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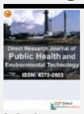

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Molecular Characterization and Malaria Transmission Potential of *Anopheles gambiae* Complex in Central Nigeria

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ABTRACT

Malaria is endemic to sub-Saharan Africa in which Nigeria accounts for the highest burden of the disease. Thus, this study characterized and determined malaria transmission potential of Anopheles gambiae complex in Federal University of Lafia (FULafia) and environs in Nasarawa State, Nigeria. Mosquito day catch survey was carried out from October to November, 2023 between 6:00am and 9:00am. Mosquitoes collected were transferred into a well labeled petri-dish and transported to the Department of Zoology Laboratory in FULafia for sorting, morphological identification and further molecular processing using polymerase chain reaction (PCR) technique. A total of 113 adult mosquitoes were collected which belong to two mosquito groups and spread across two species, Culex quinquefasciatus 84 (74.33%) and An. gambiae sensu lato 29 (25.66%). More female mosquitoes were collected 90 (79.6%) than males 23 (20.4%). Abundance of mosquitoes in relation to locations varied significantly (P < 0.05), although the students' hostels with the least mosquito population 22 (19.5%) yet had the highest population of Anopheles individuals 11 (50%). Less than one female Anopheles per room per night with a man biting rate of 0.1 bite/man/night. Out of the 20 Anopheles gambiae molecularly assayed, 90% (18/20) of them were Anopheles coluzzii while Anopheles gambiae sensu stricto accounted for the remaining 10% (2/20) and 70.0% of both Anopheles siblings were highly inclined to human host. Plasmodium infective stage was not found in the screened mosquitoes. In conclusion, entomological surveillance in the area should be continuous in order to achieve effective malaria vectors control strategies.

***Keywords**: Malaria, Molecular characterization, Anopheles mosquitoes, Sources of Blood meal, Lafia, Nasarawa State, Nigeria*

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INTRODUCTION

Malaria is endemic in about 32 countries of sub-Saharan Africa and these countries are responsible for almost 93% of malaria deaths worldwide. It is a major public health challenge in Nigeria due to the very high burden of the disease (31.9%) in comparison to other vulnerable countries (World Health Organization [WHO], 2022). Half of the global malaria mortality is pooled from four African countries, Nigeria inclusive (WHO, 2021). Malaria stands out as a major disease causing severe problem especially in the World Health Organization (WHO) African region. Global malaria report in 2021 revealed an estimated significant decline in malaria deaths from 896,000 in 2000 to 619,000 malaria deaths in 2022, also, malaria cases reduced to 247 million cases from the year 2000 (WHO, 2022). *Plasmodium* species are parasites transmitted through the bite of infected female anopheline mosquito resulting in malaria (Sitali *et al.,* 2019). They are a genus of protozoan (single-celled) parasite that belong to the Plasmodiidae family. Four different species of *Plasmodium* have been identified in humans: *P. falciparum*, *P. malariae*, *P. ovale* and *P. vivax*. Occasionally, humans become infected with *Plasmodium* species that generally infect animals, such as *P. knowlesi* (Sitali *et al.,* 2019). Several methods for identifying species of mosquito complexes have been developed such as the molecular investigation involving identification of members of the *Anopheles gambiae sensu lato* using polymerase chain reaction (PCR) techniques which is based on DNA specific nucleotide differences. This has become the standard method for species identification and studying the genetic structure (Scott *et al.,* 1993; Wilkins *et al*., 2006; Hamza *et al.,* 2014). Baseline surveys to collect this information need to be carried out prior to implementation of malaria vector control interventions and during on-going susceptibility surveys in order to guard against the development of increasing disease transmission and insecticide resistance (Nwankwo *et al.,* 2017; Ekerette & Ebere, 2022a; 2022b). Hence, this study was aimed at characterizing as well as determining the malaria transmission potential of *Anopheles gambiae* complex in a metropolitan higher Institution of learning and its environs in Central Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in the Federal University of Lafia community and environs. Federal University of Lafia (FULafia) which is situated in the Capital of Nasarawa State, and located in latitude 8º29´38" N and longitude: 8º30´5" E and 158 m above sea level. The temperature and relative humidity of Lafia is high. The wet season lasts for seven months which is between April and October, while the dry season is between November and March (Agidi *et al.,* 2017).

