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Original Article

Influence of bed net and Insecticide use on blood-feeding status and indoor resting Density of *Anopheles* and *Culex* mosquitoes in Minna, Niger State

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ABSTRACT

Mosquitoes are the most important vectors of human disease globally, transmitting malaria, lymphatic filariasis, and several arboviruses. In Nigeria, the *Anopheles gambiae* complex and the *Anopheles funestus* group are the primary malaria vectors, while *Culex quinquefasciatus* contributes significantly to lymphatic filariasis transmission. Understanding mosquito population dynamics, resting behaviour, and physiological states is critical for guiding vector control interventions. This observational study assessed the indoor resting density (IRD) and abdominal physiological conditions of *Anopheles* and *Culex* mosquitoes in Minna, Niger State, between May and August 2026. Mosquitoes were collected monthly from four sites (Bosso, Gidan Kwano, Maikunkele, and Chanchaga) using pyrethrum spray catches. Indoor resting density was calculated as mosquitoes per person per room, and abdominal physiological states were classified as unfed, fed, half-gravid, or gravid. Results showed that *Anopheles* IRD peaked in May, with Bosso (5.82 mosquitoes/person/room) and Gidan Kwano (4.13 mosquitoes/person, m/p) recording the highest values, before declining sharply in June. July revealed heterogeneous patterns, with Bosso (3.69 m/p) and Maikunkele (2.06 m/p) rebounding, while Gidan Kwano dropped to 0.25 m/p. In August, IRD remained low except for Maikunkele (2.64 m/p). *Culex* mosquitoes displayed persistently high IRD, particularly in Bosso (7.35 m/p in May, 8.50 in June, 7.38 m/p in July), with Maikunkele showing a notable rise in July (4.88). Abdominal analysis revealed fed mosquitoes predominated across months (59–92%), while gravid proportions increased in August, especially in Maikunkele (12.82%) and Chanchaga (13.67%). These findings highlight temporal fluctuations, site-specific differences in intervention impact, and sustained host-vector contact, underscoring the need for strengthened bed net and aerosol use, and integrated larval source management in Minna.

Keywords: *Anopheles*, *Culex*, lymphatic filariasis, malaria, pyrethrum spray catch

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INTRODUCTION

Mosquitoes remain the most important vectors of human disease globally, transmitting pathogens responsible for malaria, lymphatic filariasis, and several arboviruses. In Africa and Nigeria, malaria continues to account for significant morbidity and mortality, with the *Anopheles gambiae* complex and *Anopheles funestus* group serving as the primary vectors [1]. In addition, *Culex quinquefasciatus* plays a major role in the transmission of lymphatic filariasis, particularly in urban and peri-urban settings where poor drainage and sanitation create favourable breeding habitats [2].

Vector ecology is strongly influenced by environmental conditions, particularly rainfall, which determines the availability of breeding sites [3]. Indoor resting density is a key entomological indicator, reflecting both vector abundance and the effectiveness of interventions such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS) [6]. While high indoor resting mosquito densities often correspond to increased host-vector contact and elevated transmission risk for malaria and other mosquito-borne diseases [7], seasonal variations in mosquito indoor resting density (IRD) have been reported across Nigeria to typically align with rainfall patterns, which influence the availability of breeding sites and the survival of immature stages [4]. At the onset of the rainy season, IRD tend to rise sharply due to the proliferation of temporary water bodies, while later in the season, heavy rains may flush breeding habitats, leading to declines [8]. These fluctuations directly affect transmission intensity, as higher vector IRD increase the frequency of host-vector contact and the likelihood of pathogen spread [5].

