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ORIGINAL RESEARCH ARTICLE

Composition of Indoor Resting Malaria Vectors and their Seasonal Dynamics in Qua'an-Pan LGA, Plateau State, Nigeria

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ABSTRACT

Malaria vector surveillance offers data to aid in the successful planning of vector management. Thus, this study aimed to investigate the malaria vectors present indoors in some selected rural communities in Qua'an-Pan Local Government Area, Plateau State, North Central Nigeria. Endophilic mosquitoes were collected in the morning hours using the pyrethrum spray catch technique. Samples were sorted and identified using standard entomological keys. Thereafter, entomological transmission indices were analyzed. A total of 1,499 female *Anopheles* mosquitoes were collected, which belonged to five species, namely *Anopheles gambiae* and *An. funestus*, *An. coustani*, *An. rufipes* and *An. pretoriensis*. The predominant species was *Anopheles gambiae*, 1,278 (85.26%), followed by *An. funestus*, 103 (6.87%), while the least abundant was *An. pretoriensis* 10 (0.67%). Thus, there was a significant difference (χ^2 = 4008.95, df = 4, P= 0.0001) in mosquito abundance across species. The month of July recorded the highest indoor resting density (IRD) of 11 *Anopheles* mosquitoes/room/night, while February had the least with 1 mosquito/room/night, and differences between months significantly varied (χ^2 = 24.26, df = 11, P = 0.012). Similarly, the preponderant man biting rate (MBR) of 4 mosquito bites per person per night was still recorded in July, while the least MBR was recorded in both January and March with about one mosquito bite per person per night, but differences were not significant (χ^2 = 7.893, df = 11, P = 0.723). The overall one-year MBR was approximately 2 *Anopheles* mosquito bites/man/ night. Most of the female mosquitoes were fed 649 (43%). A high proportion of freshly fed mosquitoes (43%) indicates an ongoing risk of malaria transmission. The dominance of *Anopheles gambiae* in the study area necessitates continuous vector monitoring and intentional control measures.

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INTRODUCTION

Mosquitoes are insects that consume blood and are widely distributed around the world (Irikannu *et al.,* 2020). They breed around human habitations in bodies of stagnant water (Egbuche *et al.,* 2020). Mosquito bites and noise nuisance are considered public health adversaries since they have been linked to the spread of disease and sleep disturbances (Li *et al.,* 2021). They are acknowledged vectors of various viral diseases, including dengue fever, yellow fever, and Rift Valley fever, in addition to parasitic diseases such as filariasis and malaria (Wilkerson *et al.,* 2021).

The genus *Anopheles* comprises more than 400 mosquito species, with only about 30 of them being implicated in the transmission of malaria (Meyers *et al.,* 2016). *Anopheles gambiae sensu lato* (s. l.) and *Anopheles funestus* are the primary vectors in sub-Saharan Africa, owing to their significant ability to transmit *Plasmodium falciparum*, the most virulent *Plasmodium* species, and their pronounced anthropophilic behaviour (Sinka *et al.,* 2020). The two primary vectors in sub-Saharan Africa are *Anopheles gambiae sensu lato* (*s.l.)* and *Anopheles funestus,* which have high competence in spreading *Plasmodium falciparum,* the most lethal *Plasmodium* species, and a strong anthropophilic tendency (Sinka *et al.,* 2020).

The primary malaria vectors in Nigeria are *Anopheles gambiae s. s. Anopheles arabiensis*, *Anopheles coluzzii*, and the

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patchily *Anopheles funestus s. s.* (Ibrahim *et al.,* 2020). Malaria is a severe public health disease caused by *Plasmodium* parasites, which are spread by female *Anopheles* mosquitoes when they feed on human blood (WHO, 2020). Awosolu *et al.* (2021) identified *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, and *Plasmodium ovale* as the four principal malaria parasites that affect humans, while *Plasmodium knowlesi* is a zoonotic species found primarily in Southeast Asia.

