Species Composition and Gonotrophic Stages of Indoor Resting Mosquitoes in Lecture Halls of University of Jos, Nigeria

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ABSTRACT Mosquitoes are important vector of several human diseases in tropical and sub-tropical Africa. Thus, this study was aimed to determine the species composition and gonotrophic stages of indoor resting mosquitoes in lecture halls of main campus, University of Jos. Collection of mosquito species was carried out between October and December 2016 from 6am-10am, using prokopack aspirator. An overall total of 8,139 indoor resting mosquitoes belonging to 1 family, 2 subfamily 3 genera and 3 species were collected and identified from 20 lecture halls. There was a significant difference ($P < 0.05$) in the mean abundance of mosquito species. *Culex quinquefasciatus* was the most abundant species of indoor resting mosquito collected. There was a significant difference in the mean number of male and female indoor resting mosquitoes.Whereas 6,283 representing 77.20% were males, 1,856 representing 22.80% were females. There was a significant difference in relation to blood digestion stages of indoor resting mosquitoes. 1,451 representing 78.18% of the total were unfed, 229 (12.34%) were gravid, 95 (5.12%) were fed and 81 (4.36%) were half gravid respectively. There was a significant difference in the abundance of indoor resting mosquitoes in relation to name of lecture halls. However, there was no significant difference in the abundance of indoor resting mosquitoes in relation to shape and type of walls respectively. The association of the overall abundance of indoor resting mosquito species with number of hall users correlated positively. Thus, periodic indoor residual spraying of lecture halls to reduce the vector density and thereby interrupting the transmission of mosquito borne diseases in the main campus of University of Jos should be carried out.

KEYWORDS: Species composition, mosquitoes, gonotrophic, shape and type of walls, University of Jos
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INTRODUCTION

Mosquitoes are important insect that affects human health (Ekwebene *et al*., 2020). This human pest are most successful in their mission not only because they survive in different habitats, but also because of their ability to rest indoors which tends to increase their chances of blood meals intake for their eggs development and disease transmission (WHO, 2020). Mosquitoes are important vector of several human diseases in tropical and sub-tropical Africa (Gbaye *et al*., 2017). Over 3000 species of mosquitoes have been described, 100 are known vectors that transmit diseases in human (WHO, 2020). *Anopheles* mosquitoes are the only species known to carry malaria, they also transmit filariasis (WHO, 2018; Njila *et al*., 2019). *Culex* mosquitoes are vectors of filariasis, avian malaria and arbovirus infections such as: West Nile virus, Japanese encephalitis (also called St. Louis encephalitis). *Aedes* are vectors of dengue, yellow fever and other viral diseases and sometimes of filariasis. *Haemagogus* and *Sabathes* are vectors of yellow fever in the forest of South and Central America and Mansonia are vectors of *Brugian filariasis* (Njila *et al*., 2022). Understanding the species composition and indoor resting patterns of mosquito vectors are important pre-requisite for designing appropriate long lasting control interventions. This research was focused on species composition and gonotrophic stages of indoor resting mosquitoes in lecture halls of University of Jos.

MATERIALS AND METHODS

Study Area

The study area is the University of Jos, located on latitude 09°57′01″N and longitude 08°53′21″E, Jos North Local Government Area (LGA), Plateau State. There are residential houses around the campus with business activities going on.

Mosquito Collection and Technique

Twenty (20) lecture halls scattered around the main campus of university of Jos were selected for mosquito collection. This are: B-block (with a total of six classrooms); Nursing block (with a total of four classrooms), Microbiology block (with a total of three classrooms), SLT block (with a total of two classrooms), CT block (with a total of four classrooms) and A1 (with a total of one classroom). Collection of mosquitoes was done forthrightly for a period of two months (October-December 2016) from 6am-10am. The Prokopack Aspirator Model 1412 (Vazquez-Prokopec *et al.,* 2009) was used for mosquito collection.

Morphological Identification of Mosquito

Mosquitoes collected were sorted and identified using Steindorff tri-power-stereo dissecting microscope. Mosquito species were identified morphologically using identification key provided by Gillies and Coetzee (1987).

Determination of Blood Digestion Stage

Depending on the stage of blood digestion and egg development (*i.e.* the gonotrophic stage), female mosquitoes collected were graded according to their abdominal conditions into unfed, freshly fed, half-gravid and gravid.

Determination of Indoor Resting Density and Man-Biting Rate

Indoor resting density (IRD) was calculated as the number of females divided by the number of halls. Man biting rate (MA) was calculated as the total number of freshly blood females (F) divided by the total number of occupants (w).