Ethical Approval

Ethical approval was sought from Nasarawa State Ministry of Health, through Human Research Ethics Committee Lafia, Nasarawa State (Approval No.: NHREC Protocol No: 18/06/2017). Also community heads and head of households were enlightened about the research and thereafter their consent was obtained.

Selection of Houses

Prior to the day of sampling, the hostels and houses surrounding the University were carefully selected as described by WHO (2013). A total of sixty rooms were selected. Students' hostel rooms were systematically selected (Ombugadu *et al.,* 2020a) while random selection was used for houses surrounding the University (Ombugadu *et al.,* 2022). All occupants of selected rooms were informed about the study in for them to keep doors and windows closed in the morning hours until rooms were sampled.

Mosquitoes Sampling

Mosquitoes were collected indoors during the late raining season period between October and November, 2023. Trapping of adult mosquitoes was done using battery powered Prokopack Aspirator during the morning period between 6:00am and 9:00am (Ombugadu *et al*., 2020a, 2022). The occupants of rooms sampled provided information on the status of insecticide usage and use of long lasting insecticide treated bed nets, respectively, the previous night before sampling.

Morphological Identification and Preservation of Adult Mosquito

Mosquitoes were sorted out and morphologically identified based on their visible features with the aid of a dissecting microscope and identification keys by Gillies and Coetzee (1987) and Buttachon *et al.* (2022*).* The *Anopheles* mosquitoes were well preserved singly in an Eppendorf tube containing silica gel and were later taken to The Molecular Entomology and Vector Control Research Laboratory of the Nigerian Institute for Medical Research (NIMR), Yaba, Lagos State, Nigeria, for further molecular analysis.

Entomological Transmission Indices

The entomological transmission indices considered as described by Williams and Pinto (2012) include indoor resting density (IRD), man biting rate (MBR), and human blood index (HBI) and sporozoite rate.

Molecular Characterization of *An. gambiae* Complex Siblings

DNA was extracted from twenty (20) *Anopheles gambiae s. l.* following the protocol by Collins *et al.* (1984) and processed at Nigerian Institute of Medical Research (NIMR), Yaba, Lagos State, Nigeria, using species-specific Polymerase Chain Reaction (PCR) as described by Scott *et al.* (1993). The *Anopheles gambiae* complex discrimination was done according to Wilkins *et al*. (2006) based on species-specific single nucleotide polymorphisms (SNPs) in the intergenic spacer region (IGS). The PCR cycling condition for amplification of the gene were 95°C/5min x 1 cycle; (95°C/30sec, 59.2°C/30sec, 72°C/30sec) x 30 cycles; 72°C/5min x l cycle, and 4°C holding for infinite time. Primers that were designed from the DNA sequence of the intergenic spacer (IGS) region of *An. gambiae s. l.* were added simultaneously to elucidate the ribosomal DNA type which include AR-3T 5'-GTGTTAAGTGTCCTTCTCCGTC-3',

GA-3T 5'-CTTACTGGTTTGGTCGGCATGT-3', ME-3T 5'-CAACCCACTCCCTTGACGATG-3', QD-3T 5'-GCATGTCCACCAACGTAAATCC-3', IMP-S1 5'-CCAGACCAAGATGGTTCGCTG-3', IMP-M1 5'-TAGCCAGCTCTTGTCCACTAGTTTT-3' and the Intentional Mismatch Primers (IMPs) IMP-UN 5'-GCTGCGAGTTGTAGAGATGCG-3' (Wilkins *et al*., 2006). The PCR product (amplicons) was loaded on a 1.5% agarose gel stained with ethidium bromide (EtBr).