The primary malaria parasites affecting humans are *Plasmodium falciparum*, *Plasmodium vivax, Plasmodium malariae*, and *Plasmodium ovale; Plasmodium knowlesi* is a zoonotic species prevalent in Southeast Asia (Awosolu *et al.*, 2021). Malaria is a global public health and socioeconomic issue that affects roughly 234 million people in Africa (WHO, 2022). Mozambique (3.8%), the Democratic Republic of the Congo (13.2%), Nigeria (31.9%), and the United Republic of Tanzania (4.1%) account for over half of all malaria-related deaths globally (Semakula *et al.,* 2023). The settings of most African towns promote the reproduction of malaria vectors due to poor housing, inadequate drainage systems, and insufficient sanitation (Hassen & Dinka, 2020). The economic impact of malaria in Africa is reported to be $12 billion annually, resulting from higher medical expenses, lost productivity, and a decline in tourism (CDC, 2021). It is estimated that malaria costs Africa $12 billion a year due to increased medical costs, lost productivity, and a drop in tourism (CDC, 2021).

According to Russell *et al.* (2020), entomological surveillance facilitates an understanding of regional and temporal shifts in vector species, as well as the efficacy of malaria vector control measures. Despite extensive vector surveillance in Nigeria, data from Qua'an-pan, a major agricultural hub with unique microclimates, remain scarce. This study addresses this gap by quantifying the species composition, seasonal abundance, and physiological states of indoor-resting vectors to inform localized control efforts.

MATERIALS AND METHODS

Study Area

This study was conducted in Qua'an-Pan LGA of Plateau State. The L.G.A is located between latitudes 8° 48' - 8.800° N and longitudes 9° 9' - 9.150° E. The area experiences two seasons in a year - the dry season (November to March) and the wet season (April to October)- with an average temperature of 28℃ and an elevation of 218 m (715 ft). The majority of the inhabitants are farmers, with a few civil servants. The inhabitants of the locality are renowned for producing a significant amount of guinea corn, rice, and yams.

