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Full Length Research Article

Species Composition, Seasonal Abundance, and Indoor Resting Behaviour of Anopheline Mosquitoes in Rural Communities of Ebonyi State, Nigeria

[1]Anyaehie, Sylvia Ijeoma, [2]Michael Okpara Elom, [3*]David Ekene Nwele and [4]Honorius Chibuko

[1]Department of Medical Laboratory Science, Faculty of Health Sciences, Ebonyi State University
[2]Department of Applied Biology, Faculty of Science, Ebonyi State University
[3]Department of Biology/Biotechnology, Faculty of Natural Sciences, David Umahi Federal University of Health Sciences
[4]Examination and Records Unit, Coal City University, Emene, Enugu State

Corresponding Author: davideolink@gmail.com

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Abstract

This study assessed the species composition and distribution of malaria vectors in two malaria endemic communities of Ezza North Local Government Area (LGA), Ebonyi State, Nigeria, using key entomological indicators: species composition, blood feeding behaviour and indoor resting density of *Anopheles* mosquitoes. Sample collection was conducted monthly from June to December 2023 using pyrethrum spray catch method in 40 randomly selected houses. Collected specimens were transported to the laboratory where they were sorted and identified using entomological keys. Data were analyzed using Chi-square tests at a 95% confidence level. A total of 785 female *Anopheles* mosquitoes belonging to seven (7) different species (*Anopheles gambiae s.l, An. funestus, An. hancocki, An. maculipalpis, An. rufipes, An. coustani* and *An. nili*) were collected with *Anopheles gambiae* accounting for 86% of all collections ($p < 0.05$). Vector indoor resting density showed highest peak in June (6.25 and 3.8) in Ekwetekwe and Ugalaba, respectively. Gonotrophic stage analysis shows that 80.0% were blood-fed, 5.9% unfed, 4.1% half-gravid, and 10.1% gravid. These findings confirm *An. gambiae* s.l. as the primary malaria vector in Ezza North LGA. High endophagy and seasonal abundance indicate ongoing transmission risk, underscoring the need for strengthened vector surveillance and integrated control measures.

Keyword: *Anopheles*, Species Composition, Seasonal Abundance, Endemic Communities, Ebonyi, Nigeria.

Introduction

Malaria is a mosquito-borne disease caused by *Plasmodium* species and transmitted through the bite of infected female *Anopheles* mosquitoes. It remains a leading cause of morbidity and mortality in tropical and subtropical regions and ranked eighth among global causes of disability-adjusted life years (DALYs) in 2002 (WHO, 2024). Clinical manifestations due to malaria range from fever and chills to severe complications such as cerebral malaria, severe anaemia, and organ failure (Ali, 2012). Among the five *Plasmodium* species infecting humans, *P. falciparum* and *P. vivax* pose the greatest threat, with *P. falciparum* showing widespread multidrug resistance (Nwigwe *et al.,* 2025; WHO, 2024).

Although malaria is preventable and treatable, effective control depends heavily on vector-targeted interventions. Preventive strategies include use of insecticide-treated nets, indoor residual spraying, environmental management, chemoprophylaxis, and vaccination, such as the RTS, S/AS01 (Mosquirix) vaccine, which shows moderate efficacy in children (WHO, 2021; CDC, 2021). Vector control remains central, as transmission relies entirely on the behaviour and ecology of *Anopheles* mosquitoes (WHO, 2024). Historically, vector control evolved from house screening, environmental sanitation and clearing of blocked drainage, to widespread insecticide use following the discovery of dichlorodiphenyltrichloroethane (DDT) in the 1940s.

Precise knowledge of local vector species, their feeding and resting behaviour, abundance, and infection rates is essential for designing effective interventions (Nyirakanani *et al.,* 2017; Bhatt *et al.,* 2015). Although more than 400 *Anopheles* species exist, only few are efficient malaria vectors; therefore, changes in species composition can substantially affect transmission dynamics and the effectiveness of control interventions (Koffi *et al*., 2023).

This study therefore assesses malaria vector species composition, abundance, feeding and resting behaviour in Ezza North Local Government Area of Abakaliki, Ebonyi State, Nigeria, to generate evidence crucial for optimizing local vector control strategies.