Statistical Analysis

Data was analyzed using R Console software version 3.2.2. T-test was used to compare the mean abundance between sexes of indoor resting mosquito species and mean abundance of mosquito species in relation to shape of halls and type of walls respectively. One way ANOVA was used to compare between blood digestion stages of indoor resting *Anopheles gambiae* and *Culex quinquefasciatus*. Chi-square test was used to compare between proportions of *Aedes aegypti* sexes, their blood digestion stages. Similarly, Chi-square test was used to compare between abundance of mosquito species in relation to names of lecture halls. Pearson's product-moment correlation was used to compare abundance of mosquito species in relation to number of users of lecture halls. The P-value < 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Composition of Mosquitoes in Lecture Halls

Species checklist of indoor resting mosquitoes generated at the end of this study is shown in Table 1. An overall total of 8,139 indoor resting mosquitoes belonging to 1 family, 2 subfamily 3 genera and 3 species were collected and identified from 20 lecture halls of the main campus of University of Jos.

The species checklist obtained could be based on habitat availability, population, climate, environment and human activities. This was reported by Okogun *et al*. (2003) and Ombugadu *et al.* (2020a, 2022) respectively in Esan and Etsako region of Edo State (formerly Midwestern Nigeria) and a peri-urban community surrounding an Institution of learning in Lafia metropolis of Nasarawa State, Central Nigeria that mosquitoes abundance is related to population, human settlement and activities. They reported that the Universities towns of Ekpoma as well as Mararraba-Akunza area respectively are occupied predominantly by students and farmers had a higher relative abundance of mosquito species. Wang and Liu (2013) also reported that many mosquito species are spread worldwide due to ecological, environmental, and human factors such as settlement.

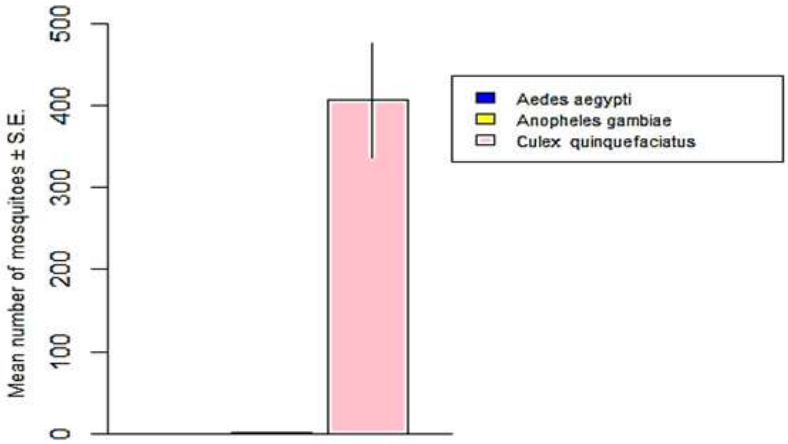


Figure 1. Mean abundance of mosquito species in lecture halls

The abundance of mosquitoes between species significantly varied (F_{28} = 8.889, Adjusted R^2 = 0.3447, P = 0.001, Figure 1). The breakdown of the results revealed *Culex quinquefasciatus* had 8,125 individuals representing 99.83% as the most abundant species of indoor resting mosquito collected. *Anopheles gambiae* had 13 (0.16%), while the least abundant as shown in Table 1 and Figure 1 was *Aedes aegypti* 1 (0.01%). The species checklist and mean abundance of indoor resting mosquitoes revealed that *Cx. quinquefasciatus* mosquitoes have the widest range of distribution in lecture halls of main campus of university of Jos and form the dominant genus in this study. This agrees with the respective findings of Ombugadu *et al.* (2020b, 2022) who reported the preponderance of *Cx. quinquefasciatus* over other mosquito species in hostels of the Federal University of Lafia (FULafia) as well as in the students dominated peri-urban settlement of Mararraba-Akunza area which surrounds FULafia's take-off site. Similarly, Amusan *et al.* (2003) surveying of adult mosquitoes in the hostel of University of Agriculture Abeokuta, Ogun State recorded *Cx. quinquefasciatus* as the most abundant species collected. Gbaye (2017) described *Cx. quinquefasciatus* as the commonest nuisance mosquitoes in most parts of Africa and it is a potential vector of filariasis. Its presence in large numbers in these study should not be ignored because it could transmit *Wuchereria bancrofti* the causative agent of filariasis. The low resting density observed in *Aedes* could be due to the fact that they were exophilic and exophagic. This agrees with the work of Okwa *et al*. (2007) in Lagos, Oringanje *et al*. (2011) in Calabar and Ombugadu *et al.* (2020a, 2020b, 2022) in Lafia who recorded low *Aedes* resting indoors in their work. The findings also revealed that a good number of *Anopheles* and *Culex* mosquito spp. were endophilic and endophagic.