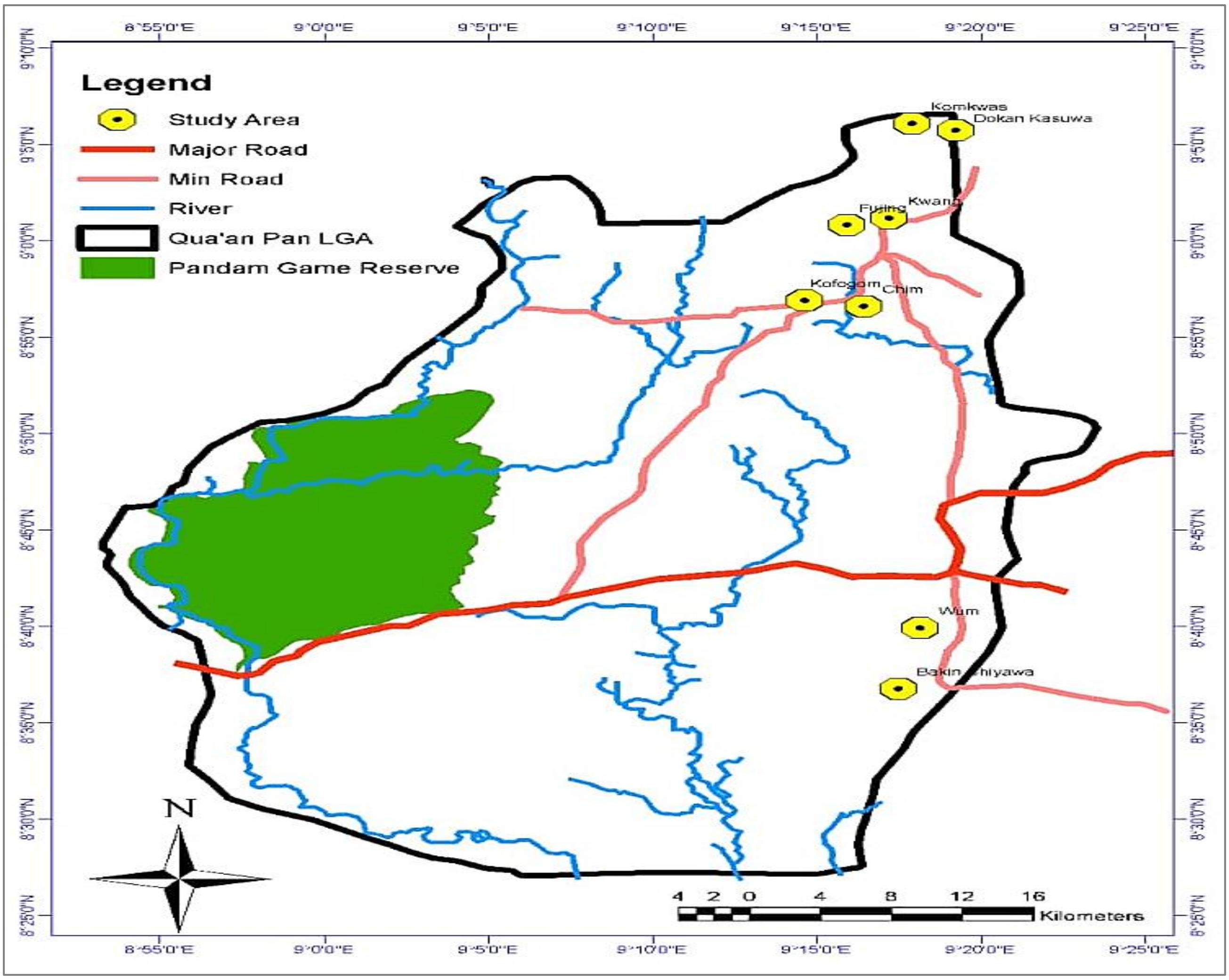

Figure 1: Sites Surveyed for Malaria Vectors in Qua'an-Pan LGA, Plateau State, Nigeria

Table 1: Checklist of *Anopheles* Mosquitoes in Qua'an-Pan LGA, Plateau State, Nigeria

District	Community	*An. gambiae*	*An. funestus*	*An. coustani*	*An. rufipes*	*An. pretoriensis*	Total (%)
Dokan/Kasuwa	D/Kasuwa	121	9	9	5	1	145 (10)
	Komkwas	174	10	12	6	1	203 (14)
Subtotal		**295**	**19**	**21**	**11**	**2**	**348 (23)**
Kwalla	Chim	53	3	2	0	2	60 (4)
	Kofogom	293	15	16	1	1	326 (22)
Subtotal		**346**	**18**	**18**	**1**	**3**	**386 (26)**
Kwande	Bakin-Chiyawa	235	15	7	3	0	260 (17)
	Wum	193	24	12	6	1	236 (16)
Subtotal		**428**	**39**	**19**	**9**	**1**	**496 (33)**
Kwang	Fujing	98	11	13	2	3	127 (8)
	Kwang	111	16	10	4	1	142 (9)
Subtotal		**209**	**27**	**23**	**6**	**4**	**269 (18)**
Total		**1278**	**103**	**81**	**27**	**10**	**1499 (100)**

Table 1.1: Morphological Identification of the Five *Anopheles* Species Collected in Relation to Their Respective Unique Observed Morphological Features

Species	Key identification features
An. gambiae	White interruption on the R1 vein of the third black area; sometimes contiguous with the proximal white area
An. funestus	Very small, black mosquito, solid black legs, palps 2x longer than head
An. coustani	Shaggy maxillary palps, white segments on the 3rd, 4th and 5th hind tarsi
An. rufipes	White hind tarsi, two pale spots on R1 vein in 2nd black area with no pale interruption in 3rd black area
An. pretoriensis	White hind tarsi, speckled legs

