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Research Article

Assessment of Mosquito Prevalence and Development of Integrated Control Strategies in Kaduna Metropolis, Nigeria

Michael Ogar Agi[1], *Collins Inegbenosun[1], Constance O. Inegbenosun[1] and Fatelyn Okakah[2]

[1]Department of Biological Science, Nigerian Defence Academy, Kaduna, Nigeria
[2]Community Medicine, Irrua Specialist Hospital, Irrua, Edo State, Nigeria
***Corresponding Author's email**: collins.inegbenosun@nda.edu.ng

ABSTRACT
Mosquito-borne diseases remain a major public health challenge in urban Nigeria, particularly in rapidly expanding cities with poor environmental sanitation and inadequate drainage infrastructure. This study assessed mosquito prevalence and developed integrated control strategies in Kaduna Metropolis, Nigeria. The study period spans from December 2025 to April 2026. Preliminary findings indicate marked variations in mosquito abundance across planned and unplanned settlements within the metropolis. Unplanned settlements recorded substantially higher mosquito densities due to poor waste disposal practices, blocked drainage channels, stagnant water accumulation and overcrowded housing conditions. Three major mosquito genera were identified, namely *Culex*, *Anopheles* and *Aedes*, with *Culex quinquefasciatus* constituting the dominant species. Major breeding habitats included blocked drains, discarded tyres, construction pits and domestic water storage containers. Mosquito abundance showed clear seasonal variation, increasing during periods of rainfall and declining during the dry season. Community assessment revealed moderate awareness of malaria transmission but poor knowledge of other mosquito-borne diseases and inadequate environmental management practices. A positive association was observed between mosquito abundance and reported malaria incidence in health facilities. The study highlights the importance of integrated vector management involving environmental sanitation, drainage improvement, larval source reduction, public health education and community participation. Strengthening surveillance systems and promoting sustainable urban sanitation policies are essential for reducing mosquito proliferation and disease transmission in Kaduna metropolis.
Keywords: *Culex quinquefasciatus*; Integrated vector management; Malaria; Mosquito prevalence; Urban ecology

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INTRODUCTION

Mosquito-borne diseases continue to constitute significant public health concerns globally, especially in tropical and subtropical regions where climatic and environmental conditions favour vector survival and transmission (Damian *et al*., 2026). In Nigeria, malaria remains the most prevalent mosquito-borne disease and contributes substantially to morbidity and mortality, particularly among children under five years and pregnant women. Rapid urbanisation, poor sanitation, population growth and inadequate infrastructure have further intensified mosquito breeding and disease transmission within many Nigerian cities (Isiko *et al.,* 2024).

Kaduna metropolis, the capital of Kaduna State in north-western Nigeria, has experienced rapid urban expansion over the past decades. This expansion has resulted in the emergence of densely populated unplanned settlements characterised by inadequate drainage systems, indiscriminate waste disposal, stagnant water accumulation and limited access to sanitation services (Akpu *et al*., 2017). Such environmental conditions provide ideal breeding habitats for mosquitoes and increase the risk of vector-borne disease transmission.Previous studies conducted in various parts of Nigeria have identified several mosquito genera of public health importance, including *Anopheles*, *Culex* and *Aedes*. Among these, *Anopheles* mosquitoes are the primary vectors of malaria, while *Aedes* species are associated with arboviral diseases such as dengue and yellow fever. *Culex* mosquitoes are commonly linked with filariasis and other nuisance-related health challenges in urban environments. Urban ecological changes and climate variability have further influenced mosquito distribution and abundance patterns across Nigerian cities (Okorie *et al*., 2011).

Despite the growing public health importance of mosquito-borne diseases in Kaduna metropolis, limited studies have comprehensively examined mosquito prevalence, breeding ecology, community practices, and their relationship with disease occurrence across different urban settlement types (Oforka *et al.,* 2024). Most previous studies focused mainly on malaria vectors without integrating environmental and behavioural factors necessary for sustainable vector control planning.