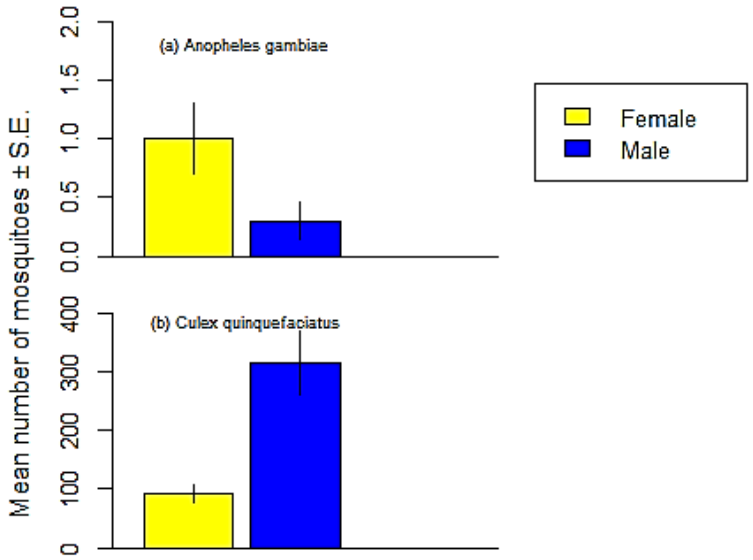
Table 1. Species checklist of indoor resting mosquitoes in lecture halls of University of Jos

Class	Order	Family	Subfamily	Species	Total (%)
Insecta	Diptera	Culicidae	Culicinae	*Aedes aegypti*	1 (0.01)
			Anophelinae	*Anopheles gambiae*	13 (0.16)
			Culicinae	*Culex quinquefasciatus*	8,125 (99.83)
			Total (%)		**8,139 (100)**

Sex-Wise Abundance of Mosquitoes

A significant difference (t = -3.1184, df = 35.321, P = 0.0036) was observed in the mean number of male and female mosquitoes resting indoors in the lecture halls. The population of males was 6,283 representing 77.20% whereas 1,856 representing 22.80% were females. The observed variation in the mean number of male and female mosquitoes resting indoors is attributed to the males going indoors in search of refuge. This is in contrast with the findings of Ombugadu *et al*. (2020a, 2020b, 2022) working on mosquitoes in students hostels of Federal University of Lafia and environs collected more females than males. However, there was no significant difference (χ^2 = 1, df = 1, P = 0.3173) between the mean number of males and females indoor resting *Ae. aegypti* in lecture halls. The single female *Aedes* species caught in this study is attributed to its diurnal behavior and ubiquitous mode of feeding. Also, it is a container inhabiting mosquito, often breeding in unused flowerpots, spare tires, untreated swimming pool and drainage ditches. In fact they thrive most in urbanized areas. Similar finding was reported by Nendongtok (1991). Females of *Aedes aegypti* are known vectors of yellow fever virus so the presence of this single species may or not pose any danger for now, but continuous monitoring of the campus for *Aedes* species is advocated.

Conversely, there was also no significant difference (t = 2.0896, df = 18, P = 0.0511) in the mean number of males and females *An. gambiae* (Figure 2a). This is contrary to the findings in hostels of FULafia and its environs where a high variation was found in favor of indoor resting female *An. gambiae* (Ombugadu *et al*., 2020a, 2020b, 2022). However, there was a significant difference (t = -3.958, df = 22.483, P = 0.0006) in the mean number of males and females *Cx. quinquefasciatus* (Figure 2b). This is in agreement with the report by Ombugadu *et al.* (2020b) who found higher number of *Cx. quinquefasciatus* males than females. On the other hand, Ombugadu *et al.* (2020a, 2022) reported a greater number of female *Cx. quinquefasciatus.*



Figures 2. The mean number of indoor resting mosquito species in lecture halls in relation to sexes