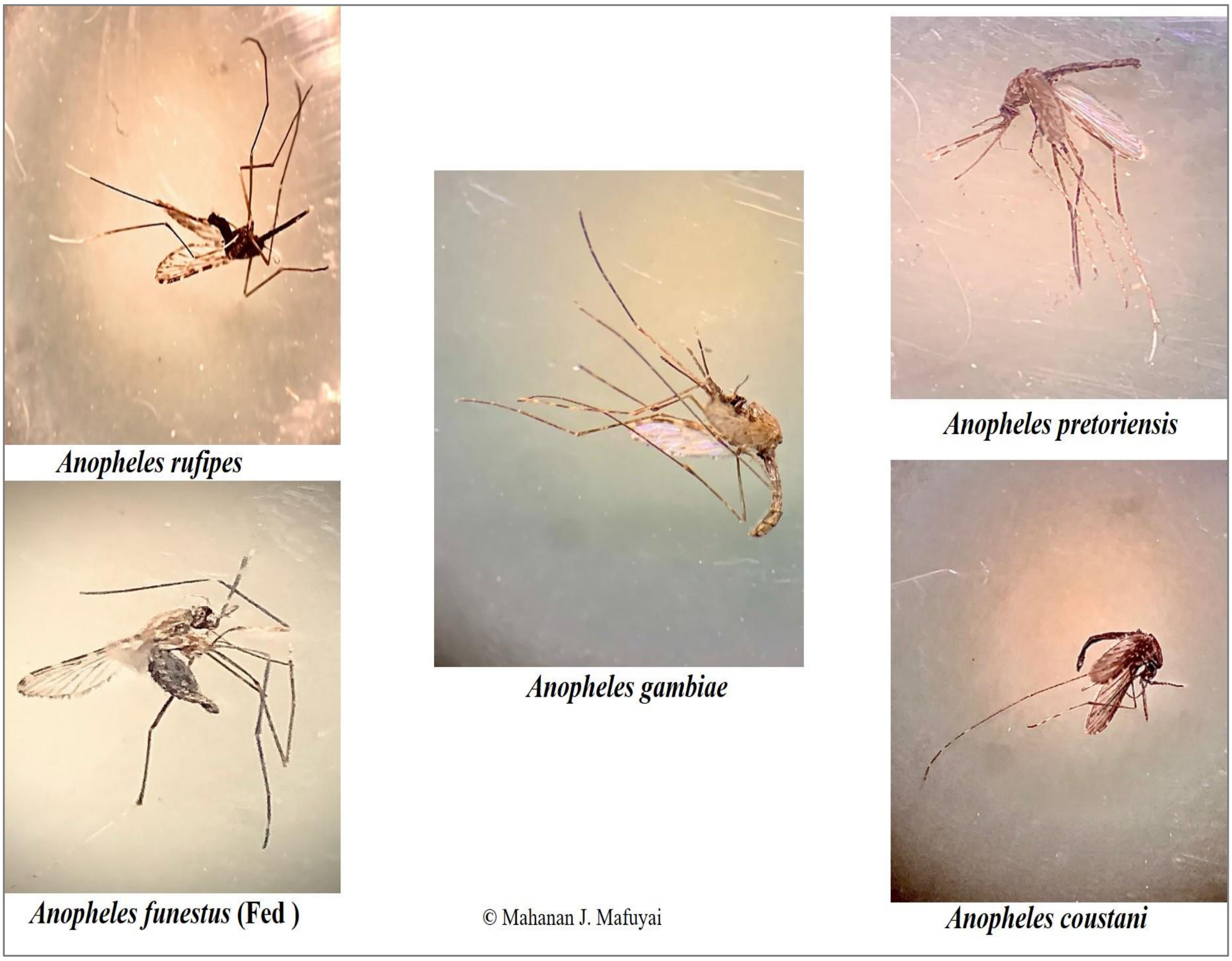

Plate 1: Malaria Vectors Present in Qua'an-Pan LGA, Plateau State, Nigeria

Study Design

Over a period of twelve (12) months, a longitudinal entomological study was conducted in the Qua'an-Pan Local Government Area of Plateau State, Nigeria. Four districts were randomly selected and sampled for the entomological investigation. Two (2) communities in each of the four (4) districts were chosen at random for the investigation. Out of the two (2) communities in every district, eight (8) households were selected at random and sampled for malaria vectors.

Ethical Clearance

Ethical clearance from the Plateau State Specialist Hospital Ethics Review Committee was obtained before the study commenced, bearing approval number (Reg. No. NHREC/05/01/2010b and Ref. No. PSSH/ADM/ETH.CO/2019/005). The locality's first-class chief granted permission for the study, and letters of notification were sent to the district heads prior to the study's commencement. Also, assent from the homeowners and community leaders was sought while the privacy of the household members was preserved.

Mosquito Sampling

The Pyrethrum spray catch (PSC) technique was used to collect the mosquitoes, as described by Williams and Pinto (2012) and Onyido *et al.* (2016). According to Abdoon and Alshahrani (2003), the technique is considered the most effective in capturing endophilic and anthropophagic mosquitoes. In this method, indoor resting mosquitoes were collected from 6:00 a.m. to 9:00 a.m. Nigerian time. In order to identify the mosquitoes that had been knocked down, white sheets were placed on the floor of each room. Then, a non-residual pyrethrum was sprayed throughout the room in a clockwise direction, moving toward the ceiling, until the entire space was covered with a fine mist. The room was then closed for ten minutes and reopened afterward. Beginning at the door of the room, the white sheet was lifted by its corners and carried outdoors. Every mosquito that was knocked down was collected with a forceps and placed in a petri dish lined with damp filter paper.