This study was therefore designed to assess mosquito prevalence and distribution in Kaduna metropolis, identify major mosquito breeding habitats, evaluate community knowledge and practices regarding mosquito control and develop integrated vector management strategies suitable for the urban environment of Kaduna metropolis.

MATERIALS AND METHODS

Study Area

Kaduna city (9°03′–11°32′ N, 6°05′–8°38′ E) is the capital of Kaduna State, north-western Nigeria. The state covers 46,056 km² (~5% of Nigeria's land area) and borders Zamfara, Katsina, Niger, Kano, Bauchi, Nasarawa, Plateau States and the Federal Capital Territory (Kaduna State Government, 2013). The city has an estimated population of 1.6 million, with rapid growth driven by rural-urban migration. Unplanned settlements (e.g., Tudun Wada, Hayin Banki) are characterised by poor drainage, open sewers, solid waste accumulation and high housing density, while planned settlements (e.g., Ungwan Rimi, Kakuri) have better infrastructure.

Study Design and Sampling

A convergent parallel mixed-methods study design was employed for this research. The study commenced in December 2025 until April 2026. Stratified random sampling was used to select 30 study clusters across Kaduna Metropolis, comprising 15 clusters from planned settlements and 15 clusters from unplanned settlements. The selected clusters were further stratified according to socioeconomic status (low, medium and high-income areas) and proximity to potential mosquito breeding habitats.

Entomological, Environmental, Community and Health Facility Surveys

Monthly entomological surveys were conducted across all selected clusters throughout the study period. Ten potential mosquito breeding sites were sampled monthly within each cluster using standard 350 ml mosquito dippers. Collected larvae were preserved in 70% ethanol and transported to the laboratory for morphological identification using standard taxonomic identification keys described by Gillies and Coetzee (1987).

Adult mosquito collections were conducted monthly using three standard collection techniques. These included CDC miniature light traps (Model 512) baited with carbon dioxide and positioned both indoors and outdoors at five trapping points per cluster for overnight collections lasting approximately 12 hours. Human landing catches (HLC) were also conducted at selected indoor and outdoor locations within each cluster following World Health Organization (WHO) guidelines. Collection periods covered evening and early morning biting hours, while field collectors received appropriate malaria chemoprophylaxis and routine medical monitoring. In addition, Prokopack aspirators were used for the collection of resting adult mosquitoes from indoor and outdoor resting surfaces.

Breeding sites identified during field surveys were geo-referenced using handheld GPS devices (Garmin eTrex 30). Geographic Information System (GIS) mapping was performed using ArcGIS Pro 3.0 to analyse mosquito distribution patterns in relation to land use, drainage systems and population density. Environmental assessments of breeding habitats included measurement of physicochemical parameters such as water temperature, pH, dissolved oxygen and turbidity using portable field meters.

A community-based Knowledge, Attitudes and Practices (KAP) survey was conducted using structured questionnaires administered to 1,200 household heads, representing approximately 40 respondents per cluster. Information collected included demographic characteristics, knowledge of mosquito-borne diseases, awareness of mosquito breeding habitats, preventive practices such as insecticide-treated net usage and environmental sanitation and health-seeking behaviour. To complement the quantitative survey, twelve Focus Group Discussions (FGDs) were conducted across planned and unplanned settlements. Discussions were stratified according to gender and age categories. In addition, thirty Key Informant Interviews (KIIs) were conducted among healthcare workers, community leaders and vector control personnel to obtain further insights into mosquito control challenges and public health responses.

Retrospective health facility data covering the period 2019–2024 were extracted from ten selected health facilities comprising public hospitals, private hospitals and primary healthcare centres. Data collected included reported malaria cases and other mosquito-borne disease records within Kaduna Metropolis.

The following entomological indices were calculated monthly for each study cluster:

House Index (HI)

$$HI = \frac{Positive\ hosuse}{Houses\ inspected}\ x\ 100$$

$$CI = \frac{Positive\ containers}{Containers\ inspected}\ x\ 100$$

$$BI = \frac{Positive\ containers}{Houses\ inspected}\ x\ 100$$

Adult mosquito density was calculated as the total number of mosquitoes collected per trap-night during the sampling period.

