International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 20-07-2026, Accepted: 19-08-2026, Published: 03-09-2026
Volume 11, Issue 3, 2026, Page No. 414-418

Prevalence and environmental predictors of mosquito distribution in Jere LGA, Borno State, Nigeria

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DOI: https://doi.org/10.66856/ijer.2026.11.3.11301

Abstract

Introduction: Mosquitoes (Diptera: Culicidae) are primary vectors of public health importance in the Sahelian region of Northeastern Nigeria. This study evaluated the prevalence, species composition, and ecological predictors of mosquito distribution across diverse anthropogenic and natural habitats in Jere Local Government Area (LGA), Borno State.

Methods: A cross-sectional survey was conducted across 15 sampling sites stratified into riparian, agricultural, and peri-urban zones. Larvae were collected using standard dipping methods, while adults were sampled using Pyrethrum Spray Catches (PSC) and CDC Light Traps. Morphological keys were used for species identification. Linear regression modeling was fitted to identify environmental predictors of larval density, and the Shannon-Wiener Diversity Index (H') was calculated to evaluate biodiversity shifts across life stages.

Results: A total of 676 mosquito specimens were collected (419 larvae and 257 adults). Five species across three genera (*Culex*, *Anopheles*, and *Aedes*) were identified. *Culex quinquefasciatus* was the dominant species, accounting for 50.1% of larvae and 72.5% of adults, followed by *Anopheles gambiae s.l.* (24.3% larvae; 21.0% adults), *Anopheles arabiensis* (13.1% larvae), *Aedes aegypti* (7.0% larvae; 4.5% adults), and *Anopheles pharoensis* (5.5% larvae). Species prevalence varied significantly by habitat type ($\chi^2 = 294.59$, df = 6, $p < 0.0001$). Linear regression demonstrated that stagnant gutters were the strongest predictor of larval density (B = 2.750, $p < 0.001$), while pools near communal boreholes acted as persistent year-round reservoirs. Biodiversity analysis revealed a sharp decline in species diversity from larvae (H' = 1.30) to adults (H' = 0.71), indicating a severe ecological survival bottleneck in human-altered urban environments.

Conclusion: Anthropogenic drainage systems and unmanaged water points are the primary drivers of vector proliferation in Jere LGA. Targeted Larval Source Management (LSM), focusing on urban drainage engineering and desilting, is critical for effective vector control in this Sahelian setting

Keywords: *Culicidae*, jere LGA, morphological identification, urban ecology, Nigeria, vector distribution

Introduction

Mosquitoes (Diptera: Culicidae) remain the primary vectors of major human pathogens globally, transmitting debilitating diseases such as malaria, yellow fever, dengue, and lymphatic filariasis [1–3]. In Sub-Saharan Africa, Nigeria carries a disproportionately high burden of vector-borne diseases, particularly malaria [4, 5]. The persistent public health threat posed by these vectors is largely driven by their remarkable ecological plasticity, which enables genera such as *Anopheles*, *Culex*, and *Aedes* to exploit both natural aquatic habitats and artificial human-made niches [6, 7]. In the semi-arid Sahelian belt of Northeastern Nigeria, vector dynamics are strongly dictated by extreme seasonal shifts [8]. In Borno State, a brief rainy season is followed by a prolonged dry period [9]. While natural wetlands and floodplains historically served as primary seasonal breeding sites, rapid urban expansion and informal peri-urban development have created a dense network of anthropogenic habitats. Infrastructure gaps such as unlined drainage channels, stagnant gutters, and wastewater overflow from communal boreholes provide nutrient-rich, semi-permanent aquatic microhabitats that sustain vector populations throughout the dry season [7, 8].

Despite localized entomological surveys in the Jere urban settlements, critical knowledge gaps remain regarding the quantitative relationships between specific urban infrastructure types and vector density. Few studies have applied regression modeling to isolate the structural predictors of larval productivity or evaluated ecological diversity shifts as vectors transition from aquatic larvae to mature adults in Sahelian urban environments.

