup> in their study from a rainforest community of southeast Nigeria reported *Culex quinquefasciatus* with highest Shannon-Wiener diversity index (0.17), and Simpson's dominance index (0.495).

However, the diverse range of ecosystems in Nigeria supports a wide range of mosquito species, many of which are important disease vectors. Varied landscapes in Nigeria, from tropical rainforests to savannahs, provide a rich habitat for numerous mosquito species.

The house structure along with the geographical location of house might influenced the indoor microclimate<sup>16</sup>. Room temperature in iron-roofed houses was significantly higher than that in thatched-roofed houses and the resting place preferred by mosquito might be affected by indoor gradient of temperature caused by solar radiation in iron roofed houses<sup>17</sup>.

Understanding the diversity and distribution of endophilic mosquitoes in Nigeria is essential for developing effective vector control strategies and mitigating the burden of mosquito-borne diseases. To predict mosquito densities and develop operational tools for surveillance and control of mosquito-borne diseases, there is the need to understand the relationships between environmental conditions and mosquitoes' population dynamics and despite this growing concerns, there are limited studies that examined the diversity of endophilic species in Kano State. This study aims to bridge this gap by assessing the diversity of endophilic mosquitoes across urban, semi-urban and rural settings in Kano State.

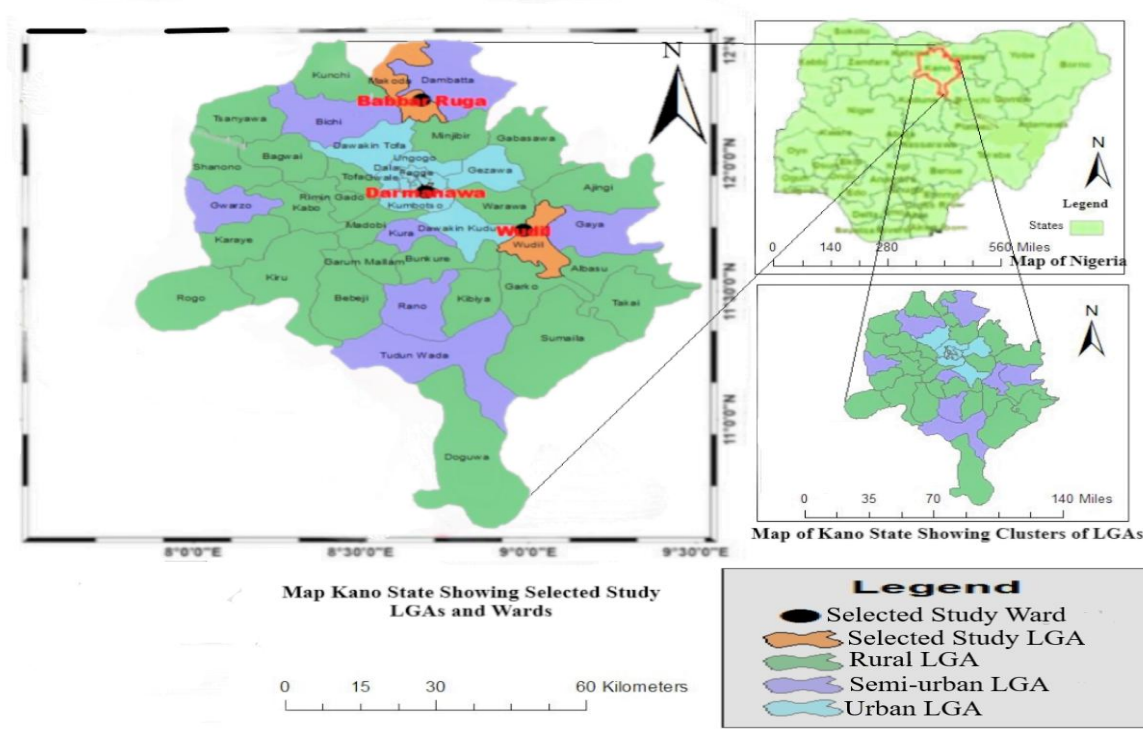
### Materials and Methods

**Study Area:** Kano State is located between latitude 10°3' N and 12°4' N of the equator and between longitude 7°4' E and 9° 3' E of the prime meridian<sup>18</sup>. It covers a land area of 20,760 km<sup>2</sup> <sup>19</sup> and shares boundaries with Katsina State to the northwest, Kaduna State to the southwest, Jigawa State to the northeast, and Bauchi State to the southeast<sup>18</sup>. The state is part of the Sudano-Sahelian zone of Nigeria<sup>20</sup> and is situated in northwestern Nigeria (Figure-1).