In addition to IRD, abdominal physiological conditions—whether unfed, fed, half-gravid, or gravid—provide critical insight into mosquito ecology. Fed mosquitoes indicate recent blood meals and active transmission potential, while gravid and half-gravid individuals reflect reproductive activity and the likelihood of population persistence [9]. Monitoring these physiological states assesses both the intensity of host-vector contact and the reproductive dynamics of mosquito populations [10]. Such information is vital for evaluating the impact of vector control interventions, as reductions in fed proportions or gravid states can signal effective suppression of transmission cycles [11]. The IRD and abdominal physiological status, thus, serve as complementary indicators of vector behaviour and control effectiveness. Their combined analysis provides a more comprehensive understanding of transmission risk, guiding the design and implementation of targeted interventions in endemic regions.

Despite large-scale distribution of ITNs and other control measures in Nigeria, variations in community compliance and ecological conditions continue to shape vector populations. Intervention effectiveness is often influenced by household practices, socio-economic status, and local environmental factors such as drainage, vegetation, and water storage [12]. For example, households that consistently use ITNs or live in areas with effective IRS coverage tend to record lower mosquito IRD, while communities with poor compliance or persistent breeding habitats experience higher transmission risk. Previous studies in Plateau, Bayelsa, Kaduna and Ebonyi States have demonstrated that intervention uptake strongly influences mosquito IRD and feeding activity, with communities showing strong ITN adherence reporting significant reductions in vector abundance and malaria incidence [4, 13 - 15]. These findings highlight the importance of community-level behaviour in sustaining vector control gains. However, entomological data from Niger State, particularly Minna, remain limited, despite its ecological significance as part of the Guinea savanna zone where seasonal rainfall strongly shapes mosquito dynamics. Generating such data is essential for tailoring interventions to local contexts and strengthening Nigeria�s broader malaria and filariasis control programs.

This study therefore investigated the indoor resting density and abdominal physiological conditions of *Anopheles* and *Culex* mosquitoes in Minna from May to August 2026. By examining seasonal and site-specific variations, the study provides evidence on the entomological and epidemiological implications of vector behaviour, with relevance for malaria and filariasis control programs in Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Minna, Niger State, Nigeria, between May and August 2026. Minna lies within the Guinea savanna ecological zone, characterised by a distinct wet season (May�October) and dry season (November�April). The rainy season provides abundant breeding habitats for mosquitoes, particularly in peri-urban communities such as Bosso, Gidan Kwano, Maikunkele, and Chanchaga. These sites were selected to capture variation in ecological settings, human population density, and vector control intervention coverage, consistent with approaches used in similar entomological surveys across Nigeria [4, 12].

Informed Consent

Informed consent was obtained from all participating households before mosquito collection. The purpose of the study, procedures, potential risks, and benefits were clearly explained to household heads in simple language. Participation was voluntary, and households were assured of confidentiality and the right to withdraw at any time without consequence. Consent was documented before pyrethrum spray catches were conducted, and all procedures adhered to ethical standards for entomological research involving human dwellings [16].

Mosquito Collection and Preservation

Indoor resting mosquitoes were collected monthly using the pyrethrum spray catch (PSC) method, a standard technique for sampling indoor resting densities [16]. Collections were carried out monthly and simultaneously in randomly selected households within the study area between 06:00 and 09:00 hours. Household water, food materials and animals were removed from each room, and white sheets were spread on floors and furniture, and rooms were sprayed with pyrethrum-based aerosol insecticide. Knocked-down mosquitoes were collected, sorted, and counted.

Adult mosquitoes collected through pyrethrum spray catches were preserved to maintain their morphological and physiological integrity. Specimens were transferred into labelled Eppendorf tubes laced with silica gel desiccant, separated with a piece of paper to prevent moisture and fungal growth on the preserved samples [16].

Species Identification

After each monthly collection, the Anopheline and Culicine species were separated and recorded following the established methods [9]. Mosquitoes were morphologically identified to genus level using standard taxonomic keys [17, 18].

Indoor Resting Density

Ten different rooms were selected every month, and from each location for sampling of adult mosquitoes. The indoor resting density (IRD) was calculated by dividing the total number of female mosquitoes (either *Anopheles* or *Culex*) collected by the number of houses (rooms) used for the spray-sheet collection [9].

