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Spatial and Seasonal Patterns of Indoor-Resting Mosquitoes Across the Sudan and Sahel Savannah Zones of Bauchi State Nigeria

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Editorial

Indoor mosquito abundance varies across ecological settings and seasons and can provide useful surveillance information for malaria-vector control. This study conducted a secondary spatial and temporal analysis of previously collected indoor mosquito surveillance data from Bauchi State, Nigeria, with emphasis on ecological-zone and local-government-area patterns. The analysis used the LGA-level and monthly observations available from a previous pyrethrum spray catch (PSC) survey covering nine LGAs and 270 rooms. The available dataset contained 6,935 adult mosquitoes, including 2,841 *Anopheles gambiae* sensu lato. Four LGAs were classified within the Sudan savannah and five within the Sahel savannah. Descriptive frequencies, percentages and reconstructed monthly index summaries were used. Because original room-level replicate observations were unavailable for this secondary analysis, no new inferential tests were performed. Bauchi LGA contributed the largest adult mosquito catch (1,200; 17.3%), whereas Dambam contributed the smallest (506; 7.3%). *Anopheles gambiae* sensu lato represented 41.0% of all adult mosquitoes. Its proportional contribution ranged from 21.9% in Jama'are to 59.9% in Dambam. The monthly reported indices showed recurrent increases during June–August and generally lower values during parts of the late dry season. The mean reported monthly index was 2.52 in the Sudan-zone LGAs and 2.04 in the Sahel-zone LGAs in the reconstructed summary. The available surveillance data demonstrate spatial heterogeneity in indoor mosquito abundance and substantial variation in the contribution of *Anopheles gambiae* sensu lato across Bauchi State. The findings support continued geographically distributed surveillance, particularly around the rainy season. Because the present analysis is based on aggregate secondary data, the observed patterns should be interpreted as descriptive rather than causal or inferential.

INTRODUCTION

Malaria remains a major public-health concern in sub-Saharan Africa, where effective control depends on epidemiological and entomological surveillance that can identify when and where transmission risk is concentrated [1,2]. Mosquito abundance is not spatially uniform. Vector distributions reflect climate, larval-habitat availability, land cover, settlement structure and the biological differences among members of the *Anopheles gambiae* complex [3-5]. Consequently, statewide averages may conceal localized patterns that are relevant to vector-control planning. Nigeria contains several eco-vegetational zones and supports multiple malaria-vector taxa. Molecular surveys have shown that members of the *An. gambiae* complex differ among ecological settings, while longitudinal studies demonstrate pronounced

seasonal changes in vector abundance and transmission indicators [6-10]. Retaining the designation *An. gambiae* sensu lato is essential when specimens have not been resolved molecularly because sibling species can differ in habitat use, resting behaviour and response to insecticides [4,7].

Pyrethrum spray catch is commonly used to sample mosquitoes resting indoors after blood feeding, but valid comparisons require standardized room selection, collection effort and sampling frequency [2,11,12]. Counts aggregated across rooms or months cannot substitute for independent room-level observations when estimating variance or testing ecological effects. Molecular identification can strengthen interpretation of complex-level records, particularly where *An. gambiae*, *An. coluzzii* and *An. arabiensis* may coexist [13-15]. Seasonal

analyses likewise require linked rainfall, temperature and collection-effort data before climatic causation can be evaluated [16,17].

The source investigation reported 6,935 adult mosquitoes collected from 270 rooms across nine Bauchi State LGAs and included a separate blood-meal analysis [18]. The present study uses the aggregate surveillance component to describe spatial distribution, ecological-zone representation and monthly patterns. Its objectives were to summarize total indoor-resting mosquito abundance by LGA, quantify the contribution of *Anopheles gambiae* sensu lato, compare descriptive summaries for the Sudan and Sahel zones, and examine the reported monthly series from June 2019 to June 2021.

MATERIALS AND METHODS

Study design and setting

This was a secondary analysis of aggregate entomological surveillance records from Bauchi State, northeastern Nigeria. The Sudan savannah group comprised Bauchi, Dass, Kirfi and Ganjuwa LGAs. Katagum, Gamawa, Jama'are, Misau and Dambam were classified as Sahel savannah LGAs. Thirty rooms were represented in each LGA, giving 270 rooms in total. The available material listed three communities per LGA but did not retain linked community- or room-level counts.