Materials And Methods

Study Area

The study was carried out in Ekwetekwe and Ugalaba Communities in Ezza North Local Government Area of Ebonyi State, Nigeria (Figure 1). Ezza North LGA has an area of 391km^2 with a projected population of 217,700 in 2022 (NPC, 2022). The inhabitants are mostly farmers, civil servants and small-scale traders. The climate of the area is tropical with a mean daily temperature of 30 ± 5 °C most of the year. The annual rainfall is between 217 mm and 240 mm, with rainy season, April to November and dry seasons, December to March (Nwele *et al.,* 2022; Nwele and Nwaorgu, 2017). The selection of the sample locations was based on the reported high endemicity of malaria in the communities of Ezza North Local Government Area. (Nwele *et al.,* 2022).

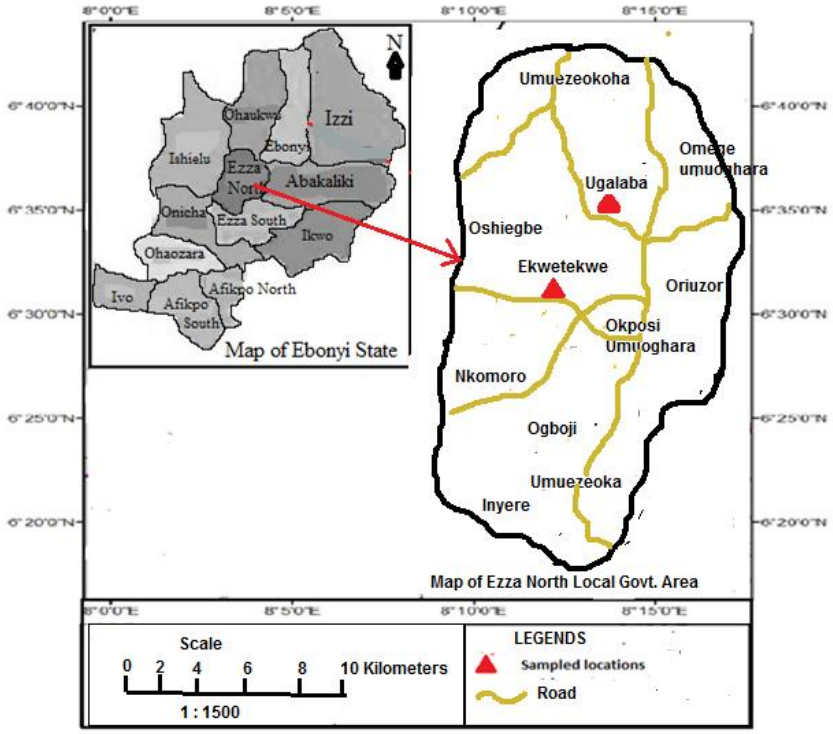


Figure 1: Map of Ezza North Local Government Area Showing the Study Communities (Source: Modified after https://www.nieriagalleria.com/Nigeria/statesNigeria/i Images/Ebonyi-State-Political-Map-jpg)

Ethical Approval and Informed Consent

The research was reviewed and approved by the Ethical Review Committee of Ebonyi State Ministry of Health, Abakaliki, with approval number EBSHREC/03/055. Additionally, Permission to conduct the study in the communities was obtained from the traditional rulers and community leaders before the commencement of the study while oral informed consent was obtained from individual household heads to perform mosquito collections in their selected rooms.

Study Design

The study design was cross-sectional, with forty (40) houses (one sleeping room per house) randomly selected from the two villages. Twenty (20) houses were selected from each village, contrary to 10 houses used by Egbuche *et al.,* (2020), in each of their study community. One room from each of the selected houses was surveyed for indoor resting malaria vectors every month for six (6) months. The selection of rooms for pyrethrum spray was based on the use of such rooms for sleeping at night.

Mosquito Collection Using Pyrethrum Spray Catch (PSC)

A total of 40 houses were randomly selected for mosquito collection by pyrethrum spray methods. Mosquitoes were collected every month between 6 am and 8am using WHO protocols as described by Onyango *et al.,* (2013) and Egbuche *et al.,* (2020). Each house was prepared for spraying by removing food, water and covering the entire floor and furniture with white cotton sheets. A collector was spraying inside the house with the pyrethrum insecticide, (RAID®) as used by Egbuche *et al.,* (2021), while another person was spraying the eave on the outside in an anti-clockwise manner to stop mosquitoes from escaping. The

house was closed for 10 minutes, after which the white sheets were moved outside to collect the mosquitoes that were knocked down using forceps. The collected mosquitoes were transferred into a petri dish lined with moist Whatman filter paper and labelled appropriately with the household code, date, month, and time of collection. All mosquitoes collected on each sampling day from each household were transported to Applied Biology Laboratory, Ebonyi State University, Abakaliki for identification and further analysis. The sampling was carried out on monthly basis for a period of 6 months to estimate the monthly indoor resting density.