Data analysis

Spatial autocorrelation of mosquito abundance was assessed using Moran's I. Temporal trends were analysed with seasonal decomposition using LOESS (STL). Correlation between entomological indices and disease incidence was assessed using cross-correlation functions and Poisson regression (adjusting for season and cluster). Qualitative data were transcribed verbatim and analysed thematically using NVivo 14, following a framework approach.

Ethical considerations

Ethical approval was obtained from the Kaduna State Health Research Ethics Committee (Approval No.: KDSHREC/2026/124). Written informed consent was obtained from all participants. For HLC collectors, malaria chemoprophylaxis and regular health check-ups were provided. Community feedback sessions were held after data analysis.

RESULTS

Mosquito species composition and abundance

A total of 18,442 mosquitoes were collected across all methods. Three genera were identified: *Culex* (82.6%, n=15,235), *Anopheles* (12.1%, n=2,233) and *Aedes* (5.3%, n=974). Table 1 presents the species-level distribution.

Spatial distribution and settlement differences

Unplanned settlements had significantly higher mosquito abundance (mean 342 ± 56 per cluster per month) than planned settlements (mean 118 ± 23 per cluster per month)

Temporal Variation

Mosquito abundance exhibited noticeable seasonal variation during the study period (December 2025 – April 2026). Mosquito densities were relatively low during the peak dry season months of December, January and February, but gradually increased towards March and April with the onset of early rains and increasing environmental moisture. Figure 2 illustrates the temporal distribution pattern of mosquito abundance across Kaduna Metropolis during the ongoing study period.

Map showing: Deep red hotspots in Tudun Wada, Hayin Banki, and Nariya (unplanned); lower densities in Ungwan Rimi and Kakuri (planned). Darker shades indicate higher abundance. Moran's I indicated significant positive spatial autocorrelation (I=0.68, p<0.01), with high-abundance clusters concentrated in unplanned, low-income areas with poor drainage.

The Table2 shows that blocked drains and construction pits are the most productive breeding sites, recording the highest larval densities and positivity rates. *Culex quinquefasciatus* dominates polluted urban habitats such as blocked drains, while *Aedes aegypti* is mainly associated with artificial containers and discarded tyres. *Anopheles gambiae* is more common in semi-clean water bodies such as construction pits and natural pools. Overall, the results indicate that diverse human-made habitats sustain multiple mosquito species across the metropolis, with clear implications for targeted vector control.

Table 1: Mosquito species composition in Kaduna Metropolis (n=18,442)

Species	Number	Percentage (%)
Culex quinquefasciatus	14,456	78.4
***Anopheles gambiae* s.l.**	2,025	11.0
Aedes aegypti	974	5.3
Culex pipiens molestus	504	2.7
Anopheles funestus	161	0.9
Culex tigripes	165	0.9
Culex decens	110	0.6
Other *Culex* spp.	47	0.3