Abdominal Physiological Status

Collected mosquitoes were examined under a dissecting microscope to determine abdominal physiological conditions. Individuals were classified as unfed, fed, half-gravid, or gravid, based on the degree of blood meal digestion and ovarian development [16]. Proportions of each category were calculated monthly for each site. This classification provides insight into feeding behaviour and reproductive potential, which are critical for understanding transmission dynamics [9].

Data Analysis

All data were collated in Microsoft Excel and analysed using R (version 4.5.2). Before analysis, data were checked for normality using the Shapiro–Wilk test and for homogeneity of variances using Levene's test. Indoor resting densities and abdominal physiological proportions were summarised as means $\pm$ standard deviations. Monthly and site-specific variations were compared using Kruskal-Wallis non-parametric tests, as the data were not normally distributed. This was followed by Dunn's post-hoc test to assess the differences in medians of the data. All statistical decisions were taken at the $p < 0.05$ level of significance.

RESULTS

Monthly Indoor Resting Density (IRD) of *Anopheles* Mosquitoes Collected in Minna

The IRD of *Anopheles* mosquitoes is shown in Table 1 and varied considerably across locations and months. The Kruskal–Wallis test revealed differences in median IRD among the four locations across the months. In May, IRD were significantly ($H(3) = 12.25$, $p = 0.0034$) highest in Bosso (5.82 mosquitoes/person/room, m/r), followed by Gidan Kwano (4.13 m/r). By June, IRD declined sharply across all sites, ranging from 0.83 m/r (at Maikunkele) to 1.82 m/r (at Gidan Kwano).

In July, the pattern became more heterogeneous, with a significant difference ($H(3) = 4.24$, $p = 0.0025$) among the study locations. Bosso (3.69 m/r) and Maikunkele (2.06 m/r) experienced an increased indoor resting density, whereas Gidan Kwano recorded a reduction to 0.25 m/r. By August, IRD remained relatively low in Bosso (1.22 m/r), Chanchaga (0.85 m/r) and Gidan Kwano (1.00 m/r), but Maikunkele exhibited a significant ($H(3) = 6.58$, $p = 0.0017$) increase to 2.64 m/r (Table 1).

Table 1: Monthly Indoor Resting Density (mosquitoes/roommosquitoes/room) of *Anopheles* Mosquitoes Collected in Minna (May to August 2026)

Month (2026)	Location			
	Bosso	Chanchaga	Gidan Kwano	Maikunkele
May	5.82^{c*}_{c**}	3.33^{a}_{c}	4.13^{b}_{d}	3.00^{a}_{b}
June	1.50^{b}_{a}	1.36^{b}_{b}	1.82^{c}_{c}	0.83^{a}_{a}
July	3.69^{c}_{b}	1.75^{b}_{b}	0.25^{a}_{a}	2.06^{b}_{a}
August	1.22^{a}_{a}	0.85^{a}_{a}	1.00^{a}_{b}	2.64^{b}_{b}

*Values followed by the same superscript letter across a row are significantly different ($p < 0.05$)
**Values followed by the same subscript letter down a column are significantly different ($p < 0.05$)

Monthly Indoor Resting Density (mosquitoes/room) of *Culex* Mosquitoes Collected in Minna

The indoor resting density of *Culex* mosquitoes also showed considerable variation across locations and months (Table 2). The Kruskal–Wallis test revealed differences in the median of indoor resting density among the four locations across the months. In May, Bosso (7.35 m/rm/r) and Chanchaga (5.00 m/rm/r) recorded the highest IRD, while Maikunkele exhibited the lowest density (1.04 m/rm/r). By June, Bosso experienced a further increase to 8.50 m/rm/r, whereas Chanchaga declined sharply to 1.86 m/rm/r. Gidan Kwano recorded a significant ($H(3) = 3.54$, $p = 0.0034$)rise in density to 6.82 m/rm/r, while Maikunkele remained low at 0.83 m/rm/r (Table 2).