Abdominal Conditions of the Mosquitoes Caught in Lecture Halls

The blood digestion stages of indoor resting mosquitoes in the lecture halls varied significantly (F_{120} = 15.58, Adjusted R^2 = 0.2623, P < 0.001, Figure 3). The result showed 1,451 representing 78.18% of the total were unfed mosquitoes, 229 (12.34%) were gravid, 95 (5.12%) were fed and 81 (4.36%) were half gravid respectively. The observed variation in the mean number of indoor resting mosquitoes in relation to blood digestion stages and ovarian development with unfed having the highest number and half gravid the least may possibly be attributed to the absence of human baits (lecturers and students) in the lecture halls surveyed. This was linked to the completion of examination by most students at the period of mosquito collection and therefore fewer sources of blood meal. The result is

in line with the very high proportion of unfed female mosquitoes found over the other physiological conditions in a community surrounding a higher Institution (Ombugadu *et al.*, 2020a). This is in contrast with the findings of Gowda and Vijayan (1992) that collected higher number of fed *Culex quinquifaciatus* females resting indoors in Mysore city, Kamataka. Likewise, the fed female mosquitoes were predominant than other abdominal conditions considered in collections from FULafia hostels and environs (Ombugadu *et al.*, 2020b, 2022).

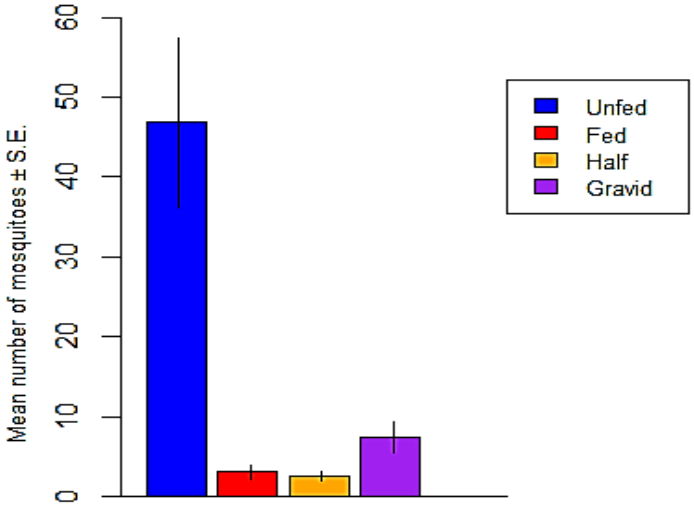
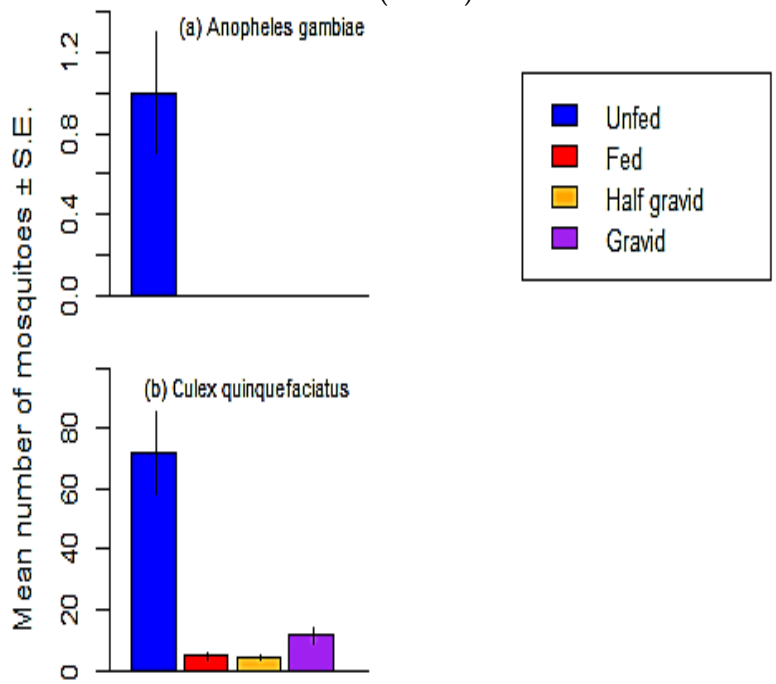


Figure 3. Mean number of indoor resting mosquitoes in lecture halls in relation to blood digestion stages

There was no significant difference ($\chi^2 = 3$, df = 3, P = 0.3916) in relation to blood digestion stage of indoor resting *Ae. aegypti* collected. The result revealed 1 unfed female representing 0.01%.There was a significant difference ($F_{36} = 11.25$, Adjusted $R^2 = 0.4409$, P <0.001) in relation to blood digestion stages of indoor resting *An. gambiae* collected (Figure 4a). The result depict unfed as the highest with 10 (100%). While fed, half gravid and gravid had the 0 (0.00%). Similarly, there was a significant difference ($F_{76} = 22.89$, Adjusted $R^2 = 0.4539$, P <0.001) in relation to blood digestion stages of the indoor resting *Cx. quinquefasciatus* collected (Figure 4b). The result showed unfed as the highest with 1,441 (78.10%) while the half gravid ones were the lowest 81 (4.40%).