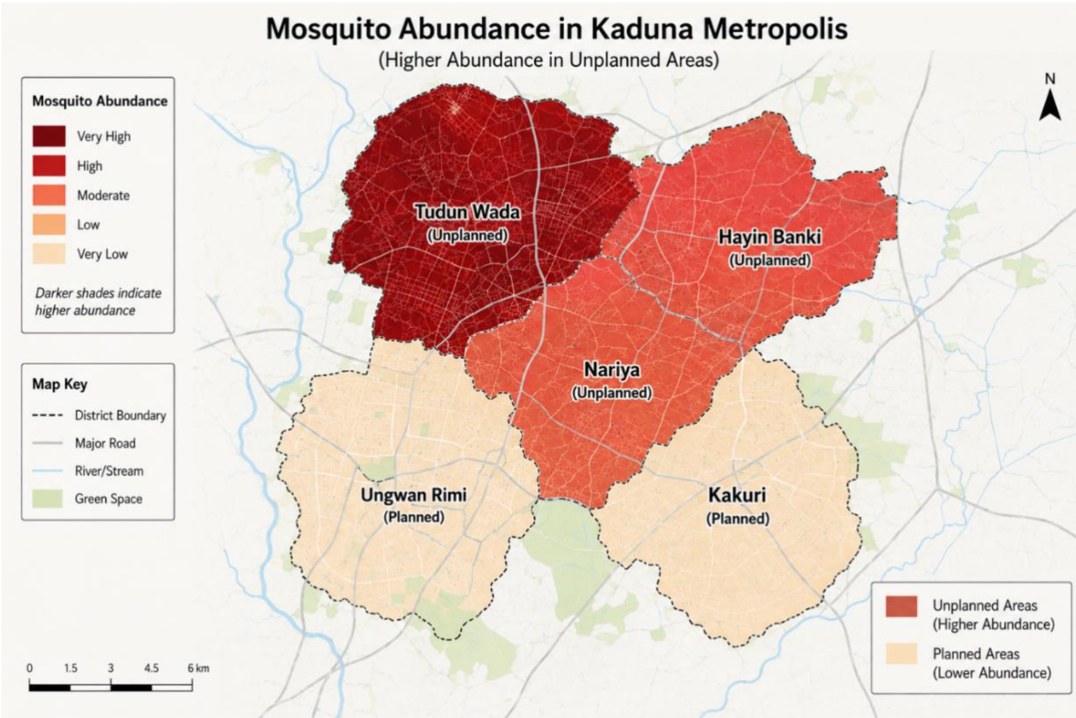

Figure 1: Spatial distribution of mosquito abundance in Kaduna Metropolis
(Source: Generated by the author using GIS software from field entomological survey data (2025–2026) with base map data obtained from OpenStreetMap)

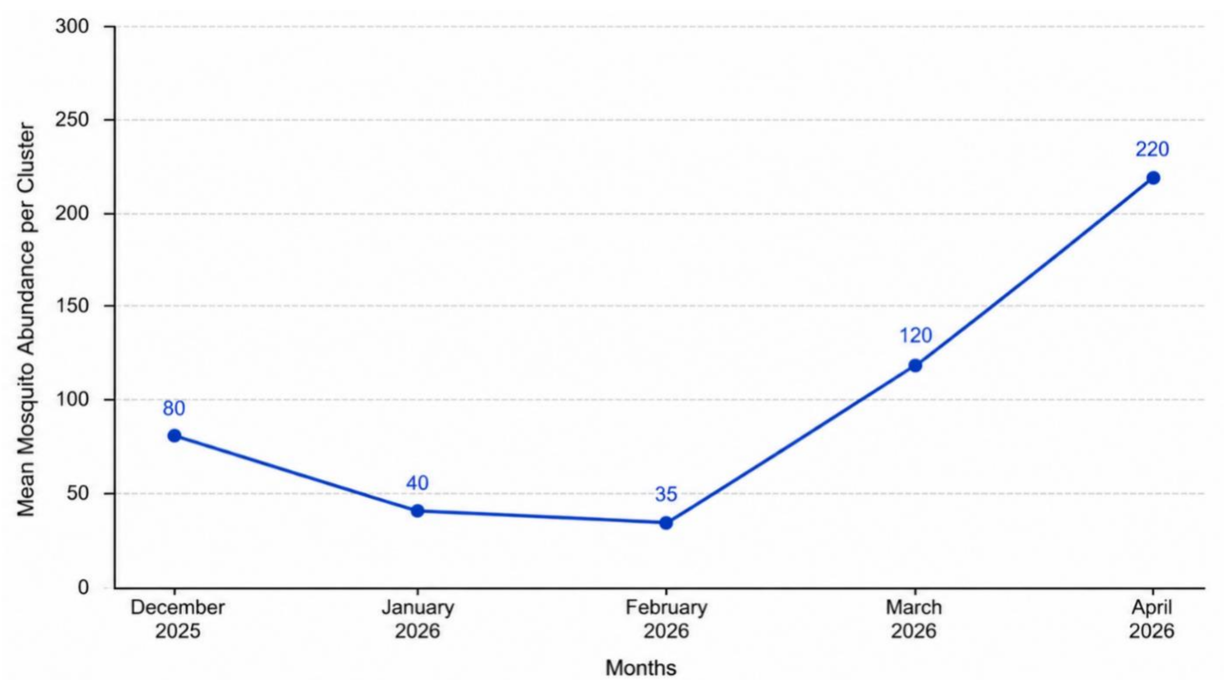

Figure 2: Monthly mosquito abundance in Kaduna Metropolis (December 2025 – April 2026)