Morphological Identification of Mosquitoes

A morphological identification key created by Gilles and Coetzee (1987), Kent (2006), and Coetzee (2020) was utilised for the identification of mosquitoes. *Anopheles* mosquitoes were classified into species based on the morphological traits of their maxillary palps, wing spot patterns, and leg scales, with the aid of a dissecting microscope. Silica gel desiccants were used to preserve individual mosquito samples in Eppendorf tubes.

Assessment of the Physiological Condition of Indoor-Captured Mosquitoes

The physiological conditions of female mosquitoes captured indoors were assessed to analyse those with blood meals and those without. The mosquitoes were categorized into four groups: half-gravid, freshly-fed, unfed, and gravid (Service, 1985).

Determination of Indoor resting density and man-biting rate of mosquitoes

Williams and Pinto (2012) used a formula to calculate the indoor resting density (IRD) of female mosquitoes per structure per night and the man-biting rate (MBR) a person received from a specific vector per night.

IRD = Total number of vectors collected/[Total number of rooms sprayed]

MBR = Number of mosquitoes collected/[Number of people that slept in the room]

Statistical Analysis

Minitab statistical software (version 21.2) was used to analyze the collected data. Pearson's Chi-square test was used to compare the abundance of mosquitoes across species, entomological indices, and physiological conditions, respectively. The level of significance was set at $P < 0.05$.

RESULTS

Anopheles Mosquitoes composition in Qua'an-Pan LGA, Plateau State, Nigeria

A total of 1,499 indoor resting female *Anopheles* mosquitoes were collected across five species, namely, *Anopheles gambiae*, *An. funestus*, *An. coustani*, *An. rufipes* and *An. pretoriensis* (Table 1). The predominant mosquito species caught was *Anopheles gambiae* (1278, 85.26%), followed by *An. funestus* (103, 6.87%), and *An. coustani* 81 (5.40%), *An. rufipes* 27 (1.80%) while *An. pretoriensis* was the least in abundance with 10(0.67%) (Table 1). Hence, there was a significant difference ($\chi^2 = 4008.95$, df = 4, P = 0.0001) in abundance across the five *Anopheles* species collected. The striking morphological features used to identify the five *Anopheles* species is shown in Table 1.1. and the respective images are shown in Plate 1.

Population of *Anopheles* Mosquitoes in Relation to House Types

The result of the mean abundance of *Anopheles* species collected in relation to house type showed that the average abundance of *Anopheles* mosquitoes based on house types was higher in a mud/cement house with a zinc roof (113.0 individuals) than mud house with thatch roof (11.9 individuals). Hence, there was a significant difference ($F_1 = 16.11$, Adj. $R^2 = 6.13\%$, $P = 0.001$, Figure 2) in the average abundance of *Anopheles* mosquitoes between the two house types.

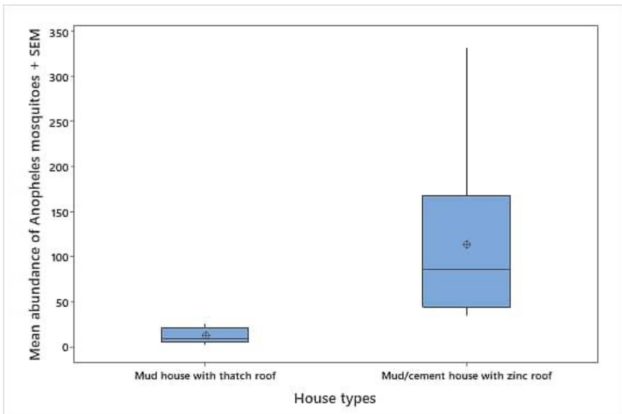

Figure 2: Mean abundance of *Anopheles* mosquitoes collected in relation to house types

Monthly Indoor Resting Density across *Anopheles* Species

The overall anopheline monthly average indoor resting density (IRD) all year round (at any period of the year) was 3.90 mosquitoes/room/night, as shown in Table 2. The species-wise monthly average IRD at any time of the year for *An. gambiae, An. funestus, An. coustani, An. rufipes, An. pretoriensis* was 3.32, 0.27, 0.21, 0.07, and 0.03 mosquitoes/room/night, respectively (Table 2).

The month of July recorded the highest anopheline indoor resting density of 11.1 female *Anopheles* mosquitoes per room/night followed 6.2 female *Anopheles* mosquitoes/room/night in August and September, respectively, while the least IRD of of 1.3, 1.2, and 1.4 female *Anopheles* mosquitoes/room/night, respectively, were observed in the month of January, February and March as shown in Table 2. Hence, anopheline IRD across the months varied significantly ($\chi^2 = 24.26$, df = 11, P = 0.012).