Figures 4. The mean blood digestion stages of indoor resting mosquito species in lecture halls

Mosquitoes Distribution in Relation to the Various Lecture Halls

The pooled mosquitoes populations between the name of lecture halls (location of the halls) significantly varied ($\chi^2 = 4500.4$, df = 19, $P < 0.001$, Figure 5). The breakdown of the result showed that SLT 1 had the highest abundance of indoor resting mosquitoes of 1,157 (14.22%). While CT1C recorded the lowest abundance of indoor resting mosquitoes of 54 (0.66%). The dominance of indoor resting mosquitoes in SLT1 lecture hall compared to other lecture halls may be due to the study period and microclimatic conditions variability between the locations of the lecture halls. There was a lot of human activities going on around SLT1 during the study period thereby giving rise to the amount of carbon dioxide within the hall which served as a very quick cue to the mosquitoes in locating their human host. The Diploma students who are the major users of SLT 1 lecture hall were still on ground for their lectures. While other lecture halls are mainly used by undergraduate and remedial students who were on holidays. This concurs with the study by Tirados *et al.* (2006) on blood-feeding behavior of malarial mosquito *Anopheles arabiensis* observed that when humans are available, they were indeed the preferred host in any given population. Shililu (2001) revealed that the presence of mosquitoes is the interplay of multiple factors, such as the presence and proximity to mosquito breeding sites and variations in the physical characteristics of the housing types. This is consistent with the result in this study, where location of SLT 1 with the presence and proximity to more breeding sites such as ditches, drainage canals, tree holes and damage septic tanks that support higher abundance of indoor resting mosquitoes compared to the locations of other lecture halls.