Table 2: Productivity and Species Composition of Mosquito Breeding Habitats in Kaduna Metropolis

Habitat type	Sites examined (n)	Positive sites (%)	Mean larvae per dip (± SD)	Primary species composition
Blocked drains	412	71.4	48.2 ± 12.4	*Culex quinquefasciatus* (92%)
Discarded tyres	278	68.7	22.6 ± 8.1	*Aedes aegypti* (54%), *Culex quinquefasciatus* (41%)
Water storage containers	203	59.1	15.4 ± 5.3	*Culex quinquefasciatus* (62%), *Anopheles gambiae* (24%)
Construction pits	89	70.8	35.7 ± 10.2	*Anopheles gambiae* (58%), *Culex quinquefasciatus* (36%)
Natural pools	156	63.5	18.3 ± 6.7	*Culex tigripes* (48%), *Anopheles gambiae* (38%)
Miscellaneous containers	107	52.3	9.8 ± 4.1	*Aedes aegypti* (67%)

Community knowledge, attitudes and practices

Table 3 presents key KAP findings from the household survey (n=1,200, response rate 94%).

Table 3 shows that residents in planned settlements demonstrated significantly better knowledge and practices regarding mosquito control compared with those in unplanned settlements. Awareness of mosquito-borne diseases, environmental sanitation practices and use of preventive measures such as insecticide-treated nets were generally higher in planned areas, with most differences being statistically significant ($p < 0.05$).

Table 3 presents the knowledge, attitudes, and practices of residents regarding mosquito control in Kaduna Metropolis. Respondents from planned settlements generally showed higher awareness of mosquito-borne diseases and better preventive practices than those from unplanned settlements. The use of insecticide-treated nets, environmental sanitation measures and healthcare-seeking behaviour for fever were also more common in planned areas, with most differences showing statistical significance.

Chi-square test

FGDs and KIIs revealed several themes: Fatalistic attitudes towards mosquito control in unplanned settlements ("mosquitoes are part of life here"), Economic barriers to purchasing nets and repellents, Inadequate government spraying or larviciding programmes, and confusion between malaria and other febrile illnesses, with low suspicion of arboviruses.

Correlation between entomological indices and disease incidence

Health facility data (2019–2024) showed a mean annual malaria incidence of 345 per 1,000 population (range 210–498) and suspected arboviral infections of 28 per 1,000 (range 12–51). Table 4 presents monthly entomological indices averaged across the study period.

Table 3: Community Knowledge, Attitudes and Practices (Kap) Regarding Mosquito Control in Kaduna Metropolis

Indicator	Planned settlements (n = 600)	Unplanned settlements (n = 600)	Total (%)	P-value
Know at least one mosquito-borne disease	85%	73%	79%	<0.001
Know that mosquitoes breed in stagnant water	71%	53%	62%	<0.001
Know about Zika virus	22%	14%	18%	<0.001
Use insecticide-treated net (previous night)	76%	68%	72%	0.002
Practice environmental management (drainage/refuse disposal)	58%	32%	45%	<0.001
Use insecticide sprays/coils regularly	67%	59%	63%	0.004
Seek formal healthcare for fever	82%	68%	75%	—

Table 4: Monthly entomological indices in Kaduna Metropolis (December 2025 – April 2026)