In July, Bosso maintained a high density (7.38 m/r), while Chanchaga (1.13 m/r) and Gidan Kwano (1.92 m/r) showed significant ($H(3) = 13.49$, $p = 0.00093$) reductions (Table 2). Maikunkele, however, recorded a significant ($H(3) = 9.62$, $p = 0.0016$) increase to 4.88 m/r. By August, IRD of *Culex* mosquitoes declined in Bosso (2.66 m/r) and Maikunkele (2.09 m/r), while Gidan Kwano (2.50 m/r) and Chanchaga (2.86 m/r) had higher values compared to the previous month (Table 2).

Table 2: Monthly Indoor Resting Density of *Culex* Mosquitoes Collected in Minna (May to August 2026)

Month (2026)	Location			
	Bosso	Chanchaga	Gidan Kwano	Maikunkele
May	7.35^{d*}_{c**}	5.00^{c}_{c}	2.55^{b}_{c}	1.04^{a}_{c}
June	8.50^{d}_{c}	1.86^{b}_{c}	6.82^{c}_{c}	0.83^{a}_{c}
July	7.38^{c}_{c}	1.13^{a}_{c}	1.92^{a}_{c}	4.88^{b}_{c}
August	2.66^{b}_{c}	2.86^{b}_{c}	2.50^{b}_{c}	2.09^{a}_{c}

*Values followed by the same superscript letter across a row are significantly different ($p < 0.05$)
**Values followed by the same subscript letter down a column are significantly different ($p < 0.05$)

Abdominal Physiological Conditions of Indoor Resting Mosquitoes in Minna

The abdominal physiological states of indoor resting mosquitoes in Minna showed consistent patterns of blood-feeding activity with site-specific variation across months (Table 3). The Kruskal–Wallis test revealed differences in the median of abdominal physiological conditions among the four locations across the months. In May, fed mosquitoes were significantly ($H(3) = 10.17$, $p = 0.0057$) the dominant condition in all locations, ranging from 59.17 ± 43.44 % in Maikunkele to 85.58 ± 16.49 % in Gidan Kwano. Bosso (63.61 ± 9.34 %) and Chanchaga (68.33 ± 2.36 %) also recorded high feeding rates, while unfed mosquitoes were comparatively fewer. Gravid and half-gravid individuals were generally low, with Bosso showing the highest gravid proportion (12.24 ± 7.83 %) (Table 3).

In June, Bosso recorded a lower fed proportion (42.76 ± 30.60 %) compared to May, while Gidan Kwano

(82.58 ± 7.19 %) and Chanchaga (82.33 ± 21.14 %) maintained high feeding rates. Maikunkele showed moderate feeding (51.95 ± 32.44 %) with balanced representation of unfed and fed states. Gravid and half-gravid mosquitoes were present in small proportions across sites, with Chanchaga recording slightly higher values (Table 3). In July, fed mosquitoes were significantly ($H(3) = 3.87$, $p = 0.007$) highest across the condition types, with proportions ranging from 74.53 ± 12.94 % (in Bosso) to 92.00 ± 10.95 % (in Chanchaga). Unfed individuals were fewer, and gravid or half-gravid states remained low, except in Bosso, where gravid mosquitoes reached 7.64 ± 10.16 % (Table 3).

By August, feeding activity declined relative to earlier months. Bosso recorded 61.24 ± 31.94 % fed mosquitoes, while Gidan Kwano (77.74 ± 19.33 %) and Maikunkele (67.44 ± 11.90 %) maintained high feeding rates. Gravid mosquitoes were more frequent in Maikunkele (12.82 ± 10.88 %) and Chanchaga (13.67 ± 9.67 %), with Chanchaga also showing the highest half-gravid proportion (10.10 ± 11.78 %). (Table 3).