This study investigated the prevalence, habitat preferences, and environmental predictors of mosquito distribution in Jere LGA, Borno State, and key objectives were to:

1. Determine the species composition and relative abundance of larval and adult mosquito populations.
2. Identify the key environmental predictors of larval density using linear regression modeling.
3. Evaluate life-stage biodiversity trends to quantify ecological bottlenecks within the vector community.

Study Area

The study was conducted in Jere Local Government Area (LGA), Borno State, Northeastern Nigeria (Latitude 11°40'N to 12°05'N; Longitude 13°05'E to 13°20'E) (Figure 1). Jere lies within the Sudano-Sahelian climate zone, characterized by a low mean annual relative humidity (36%–41%), a short rainy season from June to September (humidity 60%–70%), and a long dry season (humidity 25% – 30%) [9]. Serving as a key peri-urban belt surrounding Maiduguri,

Jere features dense residential settlements, informal housing, communal borehole infrastructure, and irrigated agricultural lands, making it a high-risk zone for malaria and lymphatic filariasis [10].

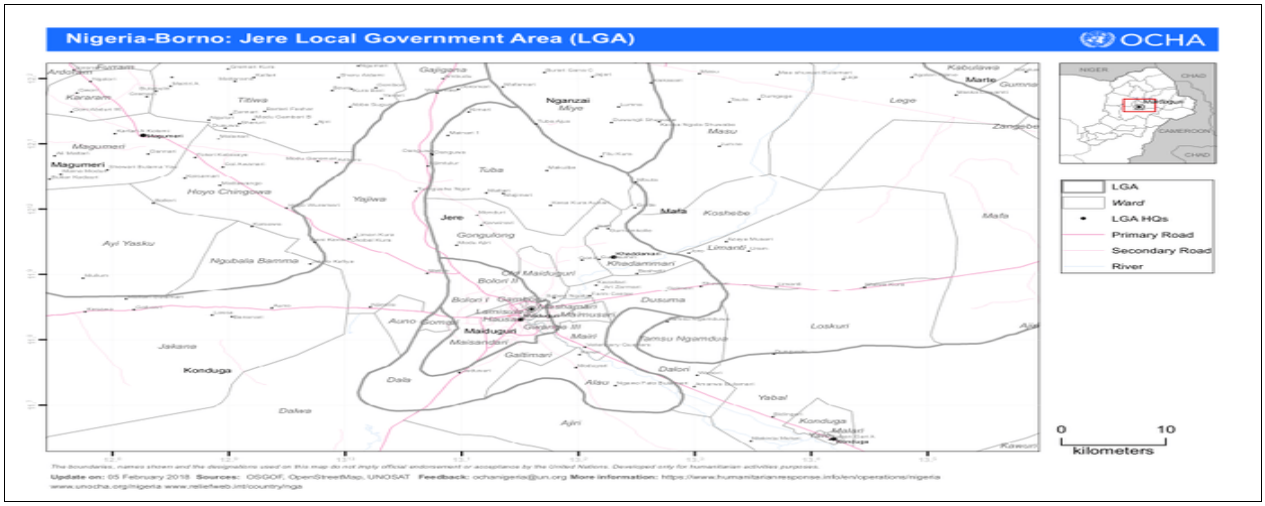

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Fig 1: Map of Jere Local Government Area Borno-Nigeria.

Sampling Design and Site Selection

A cross-sectional entomological survey was conducted across 15 sampling sites strategically chosen using a stratified sampling design to capture the ecological diversity of the LGA. Sampling sites were categorized into three distinct zones:

- **Zone A (Riparian/Riverine):** Habitats along the Ngadda River basin.
- **Zone B (Agricultural/Irrigated):** Rice paddies and vegetable farming plots.
- **Zone C (Peri-Urban/Residential):** Dense human settlements featuring open unlined gutters, communal borehole runoff pools, and discarded artificial containers.

A minimum distance of 1 km was maintained between sampling sites to ensure spatial independence.