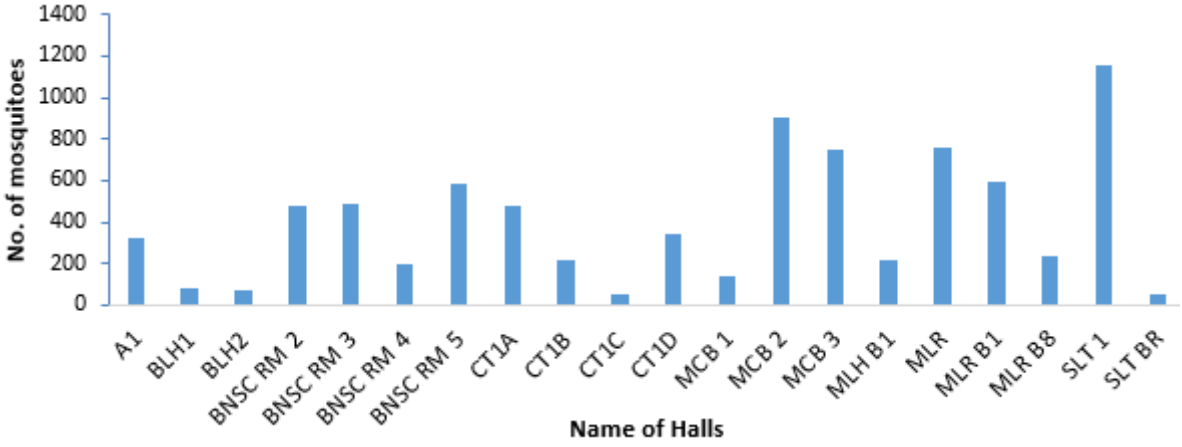


Figure 5. Abundance of indoor resting mosquitoes in relation to name of halls

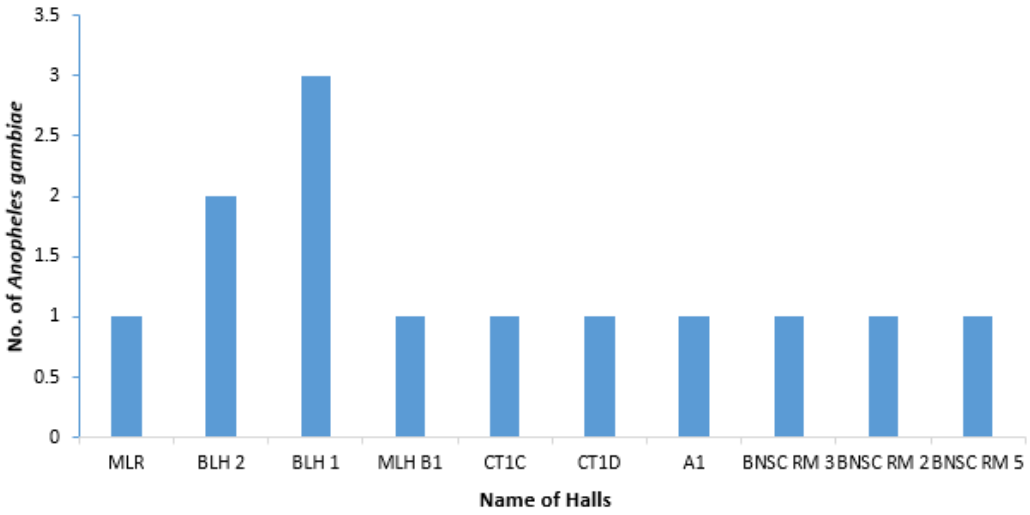


Figure 6. Abundance of indoor resting *Anopheles gambiae* in relation to name of halls

The indoor resting abundance of *An. gambiae* in relation to lecture halls showed no significant difference ($\chi^2 = 3.1538$, df = 9, P = 0.9579). BLH 1 hall had the most dominant number of *An. gambiae* 3 (23.08%) while BNSC RM II, BNSC RM III, BNSC IV, MLR, MLH B1, CT1C, CT1D and A1 were the least halls with 1 (7.70%) *An.* mosquito each as shown in Figure 6. However, for *Cx. quinquefasciatus*, there was a significant difference ($\chi^2 = 4512.6$, df = 19, P < 0.001) in the abundance of indoor resting mosquitoes *quinquefasciatus* in relation to the named lecture halls (Figure 7). SLT 1 and CT1C recorded the highest and lowest abundance of *Cx. quinquefasciatus* of 1,156 (14.23%) and 53 (0.65%) respectively.

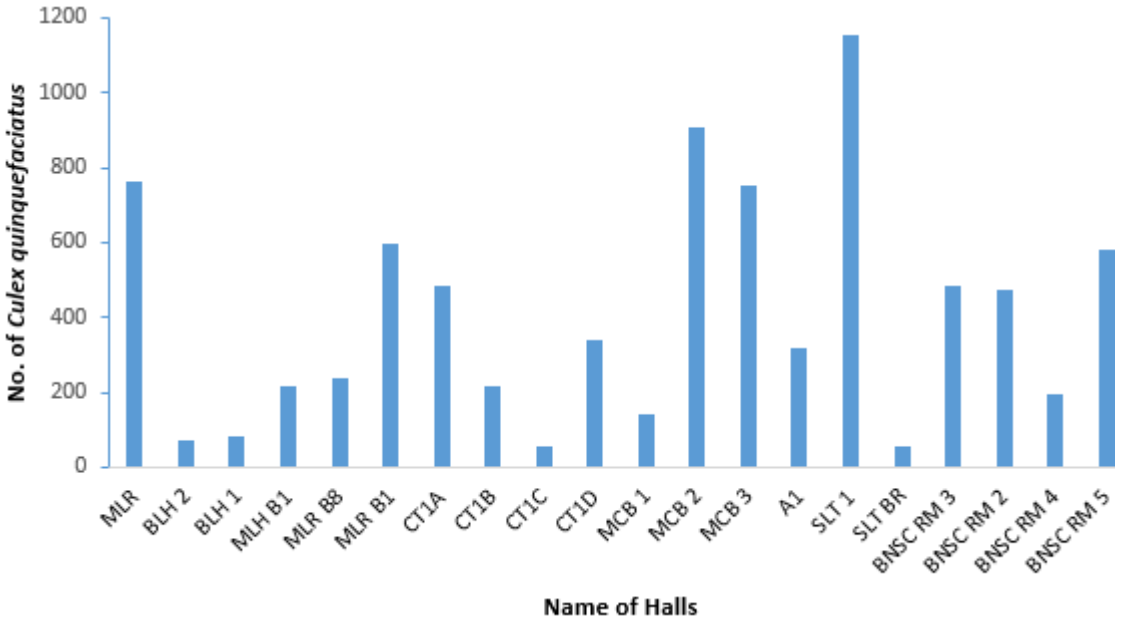


Figure 7. Abundance of indoor resting *Culex quinquefasciatus* in relation to name of halls

Occurrence of Mosquitoes in Relation to Lecture Halls Shape Types

The shape of lecture halls had no significant influence (t = 0.090451, df = 18, P = 0.9289, Figure 8) on the abundance of indoor resting mosquitoes. The lecture halls with rectangular shape had high abundance of 4, 134 (50.79%) indoor resting mosquitoes compared to lecture halls with square shape with 4,005 (49.21%). In this study, mosquitoes were well distributed in all the lecture halls of varying shapes, although higher abundance was found in lecture halls that are rectangular in shape. This is in contrast with the findings by Shililu (2001) who reported higher abundance of mosquitoes in rounded type of housing compared to the rectangular type of housing.