Table 3: Abdominal Physiological Conditions of Indoor Resting Mosquitoes in Minna during the months of May to August 2026

Month (2026)	Location	Physiological State (%)			
		Unfed	Fed	Gravid	Half Gravid
May	Bosso	$20.20 \pm 11.56^{c*}_{b**}$	$63.61 \pm 9.34^{d}_{a}$	$12.24 \pm 7.83^{b}_{b}$	$3.94 \pm 6.02^{a}_{c}$
	Gidan Kwano	$8.92 \pm 10.59^{a}_{a}$	$85.58 \pm 16.49^{b}_{b}$	$3.42 \pm 5.48^{a}_{a}$	$2.08 \pm 5.10^{a}_{b}$
	Maikunkele	$8.53 \pm 11.36^{b}_{a}$	$59.17 \pm 43.44^{c}_{b}$	$2.23 \pm 4.54^{a}_{a}$	$1.49 \pm 2.73^{a}_{b}$
	Chanchaga	$26.67 \pm 9.43^{c}_{b}$	$68.33 \pm 2.36^{d}_{a}$	$5.00 \pm 7.07^{b}_{a}$	$0.00 \pm 0.00^{a}_{a}$
June	Bosso	$23.85 \pm 19.75^{b}_{b}$	$42.76 \pm 30.60^{c}_{a}$	$3.13 \pm 4.05^{a}_{a}$	$1.69 \pm 2.27^{a}_{a}$
	Gidan Kwano	$9.96 \pm 6.16^{b}_{a}$	$82.58 \pm 7.19^{c}_{b}$	$6.13 \pm 6.77^{b}_{a}$	$1.33 \pm 2.98^{a}_{a}$
	Maikunkele	$20.05 \pm 11.65^{b}_{b}$	$51.95 \pm 32.44^{c}_{b}$	$4.00 \pm 8.94^{a}_{a}$	$4.00 \pm 8.94^{a}_{b}$
	Chanchaga	$4.89 \pm 6.74^{a}_{a}$	$82.33 \pm 21.14^{c}_{c}$	$8.96 \pm 12.41^{b}_{b}$	$3.82 \pm 5.00^{a}_{b}$
July	Bosso	$15.02 \pm 9.99^{b}_{a}$	$74.53 \pm 12.94^{c}_{a}$	$7.64 \pm 10.16^{b}_{c}$	$2.81 \pm 5.06^{a}_{c}$
	Gidan Kwano	$11.33 \pm 15.97^{c}_{a}$	$86.89 \pm 18.29^{d}_{a}$	$1.79 \pm 4.72^{b}_{b}$	$0.00 \pm 0.00^{a}_{a}$
	Maikunkele	$17.89 \pm 10.90^{b}_{a}$	$78.76 \pm 12.62^{c}_{a}$	$1.91 \pm 2.64^{a}_{b}$	$1.43 \pm 3.19^{a}_{b}$
	Chanchaga	$8.00 \pm 10.95^{b}_{a}$	$92.00 \pm 10.95^{c}_{a}$	$0.00 \pm 0.00^{a}_{a}$	$0.00 \pm 0.00^{a}_{a}$
August	Bosso	$13.91 \pm 11.53^{b}_{a}$	$61.24 \pm 31.94^{c}_{a}$	$4.29 \pm 7.07^{a}_{a}$	$3.89 \pm 6.26^{a}_{b}$
	Gidan Kwano	$14.88 \pm 20.00^{b}_{a}$	$77.74 \pm 19.33^{c}_{a}$	$5.71 \pm 9.04^{a}_{a}$	$1.67 \pm 4.08^{a}_{a}$
	Maikunkele	$15.24 \pm 9.35^{b}_{a}$	$67.44 \pm 11.90^{c}_{a}$	$12.82 \pm 10.88^{b}_{b}$	$4.50 \pm 6.22^{a}_{b}$
	Chanchaga	$10.89 \pm 7.81^{a}_{a}$	$40.33 \pm 29.65^{b}_{a}$	$13.67 \pm 9.67^{a}_{b}$	$10.10 \pm 11.78^{a}_{c}$