The vegetation in Kano primarily consists of Northern Guinea Savanna in the southern region, characterized by rich biodiversity, and Sudan Savanna in the remaining areas, which features sparse tree distribution, grasses, and shrubs<sup>20</sup>.

Kano has a tropical and dry climate<sup>20</sup>, with temperatures ranging from 15.8°C to 33°C, dropping as low as 10°C during the harmattan period. The state experiences two distinct seasonal periods: a wet season lasting five months (from May to September) and a dry season lasting seven months (from October to April). Average rainfall ranges from 63.3 mm ± 48.2 mm in May to 133.4 mm ± 59 mm in August<sup>21</sup>.

**Sampling Method:** A Multi-stage sampling techniques involving sampling frame and purposive sampling methods were employed for the selection of the study sites. The map of Kano State and the stratification 44 Local Government Areas (LGAs) into urban, semi-urban, and rural categories by the Kano State Gazette<sup>23</sup> served as the sampling frame. In each of the three strata, one LGA was chosen as the primary sampling unit (PSU). These LGAs were purposefully selected based on the presence of larger mosquito breeding sites. The selected LGAs included Tarauni (urban), which has an extensive drainage; Wudil (semi-urban), with presence of Wudil River; and Makoda (rural), which is adjacent to Tomas Dam. Within each Local Government Area, a ward was purposefully selected based on its proximity to the larger breeding site, and within each ward, a settlement was also purposefully chosen based on its closeness to the breeding site for the collection of resting adult mosquitoes (Table-1).



**Figure-1:** Map of Kano State showing the Selected Local Government Areas and Wards<sup>20,22</sup>.

**Table-1:** Description of Study Sites for the Collection of Adult Resting Mosquito Species<sup>24,25</sup>.

Local Government Area	Area (Km <sup>2</sup> )	Latitude (°N)	Longitude (°E)	Cluster	Ward	Sampling Area (Settlement)
Tarauni	28	11.95862	8.54429	Urban	Darmanawa	Darmanawa (behind Hassan Gwarzo Secondary School)
Wudil	362	11.72959	8.81859	Semi-urban	Wudil	Unguwar Fulani (behind ADUSTECH)
Makoda	441	12.419	8.233	Rural	Babban Ruga	Babban Gura (behind Audu Bako College of Agriculture)

**Study Design:** A quantitative research design (longitudinally survey design) was employed for the collection and identification of endophilic mosquitoes. Mosquitoes were collected once monthly from a selected ward that remained unchanged from August 2023 to July 2024, while the households sampled varied each month.

**Endophilic Mosquito Sample Collections:** Endophilic mosquitoes were collected in the morning from 8:00 AM to 10:00 AM using the pyrethrum spray collection (PSC) method. Collections were conducted using Gongoni Triple Action aerosol (Imiprothrin: 0.10%, Transfluthrin: 0.25%, and Permethrin: 0.50%; Gongoni Company Ltd.), along with a torch, Petri dishes, a white cloth sheet (336 cm x 244 cm), soft liner brush, labels, and containers for transporting samples<sup>26</sup>. The procedures outlined by Harbison *et al.*<sup>27</sup> was followed.

Two hundred (200) households were numbered in each settlement, and ten (10) households were randomly selected during each collection. In each household, a single room was selected, and residents were instructed to clear out any food and drinking items from that space. The area of the room was covered wall to wall with the white cloth sheet to prevent the loss of mosquitoes, and the windows and doors were closed. The collector applied Gongoni aerosol to the room until it was filled in insecticide mist, then exited the room. After ten minutes, the door was reopened, for collection of knockdown mosquitoes. The white cloth sheet was carefully removed by lifting the four corners and gently moving it to ensure that the mosquitoes were collected in the center of the sheet. The mosquitoes were then collected with soft liner brush and placed into labeled Petri dishes containing silica gel, before being transported to the laboratory for sorting, morphological identification, and storage.

**Morphological Identification of Mosquitoes:** In the laboratory of Biology Department, Aliko Dangote University of Science and Technology Wudil-Nigeria, the collected samples of endophilic mosquito were mounted on an *ELIKLIV* digital LCD microscope (Model: DM4) and identified morphologically to the species level using taxonomic keys reported by Becker *et al.*<sup>28</sup>, Ramberg<sup>29</sup>, Pecor<sup>30</sup>, Coetzee<sup>31</sup>, and WHO<sup>32</sup>. The frequency data of the identified species were recorded.