Blood Meal Enzyme-Linked Immunosorbent Assay

Blood meal enzyme-linked immunosorbent assay (ELISA) protocol as described by Beier *et al*. (1988) was adopted for the twenty (20) mosquitoes screened for sources of blood meal. Individual mosquito for testing was prepared by grinding in 1.5 ml Eppendorf tube using 100 µl phosphate buffer saline (PBS) at pH 7.4. Unfed reared laboratory mosquito (*Kisumu* strain) was used as negative control while human, goat and bovine sera (Rockland antibodies & assays) were used as positive control. Affinity purified and peroxidase-labeled antibodies were obtained from Seracare (KPL).

Fifty (50) µl of mosquito triturate and respective controls were added to the wells of a microtiter plate, including a positive control consisting of 10 µl of human serum and 500 µl of PBS. The plates were incubated for 1 hour then washed twice with 200 µl of PBS-Tween 20 solution (prepared by adding 500 µl of Tween 20 to 1L of PBS). Fifty µl of prepared enzyme conjugate solution was added and incubated for 1 hour. The enzyme conjugate solution was prepared by mixing Affinity-purified antibody to human IgG (H+L) at 1:500 dilution (primary antibody), Peroxidase-labeled affinity-purified antibody to human IgG (H+L) at 1:1000 dilution (secondary antibody) and 1 µl of each antibody was mixed with 500 µl of PBS. The plates were washed three times with 200 µl of PBS-Tween 20 solution followed by addition of 100 µl of ABTS Peroxidase substrate to each well by mixing solution A and B (5 ml + 5 ml per plate). The plates were incubated for 30 minutes, and the absorbance was read at 414 nm. Samples were considered positive if absorbance values exceeded the mean plus the standard deviation of all replicates of the negative control.

Screening of Malaria Vectors for *Plasmodium* Infective Stage

Enzyme-linked immunosorbent assay (ELISA) was developed to detect *Plasmodium falciparum*, *P. vivax*-210, and *P. vivax*-247 circumsporozoite (CS) proteins in malaria-infected mosquitoes. A total of twenty (20) stored dried mosquitoes were screened for sporozoite. In order to achieve success in the CS-ELISA assay, the anti-sporozoite monoclonal antibodies (Mabs) was first put in the 96-well plate and adsorbed to the plate. After which, blocking buffer was added to prevent non-specific binding and then mosquito triturate added to the wells of the plate. Thereafter, peroxidase-linked anti-sporozoite Mab and ABTS substrate, respectively, were added to the wells (BEI Resources, 2020). A working solution of monoclonal antibodies (mAbs) capture was prepared by adding 5 ml of phosphate buffered saline (PBS) to the 40 µl of reconstituted capture mAb (stock) for a plate. The mixture was vortexed gently and 50 µl of mAb solution made was added to each well of the ELISA plate. The plate was covered and incubated for 30 minutes at room temperature.

Thereafter, well contents aspirated and plate banged upside down on paper towel 5 times, holding sides only. The wells were filled with 200 µl blocking buffer (BB) and the plate was covered and incubated for 1 hour at room temperature. The well contents aspirated and plate banged upside down on paper towel 5 times holding sides only. Samples and controls were loaded into the plate and covered and incubated for 2 hours at room temperature. Peroxidase substrate was prepared by mixing Substrate A and Substrate B at a 1:1 ratio. A full 96-well plate was 5 ml of Substrate A + 5ml of Substrate B. A working solution of mAb conjugate for *Plasmodium falciparum* (Pf) was prepared by adding BB to 10 µl of reconstituted capture mAb. Enzyme activity was checked by mixing 5 µl of the mAb conjugate with 100 µl of the substrate in a separate tube and vortexed gently.

A rapid color change indicated that the peroxidase enzyme and the substrate were functional. Well contents properly aspirated and plate banged upside down on paper towel 5 times holding sides only. The wells were washed two (2) times with 200 µl of PBS-Tween, aspirating and banging plate 5 times with each wash. A 50 µl of peroxidase conjugate solution was added to each well and the plate covered and incubated for one (1) hour. Well contents aspirated and plate banged upside down on paper towel 5 times holding sides only.