Larval Sampling and Rearing: Larval sampling were carried out using standard dipping procedures [11, 12]. At each site, 10 dips were taken between 11:00 am and 13:00 pm using a 350 mL capacity standard dipper (Figure 2). Collected larvae were transferred into field-labeled containers and transported to the laboratory. Larvae were reared to the fourth instar under regulated conditions (27 ± 2 ºC, 70% ± 5% relative humidity) and fed a yeast suspension to facilitate morphological identification. Larval density was expressed as mean Larvae per Dip (LPD).

Fig 2: Mosquito Larval Sampling Dipping. Photographed by Raphael Njapdze, 2025.

Adult Mosquito Sampling: Two complementary methods were used to sample adult populations:

1. **Pyrethrum Spray Catches (PSC):** Conducted in 10 randomly selected human-occupied bedrooms per zone to capture indoor-resting (endophilic) mosquitoes. White cotton sheets were spread across the floor, and rooms were sprayed with a pyrethroid-based aerosol. Knocked-down mosquitoes were collected after 15 minutes.
2. **CDC Light Traps:** Three CDC light traps were deployed outdoors 10 cm above ground level overnight (18:00 to 06:00 hours) per sampling site to capture phototactic and outdoor-resting (exophilic) species.

Taxonomic Identification. Morphological identification of larvae and adults was performed under dissecting and digital microscopes (Figure 3) using standard Afrotropical

taxonomic keys [13, 14]. Diagnostic features examined included the respiratory siphon and pecten teeth (larvae), as well as wing scale patterns, palpal banding, and abdominal tergal markings (adults).

Fig 3: Morphological Identification. Photographed by Raphael Njapdze, 2025

Statistical Analysis: To evaluate species diversity across life stages, the Shannon-Wiener Diversity Index (*H'*) and Equitability (*E*) were calculated [15]. All quantitative data were analyzed using IBM SPSS Statistics Version 26.0 [16]. Species prevalence across habitats was evaluated using Pearson's Chi-square test (χ^2). A multiple linear regression model was fitted to determine environmental predictors (habitat types) of larval density (dependent variable).

Species Composition and Abundance: A total of 676 mosquito specimens were collected during the study (419 larvae and 257 adults). Five distinct species across three genera (*Culex*, *Anopheles*, and *Aedes*) were morphologically identified as shown on Figure 4. *Culex quinquefasciatus* was the overall dominant species, comprising 50.1% (n = 210) of larvae and 72.5% (n = 186) of adults. Among vectors causing malaria, *Anopheles gambiae s.l.* accounted for 24.3% (n = 102) of larvae and 21.0% (n = 54) of adults, while *Anopheles arabiensis* accounted for 13.1% (n = 55) of larvae. *Aedes aegypti* represented 7.0% (n = 29) of larvae and 4.5% (n = 12) of adults, and *Anopheles pharoensis* accounted for 5.5% (n = 23) of larvae as shown on Table 1.

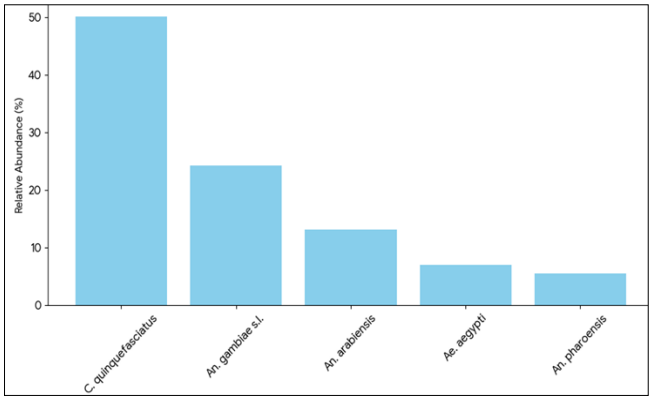

Fig 4: Percent distribution of adult mosquito genera across Jere LGA.

Environmental Predictors of Larval Density: Multiple linear regression modeling on Table 1 showed that, habitat type was a highly significant predictor of larval density (R^2 = 0.84, $p < 0.001$). Stagnant gutters exhibited the largest positive coefficient (B = 2.750, β= 1.222, $p < 0.001$), indicating they are the primary driver of mosquito productivity in Jere LGA. Rice fields (B = 1.050, $p < 0.001$) and stagnant pools near boreholes (B = 0.350, $p < 0.001$) were also significant positive predictors relative to container habitats.