The peak IRD for *An. gambiae* and *An. funestus,* respectively, was in the month of July (10.47 mosquitoes per room/night) and August (0.59 mosquitoes per room/night), while their very low IRD was recorded in February (0.81 mosquitoes per room/night) and December (0.06 mosquitoes per room/night) (Table 2). With the exception of *An. gambiae,* the differences in IRD across the months for each *Anopheles* species showed no significant difference (P > 0.05) as shown in Table 2.

Table 2: Monthly Indoor Resting Density (IRD) Across *Anopheles* Species

Month	*Anopheles* Species					Overall Anopheline IRD
	An. gambiae	***An. funestus***	***An. coustani***	***An. rufipes***	***An. pretoriensis***	
January	0.97	0.16	0.19	0.03	0	1.34
February	0.81	0.25	0.13	0.06	0	1.25
March	1.09	0.22	0.13	0	0.03	1.47
April	1.94	0.22	0.22	0.09	0.03	2.5
May	3.88	0.34	0.25	0.06	0.03	4.56
June	4.13	0.38	0.31	0.06	0	4.88
July	10.47	0.25	0.28	0.13	0	11.13
August	5.13	0.59	0.28	0.22	0.06	6.28
September	5.84	0.19	0.09	0.09	0.03	6.25
October	2.63	0.28	0.41	0.06	0.03	3.41
November	1.53	0.28	0.22	0	0.06	2.09
December	1.53	0.06	0.03	0.03	0.03	1.69
Monthly Average IRD	**3.32**	**0.27**	**0.21**	**0.07**	**0.03**	**3.9**
χ^2	26.22	0.7	0.574	0.583	0.204	24.26
df	11	11	11	11	11	11
P-value	0.006*	1	1	1	1	0.012*

Table 3: Monthly Man Biting Rate (MBR) of *Anopheles* Species

Month	*Anopheles* Species					Overall Anopheline MBR
	An. gambiae	***An. funestus***	***An. coustani***	***An. rufipes***	***An. pretoriensis***	
January	0.45	0.07	0.09	0.01	0	0.62
February	0.41	0.13	0.06	0.03	0	0.63
March	0.46	0.09	0.05	0	0.01	0.62
April	0.86	0.1	0.1	0.04	0.01	1.11
May	1.61	0.14	0.1	0.03	0.01	1.9
June	1.67	0.15	0.13	0.03	0	1.97
July	3.85	0.09	0.1	0.05	0	4.09
August	2.05	0.24	0.11	0.09	0.03	2.51
September	2.23	0.07	0.04	0.04	0.01	2.38
October	1.11	0.12	0.17	0.03	0.01	1.43
November	0.6	0.11	0.09	0	0.02	0.83
December	0.64	0.03	0.01	0.01	0.01	0.71
Monthly Average MBR	**1.33**	**0.11**	**0.09**	**0.03**	**0.01**	**1.57**
χ^2	8.679	0.272	0.229	0.227	0.097	7.893
df	11	11	11	11	11	11
P-value	0.651	1	1	1	1	0.723

Monthly Man Biting Rate (MBR) Across *Anopheles* Species

The pooled monthly man biting rate (MBR) of *Anopheles* species on average was 1.57 mosquitoes' bites per man per night all year round. The month of July recorded the highest man biting rate of the bites of 4 female *Anopheles* mosquitoes/person/night followed by August 2.5 bites /person/night, September 2.3 bites/person/night while the least MBR per person per night in descending order was recorded in the month of November (0.83) > December (0.71) > February (0.63) > January (0.62) = March (0.62) as shown in Table 3. However, there was no significant difference ($\chi^2 = 7.893$, df = 11, P= 0.723) between anopheline monthly man biting rate.

Species specific MBR revealed that *An. gambiae* had the highest average monthly MBR of 1.33 mosquito bites/man/night all year round, followed by *An. funestus and An. coustani* with 0.11 and 0.09 mosquito bites/person/night, whereas *An. pretoriensis* had the least mosquito bite of 0.1 /person/night as seen in Table 3. The MBR based on months for each *Anopheles* species was not significant (P > 0.05).