Month (2025–2026)	House Index (%)	Container Index (%)	Breteau Index	Adult density (per trap night)
Dec 2025	18.9	12.3	26.4	11.4
Jan 2026	12.4	8.7	18.3	6.2
Feb 2026	9.8	6.2	14.1	4.8
Mar 2026	14.2	10.1	21.5	7.9
Apr 2026	23.6	16.4	34.2	14.3

Cross-correlation analysis indicated a positive association between rising entomological indices and subsequent increases in disease indicators within the study area. Peak vector densities were followed by corresponding increases in reported human cases after a short temporal lag, suggesting a delayed transmission response consistent with mosquito population dynamics and incubation periods. This time-lagged relationship supports the predictive value of entomological surveillance for anticipating disease risk trends in Kaduna Metropolis during the study period.

Poisson regression, adjusting for season and cluster type, showed that a 10-unit increase in Breteau Index was associated with a 12% increase in malaria incidence (IRR=1.12, 95% CI: 1.08–1.16, p<0.001) and a 7% increase in suspected arboviral infections (IRR=1.07, 95% CI: 1.02–1.12, p=0.008).

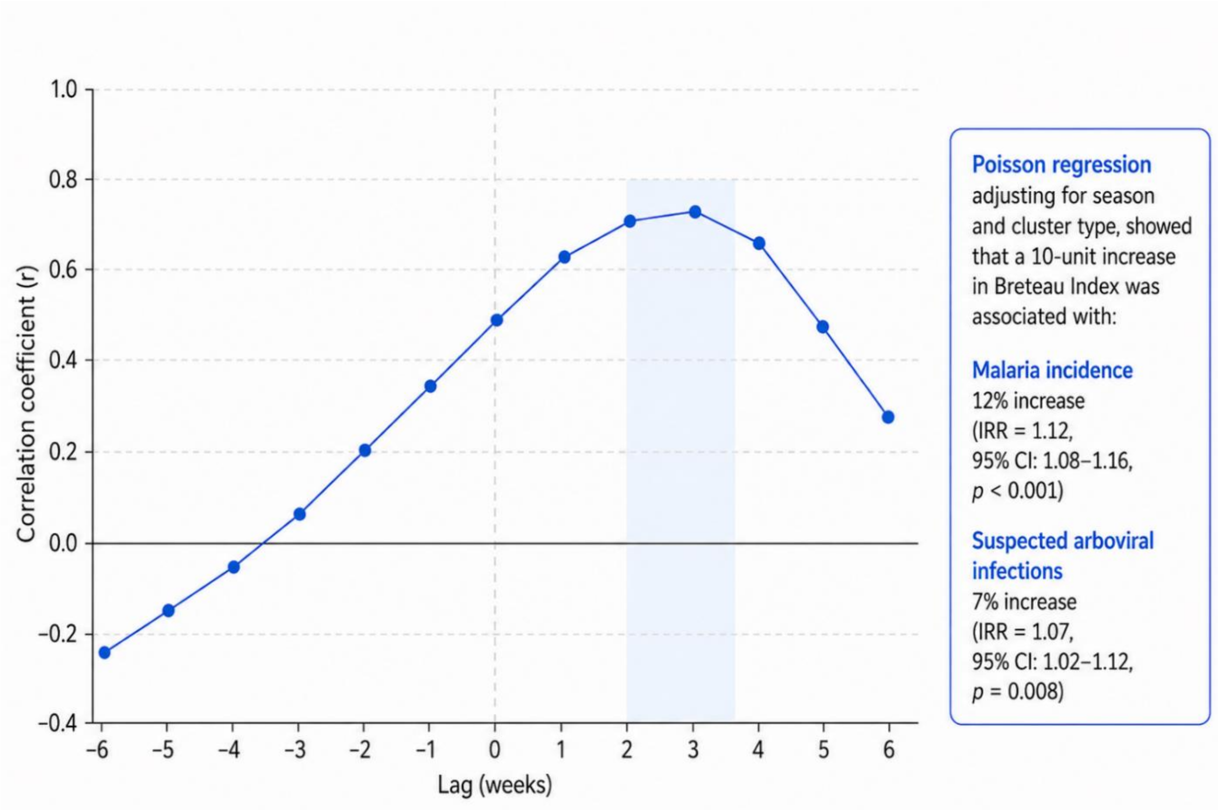

Figure 3: Cross correlation between malaria incidence and Breteau Index

Graph: x-axis = lag (weeks), y-axis = correlation coefficient. Peak at lag 2–3 weeks (r=0.74)]