Mosquito Identification and Processing

All adult mosquitoes collected in the field each day of sampling were identified morphologically using taxonomic keys provided by Coetzee (2020), with the guidance of Entomologists in the Department of Applied Biology, Ebonyi State University, Abakaliki. The abdominal appearance of the morphologically identified *Anopheles* species was examined and classified as unfed, fed, half-gravid or gravid, based on the blood digestion stage of the stomach. Fed, unfed, gravid, and half-gravid females of *Anopheles gambiae* were counted to estimate the endophagic and endophilic densities, defined as the proportion of each species resting in houses after blood feeding (Nwoke *et al.,* 2025; Sinka *et al.,* 2012). All morphologically identified *Anopheles* species were packaged individually in Eppendorf tubes containing silica gel and preserved for further analysis.

Data summary and statistical Analysis

Chi square test at 5 % % level of significance was employed to test the difference in vector species composition between months and indoor locations. The indoor resting density was expressed as the total number of female mosquitoes caught over the collection places.

Results

Anopheline Mosquito Species Composition and Seasonal Distribution

A total of 785 adult female *Anopheles* mosquitoes belonging to seven different species (*Anopheles gambiae s.l, An. funestus, An. hancocki, An. maculipalpis, An. rufipes, An. coustani* and *An. nili*) were collected using the PSC method between June and December 2023 in the two study communities **(**Figure 2). The monthly composition of the malaria vector species is presented in Table 1. Overall, the highest number of vector species was collected in the month of June (n= 201) followed by September (n= 164) while the least was collected in the month of July (n= 46) (Table 1). Test of statistical significance indicated that abundance of *An. gambiae s.l* varied significantly ($p< 0.05$) across the study months. However, there was no significant difference ($p> 0.05$) in the abundance of other species across the months.

Species composition showed that, *Anopheles gambiae s.l* was the predominant vector species, accounting for 86% (N = 675). This was followed by *Anopheles funestus* (5.4%, n=42). Other secondary vectors accounted for the remaining 8.6% of the total collections (Figure 2). The species distribution varied in the two communities, with *An. gambiae s.l* dominating in all the collections for Ekwetekwe (88.7%, n= 430) and Ugalaba (81.7%, n= 245). *An. funestus* was the second most abundant vector species in the two areas, accounting for 4.5% (n= 22) and 6.7% (n= 20) in Ekwetekwe and Ugalaba respectively. The least was *An. maculipalpis* (0.8%, n=4) for Ekwetekwe and *An. nili* (0.3%, n= 1) for Ugalaba (Figure 3a and 3b respectively). Test of statistical significance indicated a significant difference ($P< 0.05$) in the

abundance of the malaria vector species collected across the two communities.

Table 1: Monthly Malaria Vector Species Composition in the Study Area

Species	Months of Collection							
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
An. gambiae s.l	197	46	110	131	115	44	32	675(86%)
An. funestus	3	0	0	17	7	4	11	42(5.4%)
An. hancocki	1	0	0	5	1	1	1	9(1.1%)
An. maculipalpis	0	0	3	2	2	5	1	13(1.7%)
An. rufipes	0	0	0	9	5	2	9	25(3.2%)
An. coustani	0	0	0	0	2	8	3	13(1.7%)
An. nili	0	0	0	0	0	4	4	8(1.0%)
Total	**201(25.6)**	**46(5.9)**	**113(14.4)**	**164(20.9)**	**132(16.8)**	**68(8.7)**	**61(7.8)**	**785(100%)**