Mosquito collection and identification

The source investigation used pyrethrum spray catch in occupied rooms in which at least one person had slept during the preceding night. Doors and windows were closed, floors were covered with clean white sheets, pyrethroid aerosol was applied and rooms remained closed for approximately 10-15 min. Knocked-down mosquitoes were recovered and transported for morphological identification. Records were available for all adult mosquitoes and for specimens identified as *Anopheles gambiae* sensu lato; no molecular sibling-species assignments were used in this analysis.

Variables and statistical analysis

The reconstructed dataset contained LGA, ecological zone, stated number of rooms, total adult mosquito catch, *Anopheles gambiae* sensu lato count and reported monthly index values. LGA contributions were expressed as frequencies and percentages of the overall catch. The proportion of *Anopheles gambiae* sensu lato was calculated within each LGA. Zone-level totals and mean catch per LGA were summarized separately because the Sudan and Sahel groups contained four and five LGAs, respectively. Monthly indices covering June 2019-June 2021 were summarized using arithmetic means and standard deviations. No p-values, confidence intervals or causal models were generated because independent room-level observations, repeated-room identifiers and complete monthly sampling denominators were unavailable.

RESULTS

Spatial distribution by LGA

The aggregate catch comprised 6,935 adult mosquitoes. Bauchi contributed 1,200 mosquitoes (17.3%), followed by Gamawa with 911 (13.1%) and Dass with 865 (12.5%). Dambam contributed the smallest number, 506 (7.3%) (Table 1). These totals describe the archived dataset and are not inferential comparisons among LGAs.

Table 1. LGA-level adult mosquito abundance and composition of *Anopheles gambiae* sensu lato.

LGA	Zone	Rooms	Adult mosquitoes, n	<i>Anopheles gambiae</i> sensu lato, n	<i>Anopheles gambiae</i> sensu lato, %
Bauchi	Sudan	30	1200	401	33.4
Dass	Sudan	30	865	267	30.9
Kirfi	Sudan	30	601	197	32.8
Ganjuwa	Sudan	30	648	298	46.0
Katagum	Sahel	30	742	399	53.8
Gamawa	Sahel	30	911	478	52.5
Jama'are	Sahel	30	761	167	21.9
Misau	Sahel	30	701	331	47.2
Dambam	Sahel	30	506	303	59.9

Anopheles gambiae s.l. represented 2,841 of 6,935 mosquitoes (41.0%). Its proportional contribution ranged from 21.9% in Jama'are to 59.9% in Dambam (Fig. 1). Gamawa had the largest absolute *Anopheles gambiae* sensu lato count (478), followed by Bauchi (401) and Katagum (399).

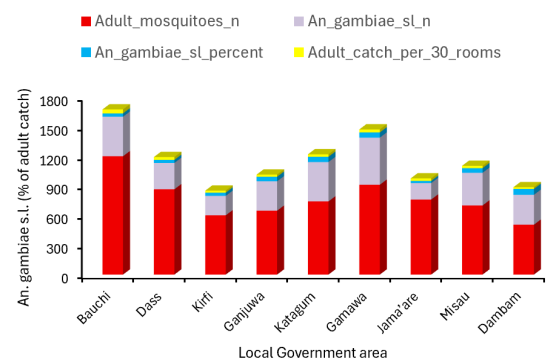


Fig. 1. Percentage contribution of *Anopheles gambiae* sensu lato to the adult indoor-resting mosquito catch in each LGA. Bars were reconstructed from the aggregate counts in Table 1; colours identify the ecological-zone classification.

Ecological-zone summary

The five Sahel LGAs contributed 3,621 mosquitoes (52.2% of the total), whereas the four Sudan LGAs contributed 3,314 (47.8%). Mean catch per represented LGA was 724.2 in the Sahel group and 828.5 in the Sudan group (Table 2). Because the groups contained unequal numbers of LGAs and monthly room-level effort was unavailable, the raw totals do not estimate an intrinsic difference in mosquito risk between zones.

Table 2. Adult mosquito catch summarized by ecological zone.

Ecological zone	Adult mosquitoes, n	Mean catch per LGA	Share of total, %
Sahel	3,621	724.2	52.2
Sudan	3,314	828.5	47.8

Seasonal pattern

The reconstructed monthly series showed recurring elevations around June-August (Fig. 2). Across the reported series, the Sudan-zone mean index was 2.36 (SD 1.00) and the Sahel-zone mean was 2.02 (SD 0.92) (Table 3). The series was retained as reported because the sampling denominator for each month could not be independently reconstructed.