The wells were washed 3 times with 200 µl of PBS-Tween, aspirating and banging plate 5 times with each wash and a 100 µl volume of substrate solution was added per well. Plate covered and incubated for thirty (30) minutes. Plate was handled carefully to avoid splashing. Plates were read at 405 – 414 nm (Rogier et al., 2017). Samples whose absorbance values were above the cut-off (twice the mean absorbance value of the negative samples) were labelled positive for *P. falciparum* infection.

Statistical Analysis

Data obtained was analyzed using Minitab Statistical Package version 21.1.3. Simple descriptive statistics was used to determine the proportion of entomological transmission indices. Pearson's Chi-square test was used to compare abundance between mosquito groups, species, and sex, respectively. One-way analysis of variance was used to compare the abundance of mosquitoes in relation to locations. The level of significance was set at $P < 0.05$.

Table 1: Checklist of Mosquito Species in Relation to Locations.

Locations	*An. gambiae* (%)	*Culex quinquefasciatus* (%)	Total (%)
Bukan Kwato	0 (0.0)	27 (100.0)	27 (23.9)
Mararraba	18 (28.1)	46 (71.9)	64 (56.6)
Students Hostels	11 (50.0)	11 (50.0)	22 (19.5)
Total (%)	29 (25.7)	84 (74.3)	113 (100)

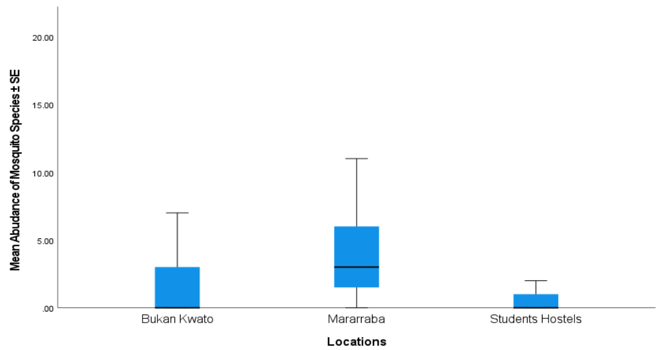

Figure 1: Mean Abundance of Mosquitoes in Relation to Locations

Table 2: Sex-wise Mosquitoes Abundance.

Species	Sex		Total (%)
	Male (%)	Female (%)	
An. gambiae s. l.	8 (27.58	21(72.4)	29 (25.66)
Culex quinquefasciatus	15(17.85)	69(82.14)	84 (74.33)
Total (%)	23 (20.4)	90 (79.6)	113 (100)

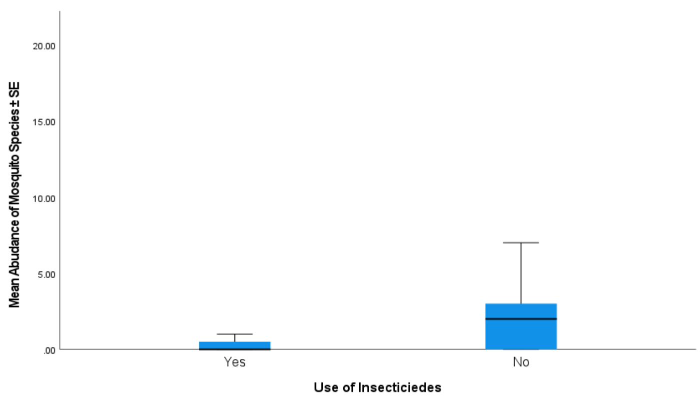

Figure 2: Mean abundance of *Anopheles* Mosquitoes in Relation to the Usage Status Insecticide Indoors.

RESULTS

Composition of Mosquito Species

A total of 113 adult mosquitoes collected in the study area belong to two mosquito groups (anopheline and culicine) which spread across two species as shown in (Table 1). Mararraba had the highest abundance of mosquitoes 64 (56.6%) followed by Bukan Kwato 27 (23.9%) and Students Hostels 22 (19.5%), respectively. Hence, there was a significant difference (df = 2, F = 10.72, P = 0.001, Figure 1) between mean abundance of mosquitoes in relation to locations. *Culex quinquefasciatus* was more abundant 84 (74.3%) than *An. gambiae s. l.* 29 (25.7%) as shown in (Table 1), and differences was significant (χ^2 = 23.6901, df = 1, P = 0.001). Table 2 shows that the population of female mosquitoes was dominant 90 (79.6%) over males 23 (20.4%), and sex-wise variations significantly differed (χ^2 = 35.0464, df = 1, P = 0.001).