Table 1: Multiple Linear Regression Model for Environmental Predictors of Larval Density

Predictor Variable	Unstandardized B	Std. Error	Standardized Beta (β)	t-value	Sig. (p)
(Constant / Containers)	1.450	0.041	—	35.30	< 0.001
Rice Fields	1.050	0.048	0.466	21.60	< 0.001
Stagnant Gutters	2.750	0.048	1.222	56.70	< 0.001
Stagnant Pools (Boreholes)	0.350	0.053	0.132	6.61	< 0.001

Dependent Variable: Larval Density (Larvae Per Dip)

Adult Capture Dynamics by Sampling Method: The choice of adult sampling method significantly influenced species yields (χ^2= 10.36, df = 2, p = 0.00565) as presented on Table 2. Pyrethrum Spray Catches (PSC) yielded predominantly endophilic *Culex quinquefasciatus* (80.0%) and *Anopheles gambiae s.l.* (18.0%), but captured few *Aedes* mosquitoes (2.0%). Conversely, CDC Light Traps captured a higher proportion of outdoor-active species, yielding 65.0% *Culex*, 25.0% *Anopheles*, and 10.0% *Aedes aegypti* (Figure 6). Multiple regression confirmed that genus identity was the primary determinant of total adult yield, with *Culex* exhibiting the highest capture coefficient (B = 87.500, p = 0.047).

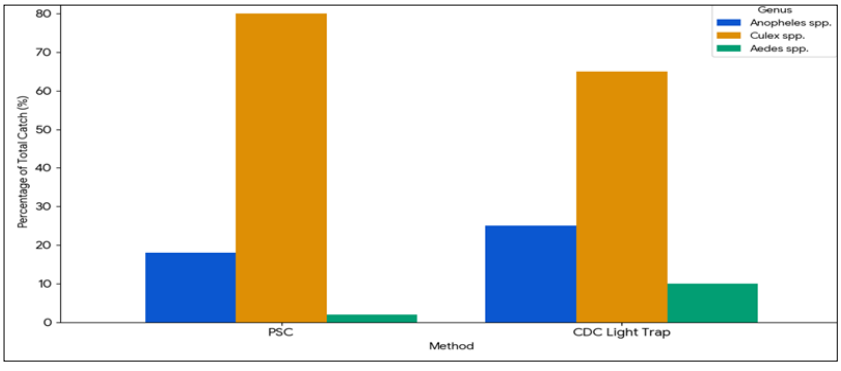

Fig 6: Comparative yield of mosquito genera by collection method (PSC vs. CDC Light Trap).

Table 2: Multiple Regression Analysis of Adult Mosquito Yields

Predictor Variable	Unstandardized B	Std. Error	Standardized Beta (β)	t-value	Sig. (p)
(Constant)	1.500	16.093	—	0.093	0.934
Method (PSC)	11.000	16.093	0.139	0.684	0.565
Genus (*Anopheles*)	20.000	19.710	0.239	1.015	0.417
Genus (*Culex*)	87.500	19.710	1.044	4.439	0.047*

* Statistically significant at $p < 0.05$. Reference category for Genus: Aedes.

Ecological Diversity across Life Stages: Community composition metrics demonstrated a major shift in species diversity between life stages as shown on Table 3. Species richness decreased from 5 species in larvae to 3 species in adults. The Shannon-Wiener Diversity Index dropped sharply from H' = 1.30 in larvae to H' = 0.71 in adults, while Equitability declined from E = 0.81 to E = 0.65.