**Determination of Endophilic Mosquitoes Diversity:** The density structure of mosquito species, the density formula

described by Dziêczkowski<sup>33</sup> and Banaszak and Winiewski<sup>34</sup> was utilized, which expresses density as the percentage of each species in the total sample<sup>35</sup>:

$$\text{Density (D)} = \frac{I}{L}$$

Where: D is the density, I is the number of specimens of mosquito species and L is the number of all specimens.

The frequency of endophilic mosquito species was used to evaluate species richness, Shannon's index and Simpson's index.

**Data Analyses:** The structure of endophilic mosquito species densities was classified based on the calculated values of the density into categories established by Adler *et al.*<sup>36</sup>: Absent (D = 0), Sporadic species (D = 0 < 1%), Rare species (D = 1 < 5%), Regular species (D = 5 < 10%), Common species (D = 10 < 30%), Frequent species (D = 30 < 60%), and Dominant species (D = 60–100%).

Additionally, the diversity of endophilic mosquito species was analyzed using the estimates of species richness (diversity of order 0), Shannon's index (diversity of order 1), and Simpson's index (diversity of order 2). These estimations were done using Species Prediction and Diversity Estimation (SPADE) software (2009).

**Ethical Approval and Informed Consent:** The study was ethically approved by the Kano State Ministry of Health Research Ethics Committee, with the assigned approval number NHREC/17/03/2018, dated March 2, 2022. Informed consent from the head of each household was obtained by having them complete a designated consent form prior to the commencement of mosquito collection. Households were also given the opportunity to withdraw from the research at any time they wished.

## Results and Discussion

A total of 2,521 mosquitoes were collected, of which 751 (29.8%) were from the Babban Gura site, 938 (37.2%) from the Darmanawa site, and 832 (33.0%) from the Unguwar Fulani site. The highest number of mosquito collections occurred in

August, with 391 (15.1%), followed by October with 311 (12.3%) and November with 265 (10.5%). Conversely, the lowest collection was recorded in May, with only 83 (3.3%) mosquitoes (Table-3).

Table-4 shows the morphologically identified twenty-one (21) species of endophilic mosquitoes across six (6) genera. The diversity structure of mosquito species based on the density criteria observed that none of the mosquito species identified falls into the dominant class of the categorization. *Culex pipiens* was frequent species (D=31.3%), while *Culex quinquefasciatus* (D=29.9%) and *Anopheles gambiae* (D=18.0%) were common species. Conversely, *Culex torrentium* were regular species (D = 9.8%). *Culex theileri* (D = 3.4%) and *Culex erythro thorax* (D=2.9%) were rare species. The remaining mosquito species were sporadic species (D=0 < 1%).

Mosquito species diversity was highest in May (H = 7.2±0.4; D = 5.2±0.3), followed by June (H = 6.9±0.8; D = 5.1±0.3) and January (H = 6.8±.5; D = 5.1±0.3). The highest species richness was observed in January (SR = 16.6±7.2) and July (SR = 13.0±1.9), while October (SR = 12.5±7.2) and May (SR = 12.5±2.3) exhibited similar levels of species richness.

Conversely, the lowest diversity of mosquitoes was recorded in December (H = 2.2±0.1; D = 1.8±0.5). September, November, and June had zero species richness. The highest heterogeneity estimate was found in December (CV = 1.32), followed by October (CV = 1.25) and July (CV = 1.22), while the lowest heterogeneity was observed in September (CV =0.28) (Table-5).

Table-6 shows that the endophilic mosquito diversity was marginally high in Unguwar Fulani (H = 5.0±0.2; D = 3.7±0.4) compared to Darmanwa (H = 4.9±0.2; D = 3.6±0.4) and Babban Gura (H = 4.8±0.2; D = 3.2±0.4). Species richness was highest at Babban Gura (SR = 21±1.8), which also exhibited the highest heterogeneity measures (CV = 2.28).

Also, during seasons endophilic mosquito species diversity was marginally high in the dry season (H = 5.8±0.2; D = 4.0±0.3) than wet season (H = 4.8±0.1; D = 3.8±0.4). Additionally, species richness was similar in both the dry (SR = 20.5±0.1) and wet (SR = 20.5±0.7) seasons.

The degree of heterogeneity was slightly higher in the dry season (CV = 1.99) compared to the wet season (CV = 1.81) (Table-6).