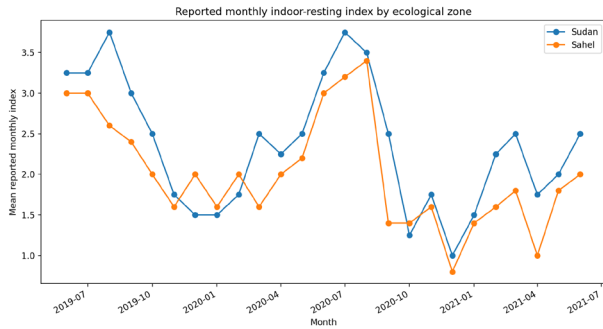


Fig. 2. Mean reported monthly indoor-resting index for the Sudan and Sahel savannah groups from June 2019 to June 2021. Points and connecting lines reproduce the aggregate monthly series supplied with the manuscript. Values are descriptive and are not adjusted for rainfall, temperature or month-specific sampling effort.

Table 3. Descriptive summary of reported monthly indices by ecological zone.

Zone	Mean monthly index	SD	Minimum	Maximum
Sahel	2.02	0.92	0	4
Sudan	2.36	1.00	1	5

DISCUSSION

The analysis demonstrates marked geographical heterogeneity in the archived indoor-resting mosquito counts. Bauchi produced the largest catch, while Dambam produced the smallest. Such variation is biologically plausible because African malaria vectors respond to local hydrology, vegetation, settlement and host availability [3,5,6]. Nevertheless, these counts cannot identify the responsible environmental factors because the source dataset lacked linked household and ecological covariates. The differences are therefore best interpreted as surveillance signals that can guide more detailed field investigation.

Anopheles gambiae s.l. accounted for 41.0% of all adult mosquitoes, but its contribution varied widely among LGAs. Similar ecological variation in complex membership has been documented elsewhere in Nigeria [6], and northern Nigerian populations include *An. coluzzii* with changing insecticide-resistance profiles [7,9,10]. Morphological complex-level identification does not support conclusions about individual sibling species. Future sampling should therefore combine morphological screening with validated molecular assays [13,14].

The recurring increase around June-August is compatible with seasonal mosquito dynamics reported in Nigeria and other West African settings [8,12,16]. Rainfall can create larval habitats, while temperature and humidity influence development, survival and host-seeking. However, the present monthly curve was not linked to meteorological observations or a recoverable month-specific denominator. It should not be interpreted as a quantified rainfall-response relationship. A stronger analysis would pair repeated room-level counts with remotely sensed or station-based environmental measurements and use models appropriate for overdispersed, clustered count data.

Zone totals also require caution. The Sahel group contained five LGAs and the Sudan group four; consequently, its larger raw total partly reflects geographical representation. Mean catch per LGA was higher in the Sudan group, but LGAs are not exchangeable experimental replicates and the available records do not capture within-LGA variation. Balanced longitudinal

sampling, documented revisit schedules and community-level denominators are necessary before testing ecological-zone effects [2,11,17].

Study limitations

The principal limitation was the absence of original room-level observations and complete sampling-occasion metadata. This prevented independent recalculation of indoor-resting density, evaluation of repeated-room dependence and valid inferential testing. The monthly index could not be tied to rainfall, temperature, vector-control coverage or consistent sampling effort. The map supplied with the source material also conflicted with the listed study LGAs and was therefore not used. Finally, *Anopheles gambiae* sensu lato was not resolved molecularly. These limitations restrict the analysis to descriptive secondary use of aggregate surveillance values.

CONCLUSION

Aggregate surveillance records from nine Bauchi State LGAs showed clear descriptive variation in indoor-resting mosquito abundance and in the contribution of *Anopheles gambiae* sensu lato. The monthly series displayed recurrent elevations around June-August, while ecological-zone summaries differed according to both catch and the number of represented LGAs. These findings support geographically distributed, year-round entomological surveillance but do not demonstrate causal ecological-zone or climatic effects. Future investigations should preserve room-level repeated observations, sampling denominators, environmental measurements and molecular species identifications.

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AUTHORS' CONTRIBUTIONS

The conceptualization of the study was led by A.A.O. Data analysis, review and editing were conducted by A.A.O. and G.U.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this article.

DATA AVAILABILITY STATEMENT

The aggregate values used in this secondary analysis are presented in the tables and figures. The original room-level field dataset was not available with the analytical material used for this study.

AI USAGE DECLARATION

During preparation of this work, the authors used OpenAI ChatGPT solely for language editing, grammatical correction, formatting support and refinement of readability. The authors reviewed and edited the resulting text and take full responsibility for the accuracy, integrity and final content.

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