Abdominal Conditions of Female *Anopheles* Mosquitoes Caught

A very high number of the female *Anopheles* mosquitoes caught were freshly fed individuals 649 (43%) followed by unfed ones 376 (25%) then those gravid 286 (19%) while the least was half gravid 188 (13%) as shown in Table 4, and differences between abdominal conditions differed significantly ($\chi^2 = 314.79$, df = 3, P = 0.0001).

Table 4: Abdominal Conditions of Female Mosquitoes Caught

Abdominal Condition	Number of Mosquitoes (%)
Unfed	376 (25)
Freshly Fed	649 (43)
Half Gravid	188 (13)
Gravid	286 (19)

DISCUSSION

The 1,499 indoor resting female *Anopheles* mosquitoes recorded in this study are of public health concern. The five *Anopheles* species (*Anopheles gambiae*, *Anopheles funestus*, *Anopheles coustani*, *Anopheles rufipes,* and *Anopheles pretoriensis*) encountered in this research are comparable to those obtained in past studies by Umar *et al.* (2021) and Osidoma *et al.* (2023), who identified *Anopheles gambiae*, *Anopheles funestus*, *Anopheles coustani*, and *An. nili* is the predominant *Anopheles* species in human habitation in Birshin Fulani village, Bauchi State, North-East Nigeria, and Doma LGA of Nasarawa State, North Central Nigeria, respectively. Among the five species identified in this research, *Anopheles gambiae* was the most abundant species, 1278 (85.26%). This may be due to the presence of numerous mosquito breeding sites in the area. This is in agreement with Chikezie *et al.* (2021), Osidoma *et al.* (2023), and Ombugadu *et al.* (2024a, b), who found that *Anopheles gambiae* was the most common mosquito species in Uyo, Akwa-Ibom State, Nigeria, and Nassarawa Eggon LGA and Nasarawa LGA, Nasarawa State, Nigeria. The results of this study also support those of Garba *et al.* (2020), that in sub-Saharan Africa and in Nigeria specifically, where the burden of malaria is at its peak, *Anopheles gambiae* is the primary malaria vector. Hien *et al.* (2020) also noted that *An. gambiae* was the most dominant species, accounting for 88% of all the vectors collected and also the most infected species. On the contrary, Ombugadu *et al.* (2022) and Benson *et al.* (2025) reported that *An. gambiae* had a low indoor abundance of 13.25% and 25.66%, respectively, in a peri-urban landscape in Nasarawa State, Nigeria. Also, in the investigation of indoor resting points of the main malaria vectors in western Kenya, Kawada *et al.* (2021) collected more female *An. funestus s. l.* (1499) than female *An. gambiae s. l.* (288).

Saili *et al.* (2023), in their investigation of *Anopheles rufipes* implicated in the indoor and outdoor transmission of malaria, found that *Anopheles funestus* was more common than *Anopheles gambiae* in rural south-east Zambia. Similarly, *An. funestus* was reported as the second most abundant (20.62%) malaria vector in a recent literature on vectors and malaria transmission in Bauchi State, Nigeria (Kurmi *et al.,* 2024). The presence *of An. funestus,* as the second most abundant species in this study, is in accordance with the finding of Matowo *et al.* (2021), who reported that *An. funestus* has shown relatively high vectorial capacity. According to Russell *et al.* (2011), *Anopheles funestus s. L.,* which is both anthropophilic and endophilic, is becoming increasingly significant in the spread of malaria in many parts of Africa, such as members of the *Anopheles gambiae* complex. Bamou *et al.* (2018) reported that mosquito species, including *An. coustani*, *An. pretoriensis*, and *An.* m*oucheti,* which were previously thought to be minor vectors of malaria, have lately been shown to play a major part in the transmission of malaria, along with several members of the *An. gambiae* complex (*An. merus*). Research by Saili *et al.* (2023) revealed that *An. rufipes* may have a role in the spread of malaria, despite its stated zoophilic, exophilic, and exophagic inclinations.