Mean Abundance of Mosquitoes in Relation to Available Control Measures Status

Insecticide Usage Status

A low number of mosquitoes 1.00±1.98 was collected from the houses that used insecticide to those that don't use insecticide indoors 2.61±1.98 mosquitoes as shown in (Figure 2), and differences varied significantly (df =1, F = 4.44, P = 0.039).

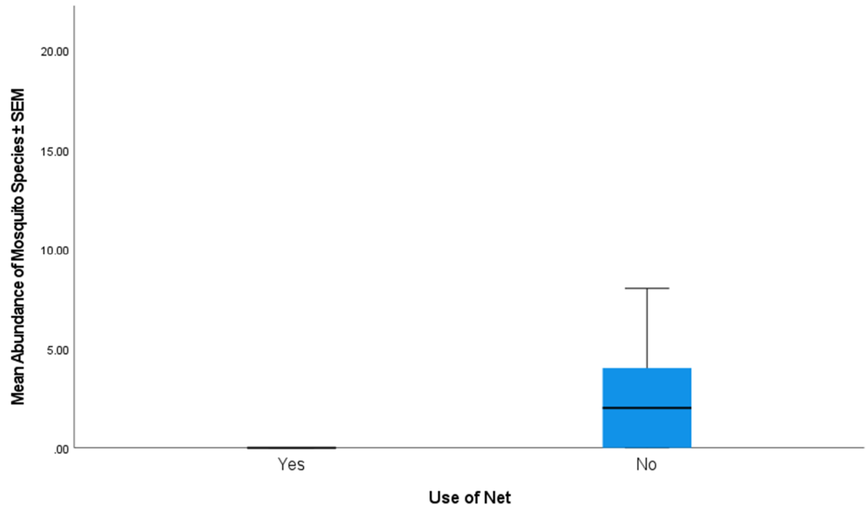

Figure 3: Mean abundance of *Anopheles* species in Relation to Status of the Use of Insecticide Treated Nets Indoors.

Table 3: Entomological Transmission Indices of *An. gambiae* (n = 29)**.**

Transmission Index	Value
Indoor resting density (n = 60 rooms)	0.5
Man biting rate (n = 285 persons)	0.1

Table 4: *An. gambiae s. l.* Siblings in an Institution of Learning and its Environs in Lafia, Nasarawa State.

Locations		Species	
	No. Examined	***An. coluzzi***	***An. gambiae s. s.***
Mararraba	9	8 (0.88)	1 (11.11)
Students Hostels	7	7 (1.00)	0 (0.00)
Bukan Kwato	4	3 (0.75)	1 (25.7)
Total	**20**	**18 (90.00)**	**2 (10.00)**

Use of Insecticide Treated Bed Nets (ITNs) Status

Figure 3 shows that fewer mosquitoes 0.85±1.85 were collect from houses that make use of insecticide treated beds nets than those that didn't sleep under ITNs 2.68±3.50 mosquitoes indoors. Yet, there was a significant difference (df = 1, F = 5.86, P = 0.019) in the mean abundance of *Anopheles* species between the two status of insecticide treated bed nets usage.

Entomological Transmission Indices of Malaria Vectors

The indoor resting density (IRD) of female *Anopheles* mosquitoes in this study was approximately one (1) mosquitoes/room/night and a man biting rate (MBR) of 0.1 bite/man/night (Table 3).

Composition of *An. gambiae s. l.* Siblings

Two *An. gambiae* siblings were recorded as shown in (Plate 1). Table 4 shows that *An. coluzzii* was more abundant 18 (90.0%) in Nasarawa LGA than *An. gambiae sensu stricto* 2 (10.0%), and differences in composition proportion between the two *An. gambiae* complex siblings varied significantly (χ^2 = 64, df = 1, P = 0.001).