Table 3: Comparative Biodiversity and Community Metrics between Life Stages

Statistical Metric	Larval Population	Adult Population	Ecological Shift
Species Richness (S)	5	3	Loss of 2 species
Chi-square ($\chi 2$)	294.59	10.36	null
P-value (p)	< 0.0001	0.0056	null
Shannon-Wiener Index (H')	1.30	0.71	Sharp Decline
Equitability (E)	0.81	0.65	Reduced Evenness

Discussion

This study provides a quantitative evaluation of how urban infrastructure and ecological filters shape vector distribution in Jere LGA, Borno State. The regression model highlights stagnant gutters as the single strongest predictor of larval density (B = 2.750, $p < 0.001$). Blocked, unlined drainage networks in peri-urban Jere accumulate organic waste, domestic sullage, and urban runoff. This organic-rich matrix creates highly favorable breeding conditions for *Culex quinquefasciatus*, enabling it to outcompete other species and produce high adult population densities [4, 7].

A key finding is the role of communal borehole overflow as permanent vector breeding sites. In semi-arid Sahelian settings, natural breeding sites dry out during the prolonged dry season [8, 10]. However, continuous wastewater accumulation around communal boreholes creates year-round "anthropogenic oases" [8]. Because these water points are situated within dense residential clusters, they shorten vector flight distances to human hosts, sustaining perennial vector-host contact and disease transmission even during dry months [7, 8, 10].

Adult sampling dynamics showed clear methodological biases. While Pyrethrum Spray Catches (PSC) efficiently sampled endophilic *Culex* and *Anopheles gambiae s.l.* inside dwellings, outdoor CDC Light Traps captured significantly more *Aedes aegypti* (10.0% vs. 2.0%). Relying solely on indoor collections like PSC would underrepresent outdoor-active vectors like *Aedes aegypti*, which is responsible for arboviral transmission in the region [1, 3]. Integrated vector surveillance must therefore combine indoor spray catches with outdoor light traps [11, 12].

The marked decline in biodiversity from larvae (H' = 1.30) to adults (H' = 0.71) illustrates a prominent ecological "survival bottleneck". While diverse species (*An. arabiensis*, *An. pharoensis*, *Ae. aegypti*) hatch in temporary larval habitats, the harsh microclimatic conditions of Jere LGA including high ambient temperatures, low indoor humidity, and indoor vector control pressure—act as selective filters [5, 6, 9]. Only highly adaptable, pollution-tolerant, and anthropophilic species specifically *C. quinquefasciatus* and *An. gambiae s.l.* successfully survive to maturity [7, 8].

Conclusion

The findings reveal Mosquito vector populations in Jere LGA are dominated by *Culex quinquefasciatus*, with significant populations of malaria vectors (*Anopheles gambiae s.l.* and *Anopheles arabiensis*). Anthropogenic habitat creation particularly unmaintained drainage gutters and borehole runoff pools is the main driver of vector density. To address these risks, the Environmental Health Department of Jere LGA and public health authorities should implement the following targeted measures:

1. **Urban Drainage Engineering:** Prioritize clearing, desilting, and lining stagnant gutters to eliminate primary *Culex* breeding grounds.

2. **Borehole Infrastructure Management:** Construct proper soakaway systems and drainage channels around communal boreholes to prevent water pooling.

3. **Targeted Larval Source Management (LSM):** Deploy biological larvicides (e.g., *Bacillus thuringiensis israelensis*) in permanent agricultural and drainage sites prior to peak transmission periods.

Ethical Considerations

The study was conducted in accordance with the ethical standards of the University of Maiduguri and local administrative guidelines. Informed verbal consent was obtained from all household heads and community leaders prior to the commencement of sampling within residential premises. Participants were informed of the study's objectives and the safety protocols regarding the collection methods. Ethical approval was not required as no human or animal was used.

Authors Contribution

Raphael Kawep Njapdze was responsible for Conceptualization, Laboratory Morphological Identification and Writing of the Original Draft Preparation.
Amina Abdullahi Muhammad did Data Curation.
Ibrahim Idris Gulani did Field Sampling,

Abba Umar did Supervision, Statistical Modeling Guidance. Idorenyin Bassey Ekerette did Critical Revision and Editing. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests. No financial or personal relationships exist that could inappropriately influence or bias the findings presented in this research.

Funding

This research was self-funded by the authors. No specific grant or financial support was received from any funding agency in the public, commercial, or not-for-profit sectors

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