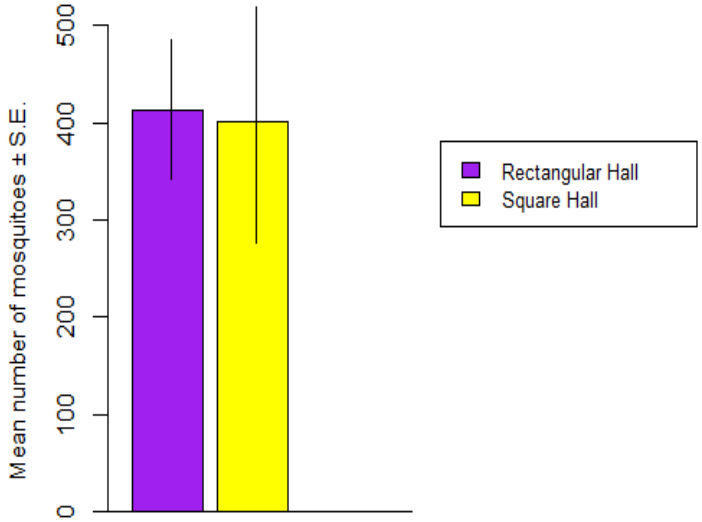


Figure 8. Mean abundance of indoor resting mosquitoes in relation to shape of halls

Wall Types Determines Mosquitoes Abundance

The abundance of indoor resting mosquitoes in relation to type of walls showed no significant difference (t = 0.28028, df = 18, P = 0.7825, Figure 9). Lecture halls of cement wall type recorded high abundance of 7,819 (96.87%) indoor resting mosquitoes than those with wooden wall 320 (3.93%). The lack of difference in the indoor resting mosquitoes abundance in relation to type of walls suggests that other regulating factors would have accounted for the presence of mosquitoes indoors and not wall types. This is in accordance with Ombugadu *et al.* (2022) who found out that mosquitoes have no preferred house type but rather display equal affinity to all house types available in an area. However, it has been previously reported that housing type with walls made of mud support high density of indoor resting mosquitoes compared with walls made of stone or concrete blocks (Umeanaeto *et al*., 2017). As a result, inhabitants of such houses are at greater risk of acquiring malaria (Gamage-Mendis, 1991). This is not in conformity with the findings of this work, were lecture halls made of cement recorded the highest abundance of indoor resting mosquitoes compared with those with wooden walls. The reason is two wall types were observed in this study, therefore one would expect that any of the walls will account for high indoor resting density of mosquito species. Shililu (2001) in a study of spatial distribution of malaria vectors in Eritrea, grouped wall types into seven categories: mud, mat, plaster, stone, thatch, tin and wooden and found wall type to be significant in explaining variation in mosquito densities.

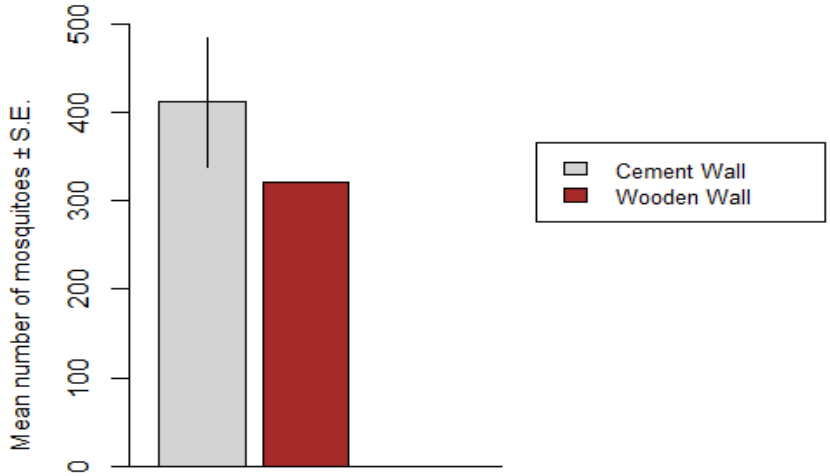


Figure 9. Mean abundance of indoor resting mosquitoes in relation to type of walls