Blood Meal Sources among the Two *Anopheles gambiae* Siblings

Table 5 shows that most individuals (6, 37.5%) of the two *Anopheles* siblings (*An. coluzzii* and *An. gambiae sensu stricto*) fed on human host followed by those that fed on both human, bovine and goat hosts (4, 25.0%) then human and goat hosts (3, 18.8%), bovine host only (2, 12.5%), human and bovine hosts (1, 6.25%), while no one fed on only goat host (0, 0.0%), however, differences across host preferences was not significant (χ^2 = 8.75, df = 5, p = 0.1194).

Prevalence of Sporozoite in *An. gambiae* Siblings

No sporozoite was recorded in the twenty *Anopheles* mosquito screened using ELISA technique as shown in (Table 6).

DISCUSSION

The species of mosquitoes encountered during this study implies the potential for the transmission of malaria in

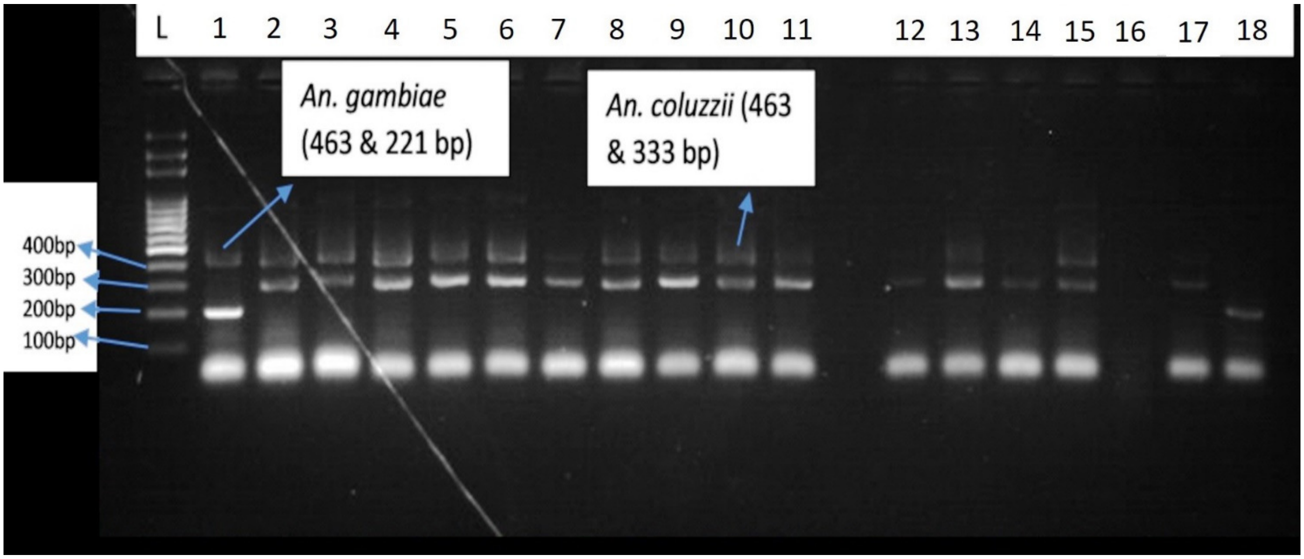

Plate 1: Agarose Gel Image of *An. gambiae s. s.* and *An. coluzzii* in Lafia Metropolis, Nasarawa State, Nigeria

Table 5: Sources of Vertebrate Blood Meal in Relation Two *Anopheles gambiae* Siblings.

Species	No. Examined	Human	Bovine	Goat	H/B	H/G	H/B/G
An. coluzzii	14	5 (35.7)	2 (14.3)	0 (0.0)	0 (0.0)	3 (21.4)	4 (28.6)
An. gambiae	2	1 (50.0)	0 (0.0)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)
Total (%)	**16**	**6 (37.5)**	**2 (12.5)**	**0 (0.0)**	**1 (6.25)**	**3 (18.8)**	**4 (25.0)**

Key: H/B = Human and Bovine; H/G = Human and Goat; H/B/G = Human/Bovine/Goat

Table 6: *Plasmodium* Infection Status in Two *An. gambiae* Siblings.