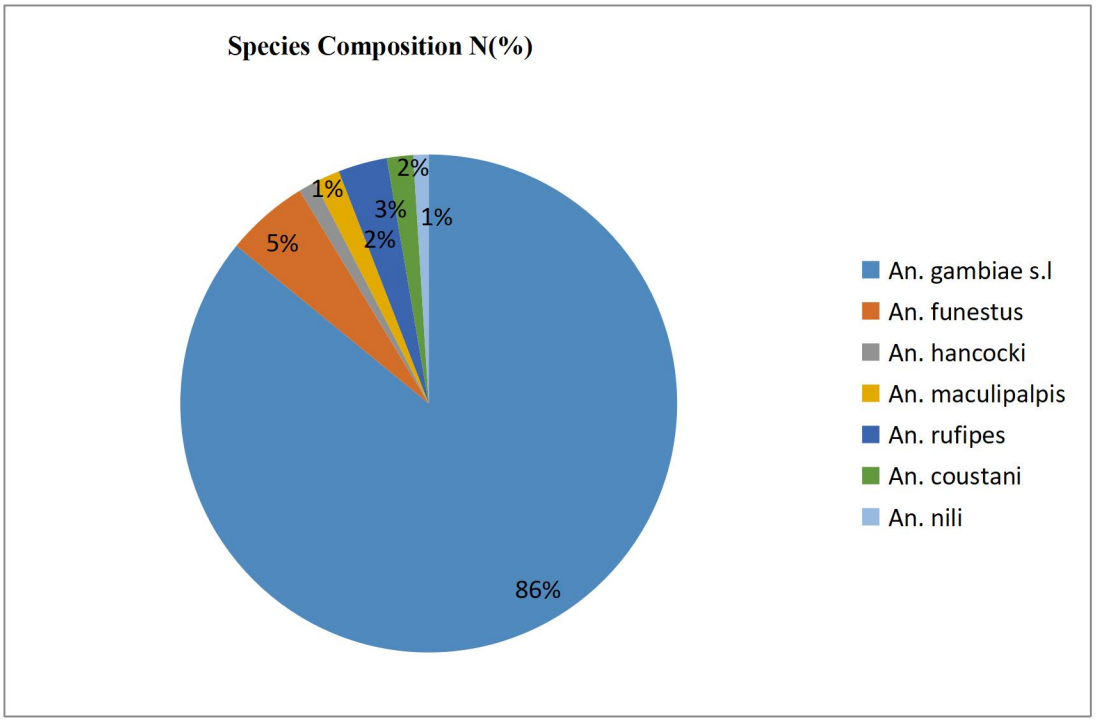


Figure 2: Overall Malaria Vector Species Composition in the Study Area

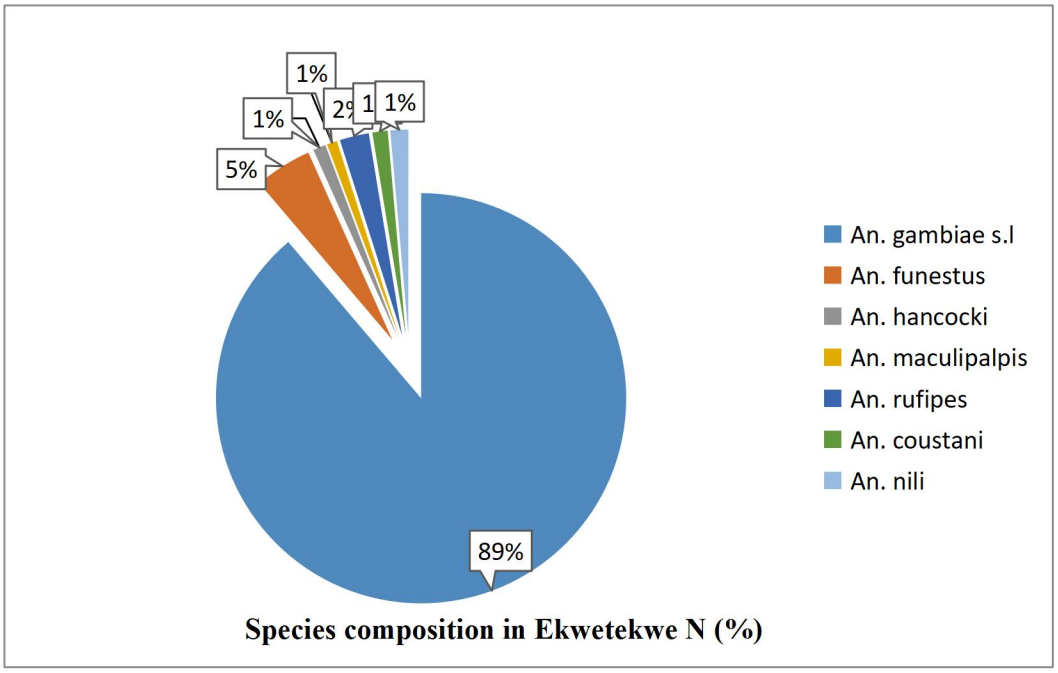


Figure 3a: Malaria Vector Species Composition in Ekwetekwe Community

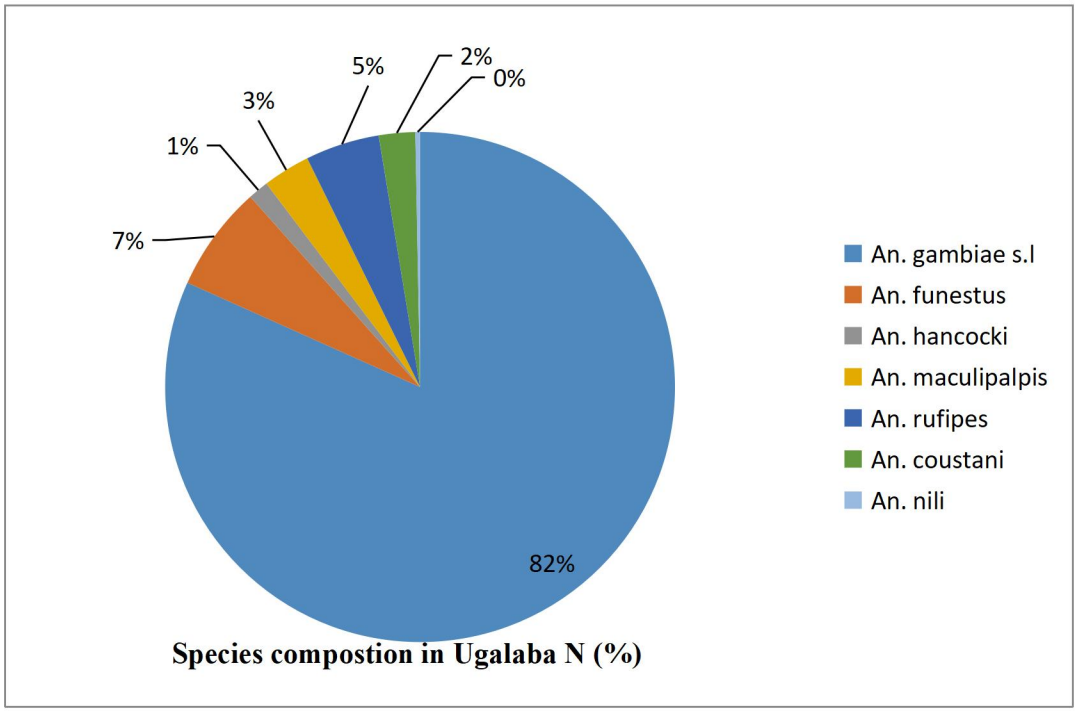


Figure 3b: Malaria Vector Species Composition in Ugalaba Community

Monthly Indoor Resting Density of Malaria Vectors in the Study Area

The indoor resting density expressed as the total number of female mosquitoes caught over the collection places, indicated higher peaks in June, 6.25 for Ekwetekwe and 3.8 for Ugalaba (Figure 4) while lower peaks were observed in September, 5.7 for Ekwetekwe and in October, 3.5 for Ugalaba. Statistically, there was a significant difference in the seasonal indoor resting densities of malaria vectors ($p < 0.05$). However, there was no significant difference in vector resting densities between study locations ($P>0.05$).