*Values followed by the same superscript letter across a row for a location and in a month are significantly different ($p < 0.05$)
**Values followed by the same subscript letter down a column for a physiological state and in a month are significantly different ($p < 0.05$)

Spatio-temporal Variation in distribution of bed net and insecticide use in selected communities in Minna

Bed net and insecticide use across the study communities showed clear temporal and spatial variation over the four months (Table 4). In May, coverage was generally high, with Chanchaga and Gidan Kwano recording full insecticide use (100.00%) and strong bed net adoption (100.00 % and 83.33 %, respectively). Bosso reported moderate bed net coverage (66.67 %) but complete insecticide use, while

Maikunkele had the lowest uptake, with bed net use at 42.86 % and insecticide use at 57.14 %. By June, patterns shifted. Bosso achieved full bed net coverage (100.00 %), but insecticide use dropped sharply to 28.57%. Chanchaga and Gidan Kwano maintained high compliance with both measures, while Maikunkele showed full bed net coverage but low insecticide use (25.00 %) (Table 4).

In July, intervention coverage became more uneven. Bosso recorded no use of either bed nets or insecticides, while Chanchaga maintained full bed net coverage but low insecticide use (20.00 %). Gidan Kwano reported partial bed net use (28.50 %) with no insecticide application, whereas Maikunkele demonstrated full bed net coverage and moderate insecticide use (40.00 %). By August, coverage declined further across all sites. Bosso reported moderate bed net use (50.00 %) and low insecticide use (16.67 %). Chanchaga showed reduced coverage for both measures (25.00 % each), while Gidan Kwano and Maikunkele recorded no use of either bed nets or insecticides (Table 4).

Table 4: Spatio-temporal Variation in distribution of bed net (%) and insecticide use (%) in selected communities in Minna (May to August 2026)

Month (2026)	Location							
	Bosso		Chanchaga		Gidan Kwano		Maikunkele	
	Bed net Use	Insecticide Use	Bed net Use	Insecticide Use	Bed net Use	Insecticide Use	Bed net Use	Insecticide Use
May	66.67	100.00	100.00	100.00	83.33	100.00	42.86	57.14
June	100.00	28.57	75.00	100.00	80.00	100.00	100.00	25.00
July	0.00	0.00	100.00	20.00	28.50	0.00	100.00	40.00
August	50.00	16.67	25.00	25.00	0.00	0.00	0.00	0.00

DISCUSSION

The indoor resting density of *Anopheles* mosquitoes in Minna between May and August 2026 revealed clear seasonal fluctuations with important epidemiological implications. Indoor resting densities peaked in May, particularly in Bosso and Gidan Kwano, indicating intense vector activity at the onset of the rainy season. This pattern is consistent with findings from Plateau State, where peak densities of *Anopheles* mosquitoes were observed during the early rainy months, driven by abundant breeding habitats and limited intervention coverage [4]. The sharp decline in June across all sites may be attributable to a possible increase in vector control measures adoption, such as bed nets and aerosol spray [12] and/or increased rainfall flushing of breeding sites [3]. By July, heterogeneity emerged: Bosso and Maikunkele experienced rebounds, while Gidan Kwano recorded a dramatic reduction in IRD of mosquitoes. In August, IRD remained low in Bosso and Chanchaga but rose in Maikunkele. This could be due to localised persistence of breeding sites [3] or lapses in intervention coverage [12]. These findings highlight the need for sustained and equitable distribution of vector control interventions to prevent af mosquito-ourne disease in the study area.