Species	No. Examined	No. Infected
An. coluzzii	18	0 (0.0)
An. gambiae s. s.	2	0 (0.0)
Total (%)	**20**	**0(0.0)**

academic training ground and its environs that may negatively affect the well-being of students which would result in economic loss and poor academic performance at the long run. The high population of *Culex quinquefasciatus* in this study indicates the presence stagnant polluted water bodies. This is in line with the findings of other researchers such as Okorie *et al*. (2014), Ombugadu *et al*. (2020a) and Njila *et al*. (2022) who reported *Culex* mosquitoes as the most abundant species in their studies. However, the finding in this study was contrary to that of various studies by Manyi *et al*. (2014), Ezihe *et al*. (2019), Ombugadu *et al.* (2020b) and Osidoma *et al*. (2023), respectively, who reported *Anopheles* mosquito as the most abundant.

The high number of indoor resting female mosquitoes than males could be due to their physiological need for blood meal in order to provide the requirednutrient for the development of their fertilized eggs. This agrees with the studies by Onyido *et al.* (2008), Madara *et al.* (2013) and Ombugadu *et al.* (2020a) who collected more female mosquitoes compared to males. Consequently, Okwa and Sulaimon (2004), Okwa *et al.* (2007) and Oyewole *et al.* (2007) confirmed more female mosquitoes than males in their studies.

The observed variation in the abundance of mosquitoes in favour of Mararraba area may be attributed to dense human population which influence high concentration of volatiles such as carbon dioxide (CO_2), habitat characteristics, breeding sites availability and poor sanitary conditions of the area. Similar findings were reported by Umeanaeto *et al.* (2019) and Ombugadu *et al.* (2020a) who reported variation of mosquito species abundance by locations in their works.

The use of mosquito net has been recognized as an effective, productive, and low-cost intervention that has greatly reduced malaria infection in endemic countries. The finding in this study shows that the ownership of mosquito bed nets and sleeping under it the night prior to entomological survey period significantly reduced mosquitoes population indoors and limited human-vectors contact that would have facilitated malaria transmission among indoor occupants. Our finding corroborates the report of Oluwaseun *et al.* (2021) during a study in some peri-urban communities in Southwestern Nigeria who found a significant reduction in malaria infection among those children who slept under the mosquito net which could be due to the protective capacity of the mosquito net. Mosquito net has been demonstrated to be highly effective in the control of malaria transmission if well utilized.

The overall indoor resting density about 1 mosquito per room in this study suggests a possibility of human-vector contact since the number of occupants in each room is a maximum of 4 persons. This is in line with the finding of Ombugadu *et al.* (2020a) who reported a room density of 2 mosquitoes per room. Similarly, Osidoma *et al*. (2023) reported a higher indoor resting density of 14.3 mosquitoes per room.

An overall man biting rate of less than 1 mosquito per man per night indicates a low occurrence of human-vectors contact due to the use of insecticides and or mosquito treated nets during the previous night by some individuals in the study areas. This is in agreement with the finding of Ombugadu *et al*. (2020a) who recorded a biting rate of 1 mosquito per man per night. This also agrees with the findings of Osidoma *et al*. (2023) who reported a higher man biting rate of 5 mosquitoes per man per night in two communities of Doma Local Government Area of Nasarawa State.

Anopheles coluzzii is the major malaria vector in the study area which may be attributed to the time this research was conducted which falls towards the end of the raining season and favourable farming practices, vegetation and breeding grounds. It has been documented that *Anopheles coluzzii* tend to be more abundant during the onset of the dry season (Adamu *et al*., 2023). The findings of this study is in line with the findings of Ukonze *et al.* (2023) and Egedegbe *et al*. (2023) who reported *Anopheles coluzzii* as the dominant species in rice farms randomly selected from four Local Government Area of Anambra state and in different communities in Ughelli North LGA, Delta State, Nigeria. However, this is not in disagreement with the findings of Atting and Akpan (2016) who reported *Anopheles gambiae s. s.* to be the most dominant *Anopheles* species collected in Oyo state, Nigeria.