Relationship between the Number of Hall Users and Mosquitoes Abundance

The pooled abundance of indoor resting mosquito species with number of hall users positively associated (t = 0.0021642, df = 29, P = 0.9983, r = 0.0004018733, Table 2). SLT 1 lecture hall with a total of 60 users had the highest abundance of indoor resting mosquito species of 1,157 (14.22%). The positive relationship seen here suggests that, the number of indoor resting mosquitoes will consistently increase as the number of hall users increases is in line with the findings of Lwetoijera *et al.* (2013) and Ombugadu *et al.* (2020b) who obtained similar record. Suffice it to say that, female mosquitoes need vertebrate host blood for reproduction and understanding this host-seeking behavior (Khan *et al*., 2021) would be essential for estimating the transmission of mosquito borne diseases, including malaria (Njila *et al*., 2022). The host-seeking behaviour is influenced by many factors, including host odour cues, host density, dispersal ability of the mosquitoes and host distribution availability. Indeed, where distribution of human populations is heterogeneous, the distribution of adult mosquitoes also tends to be heterogeneous even if the breeding sites are uniformly distributed in the environment (Imbahale *et al*., 2011). Based on the coefficient of determination value obtained, the number of students occupying the halls influenced mosquitoes abundance by 0.000016% while other factors were responsible for their abundance in the halls.

From Table 2, the relationship between the abundance of *An. gambiae* and number of hall users showed a negative association (t = -1.2158, df= 8, P = 0.2587, r = -0.3949) between the abundance of and number of users. But, there was a positive association (t = 0.58034, df = 18, P = 0.5689, r = 0.1355) between the abundance of *Cx. quinquefasciatus* and number of hall users (Table 2).

The indoor resting density (IRD) of female mosquito species are as shown in Table 3. *Culex quinquefasciatus* female had the highest IRD of 92.80 *Cx.* mosquito per lecture hall and the bite (MA) of a less than 1 *Cx.* mosquito per student compared to *Aedes aegypti* and *Anopheles gambiae* with 0.05 and 0.50 mosquito per lecture hall respectively (Table 3). Estimating the indoor resting density and human-biting rate is a key metric used for quantifying the risk of infection with mosquito-borne pathogens (Tangena *et al*., 2015). The higher IRD and MA of *Culex quinquifaciatus* confirmed that mosquitoes tend to be more endophagic, endophilic and anthropophagic, in order to avoid the harsh environmental outdoor conditions (Omoregie *et al*., 2019). Similar findings were reported for anopheline mosquitoes by Loaiza *et al*. (2008). The high IRD of adult female Cx. *quinquifasciatu*s was not surprising because the locations of the lecture halls surveyed contain numerous transient natural breeding habitats (Ombugadu *et al*., 2020). Previous studies by Imbahale *et al*. (2011) and Olayemi *et al*. (2014) confirmed that high proliferation of natural breeding sites guaranteed faster developmental and higher survival rates of immature stages of mosquito species.

Table 2. Association between abundance of mosquito species and number of hall users

Parameter	t	df	P	Correlation value (r)	Coefficient of determination (r^2)
Pooled abundance of mosquito species versus number of hall users	0.00216	29	0.9983	0.0004	0.00000016
An. gambiae abundance versus number of hall users	-1.2158	8	0.2587	-0.3949	0.1559
Cx. quinquefasciatus abundance versus number of hall users	0.58034	18	0.5689	0.1355	0.01836

Table 3. Indoor Resting Density and Man Biting Rate of female mosquito species in lecture halls of University of Jos

Mosquito Species	**Indoor Resting Density (IRD)** (No. of female mosquitoes/ No. of halls)	**Man-biting Rate (MA)** (Total No. of freshly blood fed females/Total No. of hall users)
Aedes aegypti	0.05	0.0004
Anopheles gambiae	0.50	0.0000
Culex quinquefasciatus	92.80	0.0401

CONCLUSION

Baseline information on species composition and blood digestion stages of indoor resting mosquitoes in lecture halls of University of Jos was provided. The findings regarding species composition and blood digestion stages of indoor resting mosquitoes is useful for planning prevention and control of vector-borne diseases, such as filariasis, dengue, yellow fever and malaria and the bites of the vectors can be prevented by quality indoor residual spraying and windows/doors screening of lecture halls to reduce the vector density and thereby interrupting the transmission of malaria and other mosquito borne diseases.

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