The indoor resting density of *Culex* mosquitoes followed a somewhat different trajectory. Bosso consistently recorded high IRD, rising in June, while Chanchaga declined sharply during the same period. Gidan Kwano showed a notable increase in June. Unlike

Anopheles mosquito IRD, *Culex* densities remained high in Bosso through July, while Maikunkele IRD surged, reflecting possible lapses in intervention use. By August, IRD declined across most sites, though Chanchaga rose slightly. This persistence of *Culex* mosquitoes is epidemiologically significant, as they are primary vectors of lymphatic filariasis. Their less predictable response to rainfall compared to *Anopheles* mosquitoes [19] underscores the need for integrated vector management strategies, including larval source reduction, in addition to bed nets and aerosol spray. Similar persistence of *Culex* populations has been documented in Bayelsa State, where inconsistent bed net use correlated with sustained biting rates [12].

The abdominal physiological conditions of indoor resting mosquitoes further illuminate transmission dynamics. Across all months, fed mosquitoes predominated, with proportions ranging from 59 % in Maikunkele to over 85 % in Gidan Kwano in May. This dominance of blood-fed individuals indicates high levels of host-vector contact, sustaining malaria and filariasis transmission potential. Comparable findings were reported in Dutse, Northwestern Nigeria, where fed states accounted for over 70 % of indoor resting *Anopheles* [9]. In June, Bosso recorded a decline in fed proportions, while Gidan Kwano and Chanchaga maintained high feeding rates above 80 %, again reflecting possible differences in intervention uptake [6]. July saw a resurgence of feeding activity, with proportions exceeding 90 % in Chanchaga, while gravid and half-gravid states remained low. By August, feeding activity declined, but gravid mosquitoes became more frequent in Maikunkele and Chanchaga, suggesting ongoing reproduction and potential for population rebound. The rise in gravid mosquitoes late in the season highlights the importance of sustained intervention coverage to prevent resurgence once feeding activity declines.

The findings of this study suggest that use of vector control interventions such as bed nets and aerosols in Minna is uneven across communities. High early-season IRD and predominance of fed mosquitoes are possible indicators of elevated transmission risk, while localised rebounds and persistence of gravid mosquitoes may point to gaps in intervention coverage. Strengthening community compliance, ensuring equitable distribution of interventions, and incorporating larval source management are critical to sustaining gains in malaria and filariasis control.

Limitation

Despite the results obtained from this study, several limitations are acknowledged to avoid overgeneralisation of the findings. These limitations include a short four-month observation period (May to August 2026), morphological identification was done to the genus level, lack of blood-meal source analysis, and observational nature of intervention-use data.

CONCLUSION

The results from Minna between May and August 2026 show temporal and site-specific variations in mosquito IRD and abdominal physiological states. *Anopheles* IRD were highest in May, particularly in Bosso and Gidan Kwano, before declining sharply in June. By July, IRD rebounded in Bosso and Maikunkele but dropped markedly in Gidan Kwano, while August values remained generally low except for Maikunkele. *Culex* mosquitoes displayed persistently high

IRD in Bosso, with fluctuations across other sites, including a notable rise in Maikunkele in July. Abdominal physiological analysis revealed that fed mosquitoes predominated across all months, confirming sustained host-vector contact, while gravid mosquitoes became more frequent in August, indicating ongoing reproduction. These findings suggest that while vector IRD declined mid-season, localised rebounds and persistence of gravid mosquitoes highlight continued transmission potential and uneven intervention impact across communities.

Declarations

Authors Contribution

ASO, UAC, AK, and OIK conceived and designed the experiments. UAC, AK, UMB, UCC, and BE performed the experiments. UAC, UCC, and OOA analysed the data. ASO, UAC, UCC, and BE wrote the first draft of the manuscript. OOA, UMB and OIK corrected the draft copy. All AUTHORS agreed to the final state of the manuscript.

Disclosure of Conflict of Interests

The authors declare that they have no competing interests. This study was funded by a grant from TETFund (Institutional Based Research). However, the funder has not influenced the results or decision to publish.

Ethics Approval and Informed Consent

This study involved intrusion into the privacy of human homes, so ethical approval was sought from the Niger State Ministry of Secondary and Tertiary Health with the approval number ERC PIN/25/06/2025. The consent of selected heads of households was sought before activities were carried out in each home.

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