The primary source of blood for *An. coluzzi* and *An. gambiae s. s.* was human host. Mixed blood meal from other potential sources (human, bovines and goats) were secondary. This indicates that the two malaria vectors in this study are highly attracted to humans which in turn makes such vertebrate host more prone to malaria and other diseases transmitted by the two *Anopheles* siblings. This is in agreement with the findings of Mutuku *et al.* (2011), Ndenga *et al.* (2016) and Abubakar *et al.* (2023) who reported human blood as the most preferred blood meal by *Anopheles* mosquitoes. The high prevalence of human host blood-feeding by *Anopheles* species observed here is consistent with Mzilahowa *et al.* (2012) findings from southern Malawi, in which blood meals were nearly entirely from humans and secondarily from bovines. However, previous literature by Altahir et al. (2022) reported that the blood meals of cattle to be higher, followed by human, dogs and goat. The secondary preference for other vertebrate hosts may attributed to the fact that people kept bovine and goats in their houses outdoors and in the event or instance that humans were not available then the animals in the compound were fed upon as alternative source of blood meal. This agrees with the assertion by Orsborne *et al*. (2020) on studies of mosquito populations in Ghana, who emphasized that local host availability even for known anthropophilic malaria vectors, is a powerful driver for host selection. This research agrees with previous findings and suggestions that malaria vectors have shifted a little from feeding on humans to animals (Getachew *et al*., 2019; Agudna *et al*., 2021). The presence of domesticated animals in the same house with humans may play a role in blood feeding habit of mosquitoes from both humans and animals (Ndenga *et al*., 2016). The presence of alternative host like goats and bovines can significantly affect mosquitoes feeding preference (Mayagaya *et al*., 2015; Ogola *et al*., 2017).

The absence of sporozoites in the *Anopheles gambiae* complex in this study could be attributed to fact that they were either nulliparous or did not feed on infected human hosts during blood meal. This agrees with the report by Oduola *et al.* (2021) who found 0% sporozoite infection rate in *An. arabiensis* in six localities of Kwara State North-Central Nigeria while Obembe *et al.* (2020) reported 0% sporozoite infection rate in *An. coluzzii* in Gaa-Bolorunduro, Kwara State, Nigeria. Our finding is contrary to previous research of Oyewole *et al*. (2010) who reported a sporozoite rate (SPR) for *An. gambiae s. s.* that ranged from 3.0% – 6.0% along Badagry Axis of Lagos Lagoon, Lagos, Nigeria. Also, sporozoite infection rate of 12.8% and 22.3 % for *An. gambiae s. s.* and *An. coluzzii* and was obtained during a survey in Kwara State, North-Central Nigeria (Oduola *et al.* (2021). Furthermore, Obembe *et al.* (2022) reported *Plasmodium falciparum* sporozoite infection rate of 1.6% in *An. gambiae*, 0.9% in *An. arabiensis* in Gaa-Bolorunduro, Kwara State, Nigeria. Ahouandjinou *et al.* (2024) reported sporozoite rate of 0.80% and 0.69% for *An. gambiae* and *An. coluzzii*, respectively, in Benin City, Nigeria. High sporozoite rates of 73.29% and 75.0% in *Anopheles gambiae* was documented in a study conducted in Rivers State, Nigeria (Noutcha *et al*., 2019). In Ethiopia, sporozoite infection was up to 3.88% between year 2001 to 2021 (Aschale *et al*., 2023).

Conclusion

This study clearly shows that mosquitoes are present in Federal University of Lafia students' hostels and environs. Mararraba area had the highest mosquito population. Majority of the female mosquitoes were blood fed. Mosquitoes easily accessed rooms that did not utilize aerosols as well as long lasting insecticide treated bed nets. *An. coluzzi* and *An. gambiae sensu stricto* are the two *An. gambiae* siblings present in the area and they prefer to feed on human host. Hence, students and individuals resident around the University community should always endeavor to make use of insecticide treated bed nets which is an effective measure for malaria prevention.

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