**Table-3:** Frequency and Percentage of Endophilic Mosquitoes Collected from Selected LGAs in Kano State.

Month	Babbangura Number (%)	Darmanawa Number (%)	Unguwar fulani Number (%)	Total (%)
August	152 (6.0)	57 (2.3)	182 (7.2)	391 (15.5)
September	124 (4.9)	68 (2.7)	49 (1.9)	241 (9.6)
October	129 (5.1)	111 (4.4)	71 (2.8)	311 (12.3)
November	87 (3.5)	153 (6.1)	25 (1.0)	265 (10.5)
December	20 (0.8)	123 (4.9)	76 (3.0)	219 (8.7)
January	19 (0.8)	145 (5.8)	41 (1.6)	205 (8.1)
February	14 (0.6)	95 (3.8)	68 (2.7)	177 (7.0)
March	39 (1.5)	69 (2.7)	43 (1.7)	151 (6.0)
April	25 (1.0)	19 (0.8)	54 (2.1)	98 (3.9)
May	25 (1.0)	27 (1.1)	31 (1.2)	83 (3.3)
June	46 (1.8)	18 (0.7)	64 (2.5)	128 (5.1)
July	71 (2.8)	53 (2.1)	128 (4.2)	252 (10.0)
Total	751 (29.8)	938 (37.2)	832 (33.0)	2521 (100)

**Table-4:** Endophilic Mosquito Species Structure Based on their Density from Selected LGAs in Kano State.

Mosquito Species	Number of Species	Density (%)	Status
<i>Aedes atropalpus</i>	7	0.3	Sporadic
<i>Aedes geniculatus</i>	2	0.1	Sporadic
<i>Aedes vexans</i>	2	0.1	Sporadic
<i>Anopheles funestus</i>	10	0.4	Sporadic
<i>Anopheles annularis</i>	7	0.3	Sporadic
<i>Anopheles barberellus</i>	9	0.4	Sporadic
<i>Anopheles domicolus</i>	12	0.5	Sporadic
<i>Anopheles gambiae</i>	446	18.0	Common
<i>Anopheles nigerrimus</i>	5	0.2	Sporadic
<i>Anopheles plumbeus</i>	9	0.4	Sporadic
<i>Culex erythro thorax</i>	72	2.9	Rare
<i>Culex pipiens</i>	788	31.3	Frequent
<i>Culex quinquefasciatus</i>	754	29.9	Common
<i>Culex tarsalis</i>	1	0.04	Sporadic
<i>Culex theileri</i>	98	3.4	Rare
<i>Culex torrentium</i>	247	9.8	Regular
<i>Culex tritaeniorhynchus</i>	12	0.5	Sporadic
<i>Culex Bivittatus</i>	13	0.5	Sporadic
<i>Culiseta inornata</i>	19	0.8	Sporadic
<i>Mansonia uniformis</i>	2	0.1	Sporadic
<i>Psorophora ciliata</i>	6	0.2	Sporadic
Total	2521	100	

**Table-5:** Diversity Indices of Endophilic Mosquito Species according to Months from Selected LGAs in Kano State.

Month	Number of Individual	Number of Observed Species	Estimated Coefficient of Variation	Species Richness (Choa1) ± Standard Error	Shannon Index = H (Choa1 & Shen) ± Standard Error	Simpson Index = D ± Standard Error
August	391	5	0.87	5.5±1.3	3.1±0.1	2.9±0.4
September	241	3	0.28	0	2.9±0.1	2.8±1.2
October	311	8	1.25	12.5±7.2	3.7±0.2	3.1±0.5
November	265	4	0.92	0	2.4±0.1	2.2±0.4
December	219	5	1.32	5.0±0.0	2.2±0.1	1.8±0.5
January	205	12	1.16	16.6±7.2	6.8±0.5	5.1±0.3
February	177	7	1.14	7.5±1.3	3.8±0.2	3.0±0.4
March	151	9	0.82	9.0±0.0	6.2±0.4	5.2±0.2
April	98	11	1.16	6.6±0.7	6.0±0.6	4.7±0.3
May	83	11	1.04	12.5±2.3	7.2±0.7	5.2±0.3
June	128	12	1.18	0	6.9±0.8	5.1±0.3
July	252	12	1.22	13.0±1.9	6.1±0.4	4.8±0.3

**Table-6:** Diversity Indices of Endophilic Mosquito Species within Sites.

Variables	Number of Individual	Number of Observed Species	Estimated Coefficient of Variation	Species Richness (Choa1) ± Standard Error	Shannon Index = H (Choa1 & Shen)± Standard Error	Simpson Index = D ± Standard Error
Sites						
Babban Gura	751	20	2.28	21.1±1.8	4.8±0.2	3.2±0.4
Darmanawa	938	13	1.62	17.5±7.2	4.9±0.2	3.6±0.4
Unguwar- Fulani	832	16	1.82	18.3±3.4	5.0±0.2	3.7±0.4
Season						
Dry	1426	20	1.99	20.5±1.0	5.8±0.2	4.0±0.3
Wet	1095	16	1.81	20.5±7.2	4.8±0.1	3.8±0.4

**Discussion:** The most notable finding of this study is that, it is the first to report the identification of *Culex tarsalis*, *Culex erythro thorax*, *Culex tritaeniorhynchus*, *Culex torrentium*, *Anopheles nigerrimus*, *Anopheles plumbeus*, *Anopheles barberellus*, *Anopheles domicolus*, *Anopheles annularis*, *Aedes vexans*, *Aedes atropalpus*, and *Aedesg eniculatus* at both morphological and molecular levels from Kano State.