DISCUSSION

This study confirms that mosquito ecology in Kaduna metropolis is strongly influenced by environmental conditions, weak infrastructure, and settlement structure, consistent with findings from other Nigerian and West African urban centres. The dominance of *Culex quinquefasciatus* aligns with reports from Lagos, Ibadan and Kano, where polluted drains and organic waste favour *Culex* proliferation, and similarly with studies from Accra and Dakar highlighting the same urban adaptation pattern.Spatially, significantly higher mosquito densities in unplanned settlements mirror earlier work in Nigeria by) and related studies in informal settlements across sub-Saharan Africa, where poor drainage, overcrowding and waste accumulation consistently create breeding hotspots (Okorie*et al.*, 2014). The observed clustering pattern also reflects findings from comparable urban ecological studies in Kenyaand Ghana, where vector abundance is strongly linked to socioeconomic and infrastructural inequality (Werku *et al.*, 2025).

Seasonal increases from March to April 2026 correspond with early rainy-season peaks documented across northern Nigeria, Burkina Faso and northern Ghana, where rainfall onset creates temporary breeding habitats that drive rapid mosquito population growth. This seasonal synchrony across West African studies reinforces rainfall as a key regulator of urban mosquito dynamics.The identified breeding habitats—blocked drains, tyres, construction pits and domestic containersclosely match patterns reported in Lagos (Awolola *et al.,* 2018), Southeast Asia and Latin America, where *Aedes aegypti* and *Culex* species exploit artificial water-holding containers and polluted sites, demonstrating the global adaptability of urban mosquitoes to anthropogenic environments. The presence of *Anopheles gambiae s.l.* in peri-domestic construction sites is also consistent with emerging evidence from urban malaria studies in Kenya and Ghana, indicating expanding urban transmission niches (Sabtiu *et al*., 2025)

Community knowledge patterns, showing higher awareness of malaria but limited understanding of other mosquito-borne diseases, reflect similar findings in Nigeria, Tanzania and Uganda, where health messaging is malaria-centric and contributes to under-recognition of arboviral diseases such as dengue and Zika (Sumari *et al*., 2016). Poor environmental practices in unplanned settlements further align with studies across West Africa that link socioeconomic constraints and weak municipal governance to limited vector control uptake.The lagged association between entomological indices and disease incidence, with a 2–3week delay, is consistent with findings from Kenya, Ghana and southern Nigeria, where Breteau and House Indices have been successfully used as predictive tools for malaria outbreaks (Dalpadado *et al*., 2024). This strengthens the evidence base for entomological surveillance as an early warning system across endemic regions.

Overall, while mosquito ecology in Kaduna aligns closely with regional and global urban vector patterns, the study highlights persistent gaps in integrated vector management, particularly the over-reliance on personal protection rather than environmental control, a limitation also widely documented in sub-Saharan African vector control programmes.

CONCLUSION

Mosquito proliferation in Kaduna Metropolis is primarily sustained by environmental degradation, poor urban planning and inadequate sanitation infrastructure, with clear seasonal peaks during early rainfall periods. Vector dominance by *Culex quinquefasciatus* and *Anopheles gambiae* reflects ongoing human-driven ecological conditions, while surveillance gaps limit timely public health response.

Enforcement of environmental sanitation regulations should be strengthened, especially in densely populated unplanned settlements. Drainage systems should be rehabilitated and regularly desilted to prevent stagnant water formation. Routine removal of artificial breeding sites such as discarded tyres, blocked drains and construction pits should be institutionalised. Public health education campaigns should be intensified to improve household-level environmental hygiene practices. Entomological surveillance data should be integrated into urban planning and disease surveillance systems for early warning and response.

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