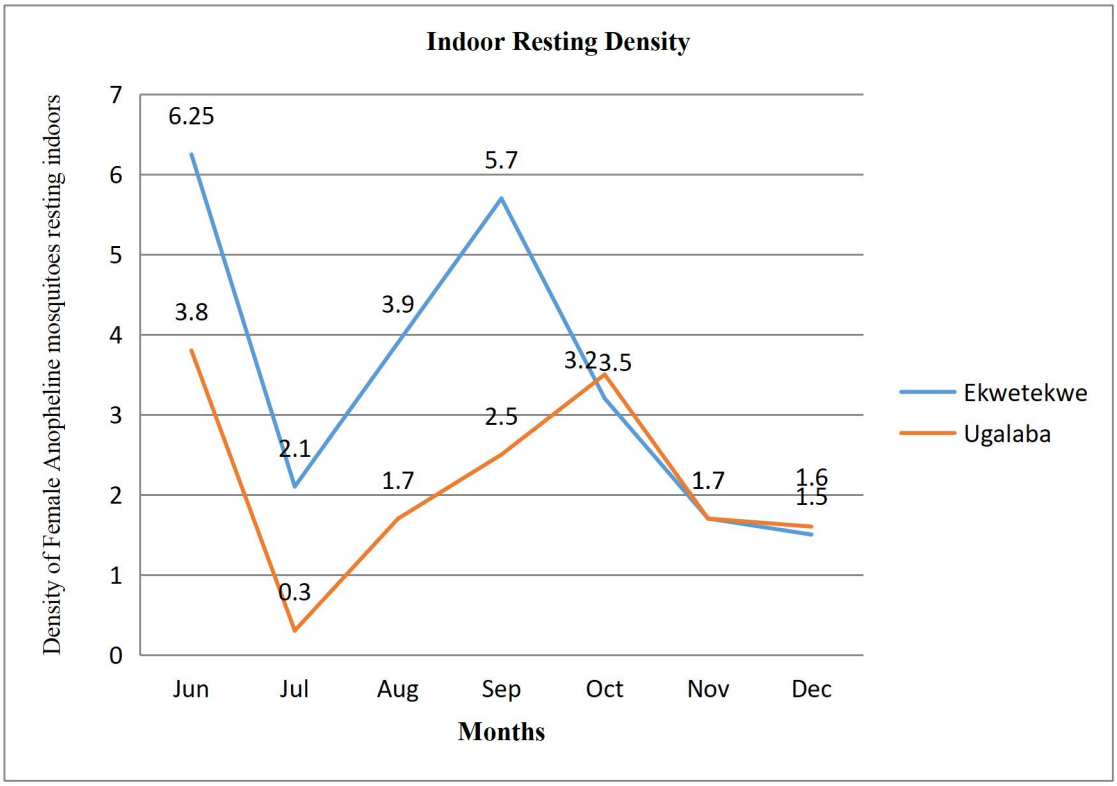


Figure 4: Monthly Densities of Female Anopheline Mosquitoes Resting Indoors

Blood digestion/abdominal status of indoor resting Anopheline mosquitoes caught during the study

Anopheline mosquitoes collected using PSC method was analyzed for blood digestion/abdominal status (Table 2). A total of 785 *Anopheles* species were caught in the study, in which 485 were collected from Ekwetekwe and 300 were collected from Ugalaba. The *Anopheles* mosquitoes were analyzed for blood digestion/abdominal status and discovered that 628 were fully-fed with blood meal, 46 were not fed at all, and 32 were half gravid while 79 were gravid. The above classification was based on the appearance of the abdomen observed under the microscope. Statistical analysis showed that the blood feeding and stomach stage of malaria vectors during the study period at the two communities varied significantly ($p < 0.05$).

Table 2: Abdominal Status of Indoor Resting *Anopheles* Mosquitoes Caught during the Study

Months	Stomach/blood digestion stages				
	UF	**BF**	**HG**	**G**	**Total**
Jun	11	161	6	23	201(25.6%)
Jul	0	46	0	0	46(5.9%)
Aug	6	100	0	7	113(14.4%)
Sep	23	105	13	23	164(20.9%)
Oct	5	94	9	24	132(16.8%)
Nov	1	61	4	2	68(8.7%)
Dec	0	61	0	0	61(7.8%)
Total	**46(5.9)**	**628(80.0)**	**32(4.1)**	**79(10.1)**	**785(100%)**

Key: UF = unfed, BF = blood fed, HG = half gravid and G = gravid

Discussion

This study identified seven *Anopheles* species, with *An. gambiae* s. l. emerging as the overwhelmingly predominant vector, followed by *An. funestus*, while species such as *An. maculipalpis* and *An. nili* were only minimally represented. This distribution pattern provides a basis for interpreting the ecological dynamics of the vector population and their implications for malaria transmission in the study area.

The dominance of *An. gambiae* s.l. observed in this study is epidemiologically significant, given its well-documented efficiency as a malaria vector due to its strong anthropophilic, endophagic, and endophilic behaviour. The predominance of this species likely reflects the availability of suitable breeding habitats such as temporary rain-fed pools, agricultural farmlands, and human settlements with close proximity to larval sites, all of which favour *An. gambiae* proliferation (Egbuche *et al.,* 2019). In addition, housing structures with unscreened windows and eaves, common in rural communities, may further enhance indoor resting opportunities for this species. Similar dominance of *An. gambiae* s.l. has been reported across Nigeria and other malaria-endemic regions (Maaji *et al.,* 2024; Bassey *et al.,* 2024; Davis *et al.,* 2024; Ogbuefi and Aribodor, 2023; Egbuche *et al.,* 2020), reinforcing its central role in malaria transmission in rural settings.