Other mosquito species identified in the current study include *Anopheles funestus*, *Anopheles gambiae*, *Culexunivittatus*, *Culiseta inornata*, *Culexpapiens*, *Culex quinquefasciatus*, *Mansonia uniformis*, *Psorophora ciliata*, and *Culextheileri*. These findings are consistent with those of Oguoma and Ikpeze (2008)<sup>37</sup>, who also reported the identification of the *Anopheles gambiae* complex, *Anopheles funestus* complex, *Culex quinquefasciatus*, *Culex pipiens pipiens*, *Culex pipiens fatigans*, *Mansonia* spp., and *Psorophora* spp. among the mosquitoes they collected in various parts of Kano State. Also Yayock *et al.*<sup>38</sup> who reported the identifications of *Culex quinquefasciatus*, *Culex tritaeniorhynchus*, *Culex univittatus*, *Culex pipiens* and *Anopheles gambiae* in Kaduna Metropolis, Nigeria.

The study revealed that *Culex pipiens* was frequent species while *Culex quinquefasciatus* and *Anopheles gambiae* were common species. Also, *Culex torrentium* was regular species, *Culex erythrothorax* and *Culex theileri* were rare species and the remaining 15 identified endophilic mosquitoes were sporadic species. In a study from Pakistan by Attaullah *et al.*<sup>39</sup> they reported *Culex quinquefasciatus* and *Culex tritaeniorhynchus* as dominant species while *Anopheles annularis* as satellite species. None of the endophilic mosquito species fell into the dominant category, this shows that the mosquito coexist in a relatively balanced and more diverse background.

The temporal diversity assessment of endophilic mosquito showed higher values of Shannon and Simpson indices in May, June and January respectively. Species richness values was higher in January.

Urbanization diminishes the biodiversity and richness of wild mosquito species while boosting the numbers of those that thrive in urban environments. This shift heightens the risk of transmitting diseases to humans and could enable new pathogen to infect people, potentially leading to the emergence of novel illnesses<sup>40</sup>. In the present study the number of endophilic mosquito are higher in the urban (Darmanawa) settlement with least species richness, however, highest species richness with least mosquito abundant was recorded in rural (Babban Gura) settlement. Also the findings from the study showed higher similar values of Shannon and Simpson indices in semi-urban and urban areas than in rural area. This findings aligned with a study from India that reported higher significant Shannon index values in the peri-urbanset-up (2.204), followed by rural (1.968) and comparatively lower values (1.671) in urban topographies while thee venness values were relatively similar in both rural (0.854) and peri-urban (0.813) topographies, which are higher compared to urban (0.760) areas<sup>41</sup>. This indicates higher biodiversity of mosquito species within the three different settings.

The values of Shannon and Simpson indices were significant higher in the dry season than wet season, though the values of species richness were similar in both seasons. Therefore, the dry season appears to show greater diversity and evenness of endophilic mosquitoes.

The diversity indices of endophilic mosquitoes recorded in the present study, including the Shannon index and Simpson index, were relatively high compared to those reported by Fagbohun *et al.*<sup>42</sup>, who found that mosquito species diversity ranged from 1.187 to 1.242 for the Shannon index (H) and from 0.6751 to 0.6926 for the Simpson index (D). Lapang *et al.*<sup>43</sup> reported that mosquito diversity in Plateau State, Nigeria was relatively low, with a Shannon-Wiener index (H' ≈ 1.5). These differences in diversity indices may be attributed to variations in the ecological zones where the studies were conducted.

## Conclusion

The high diversity indices of Shannon and Simpson observed in this study indicate that most of the species were well represented and randomly sampled. *Culex pipiens*, *Culex quinquefasciatus*, and *Anopheles gambiae* were the most abundant species resting within human dwellings. These mosquitoes exhibited greater diversity in May, June, and January, with several species found in rural settlements during the dry season. The predominant species *Culex pipiens*, *Culex quinquefasciatus*, and *Anopheles gambiae* were entomological indicators of filariasis and malaria in these settlements.

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