In contrast, the low representation of *An. maculipalpis* and *An. nili* in this study differs from earlier findings in which *An. rufipes* and *An. arabiensis* were the least abundant species (Oduola *et al.,* 2021; Maaji *et al.,* 2024). However, the minimal presence of *An. maculipalpis* is consistent with the results of Nwana *et al.* (2021). It could be that favourable breeding habitats for the species encountered are not evenly distributed or present in equal number.

Temporal variations in vector abundance were also evident. The highest number of mosquitoes was recorded in June (n = 201), followed by September (n = 164), with July yielding the lowest abundance (n = 46). Such monthly fluctuations have been widely documented. Lamidi (2009) observed peak *An. gambiae* abundance in August in Nguru, Yobe State, with a gradual decline thereafter. Garba (2023) similarly reported high vector abundance in August and low levels in March in Kontagora. In Southeastern Nigeria, Egbuche *et al*. (2020) reported that the peak abundance of *Anopheles* mosquitoes occurs between March and June.

On the other hand, Elosiuba *et al*. (2023) reported bimodal peaks occurring in June and October, while January had the lowest abundance. Maaji *et al.* (2024) found the highest mosquito catches in May and the lowest in June in Kano State. These findings suggest that mosquito abundance is influenced by species-specific responses to seasonal, climatic and environmental factors, including breeding habitat availability (Egbuche *et al.,* 2020; Egbuche *et al.,* 2019).

Variations across months can be attributed to rainfall patterns, temperature, humidity, vegetation, land use, and socio-demographic conditions that influence human–vector contact. The low abundance recorded in July during this study may be due to heavy rainfall, which can wash away eggs and larvae and disrupt mosquito development. Similar associations between climatic variables and mosquito distribution have been reported by Nwele *et al.* (2025). Conversely, the dry season provides fewer suitable breeding sites, contributing to reduced mosquito proliferation.

Ongoing climate change may further influence vector distribution patterns. Species not previously documented in certain areas may emerge, while historically dominant species may decline. Changing feeding preferences and host availability could also reshape local vector ecology and influence malaria transmission dynamics.

The study identified clear seasonal peaks in vector indoor resting density, with highest peaks observed during the rainy season (June to September). These patterns were uniform across the study communities with *An. gambiae* complex recording the highest peak. Rainy seasons provide optimal breeding conditions for *An. gambiae*, as water accumulates in ground pools (puddles), swamps, domestic containers, and drainage channels (gutters), creating suitable breeding sites (Egbuche *et al*., 2019; Sande *et al*., 2016). Given the pronounced seasonal peaks in vector abundance, scaling up interventions during the rainy season could maximize their impact. Pre-emptive distribution of ITNs and intensified IRS campaigns before the onset of rains may help suppress vector populations.

With respect to the feeding status of the mosquitoes, higher proportion of the female mosquitoes caught (80%) had taken blood meal from the occupants and were resting indoors prior to the collection compared to the 5.9% of non-blood fed females resting indoors which explains the host seeking and endophagic behaviour of the local malaria vectors. Other studies (Woke *et al.,* 2025; Adeleke *et al.,* 2010) have reported similar trend in blood feeding behaviour of local malaria vectors in Nigeria especially *An. gambiae* complex.

Conclusion

This study provides key insights into the species composition and seasonal abundance of *Anopheles* mosquitoes in the study area. The overwhelming dominance of *An. gambiae* s.l. reinforces its central role in malaria transmission and highlights the need for sustained, targeted vector control strategies. Seasonal fluctuations in vector populations underscore the importance of considering environmental and climatic factors when planning control interventions. The presence of multiple *Anopheles* species, including less abundant vectors, emphasizes the need for continuous entomological surveillance to detect shifts in species composition resulting from environmental change, urbanization, or climate variability. Strengthened surveillance, coupled with adaptive and ecologically informed vector management, is essential for reducing malaria transmission and supporting regional malaria elimination efforts.

Conflicts of Interest

The authors declares that no conflicts of interest exist among them.

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