Anopheles mosquito indoor resting density (IRD) and man-biting rates (MBR) are indicators of human-vector interaction. Tangena *et al.* (2015) and Ombugadu *et al.* (2024c) reported that indoor resting density and man-biting rate are used to quantify the risk of infection with mosquito-borne pathogens. In this study, the highest indoor resting density was recorded in July, with a total of 11.1 *Anopheles* mosquitoes per room. This may be attributed to the favorable tropical weather conditions available in July, as well as the availability of breeding grounds in the sampled research communities. This agrees with the *An. gambiae* IRD findings of 18.05 and 25.4 mosquitoes per room per night in two LGAs of Nasarawa State, Nigeria, respectively (Osidoma *et al.*, 2023; Ombugadu *et al.,* 2024c). Our IRD finding aligns with the range reported by Umar et al. (2015), who found that female *Anopheles* mosquitoes had a greater indoor resting density (9.10 – 14.00) during the late rainy seasons. Ebenezer *et al.* (2013) found that *An. gambiae* had a room density of 20.5 mosquitoes per room in the lowland rainforest of Bayelsa State, Nigeria, which was greater than what was obtained in this study. However, the result obtained in this study was higher than the reports of Irikannu et al. (2020) and Ogbuefi and Aribodor (2023), who recorded indoor resting densities (IRD) of 2.20 and 1.40 mosquitoes per room, respectively. At the month-wise and species-specific levels, *Anopheles gambiae* had the highest monthly indoor resting density of 10.47 mosquitoes per room in July. This could be attributed to their preference for indoor feeding and resting. Ferreira *et al.* (2017) reported that *Anopheles gambiae* takes a rest indoors following blood feeding.

The highest monthly man-biting rate of 4 female *Anopheles* mosquitoes per person per night was recorded in the month of July. This is in line with the MBR of 8.5 and 4.51 mosquito bites per man per night as reported by Osidoma *et al.* (2023) and Ombugadu *et al.* (2024c). Similarly, Ogbuefi and Aribodor (2023) recorded an average MBR of 5.05 mosquitoes per person per night. Interestingly, Ebenezer *et al.* (2013) recorded an *An. gambiae* MBR of 8.7 bites per person per night in Bayelsa State, Nigeria, which was higher than our finding. Ezihe *et al.* (2017) recorded a man biting rate of approximately 4 mosquitoes per person in Enugu State, which was far higher than the findings of Irikannu *et al.* (2020) whose highest MBR was only 1.0 bites per person per night. Irikannu *et al.* (2019) in previous studies also recorded a low rate of man-biting, at 0.017 bites /person per night/night in Awka, Anambra State, Nigeria.

Anopheles gambiae exhibited the greatest human biting rate of 3.85 bites per individual in July. This is less than the results of Kouassi et al. (2023), who documented mean man-biting rates of 48.5, 81.4, and 26.6 bites per person each night in the Béoumi, Dabakala, and Nassian regions of Côte d'Ivoire, respectively. The high biting rates exhibited by *Anopheles gambiae* in this study were not surprising, as *Anopheles* mosquitoes prefer to live and feed indoors, as well as feed on human blood. Loaiza *et al.* (2008) asserted that to evade severe outside environmental circumstances, *Anopheles* mosquitoes exhibit a propensity for endophagy, endophily, and anthropophagy. The maximum human biting rates and indoor resting density of *Anopheles* mosquitoes observed in July may be attributed to favourable climatic circumstances and the abundant presence of the vectors.

More mosquitoes were collected in a mud/cement house with a zinc roof than in a mud house with a thatched roof. This is similar to the research of Njila et al. (2022a), who recorded a higher population of *An. gambiae* in a house type whose combination is of mud and cement over strictly mud or cement-only house types in Jos North LGA, Plateau State. On the other hand, Ombugadu *et al.* (2022) showed that a higher number of indoor resting mosquitoes (62.05%) were captured in cement block houses than in mud and mud/cement structures. Additionally, Ondiba et al. (2018) found that buildings with grass-thatched roofs had a greater abundance of malaria vectors than those with corrugated iron sheet roofs. Okech *et al.* (2004) found that mosquitoes resting indoors in homes with corrugated iron roofs survived just as well as those in homes with grass thatch, despite the higher temperatures inside the former. According to Lindsay *et al.* (2019), mosquitoes in metal-roofed homes tend to migrate from heated roofs to cooler areas near the floor in order to survive. This behavior could ensure their survival, thereby increasing their abundance in the metal-roof houses.

The literature by Okuneye *et al.* (2019) on the gonotrophic cycle of adult female mosquitoes categorized them as either being unfed, blood-fed, half-gravid, or gravid. Most of the adult female *Anopheles* mosquitoes in this study were freshly fed (649, 43%). This implies a high likelihood of malaria infection transmission if, perhaps, the mosquitoes harbor the infective stage of *Plasmodium*. This finding aligns with the results of Ombugadu et al. (2020) and Ombugadu et al. (2022), who reported that most female mosquitoes caught in students' hostels at the Federal University of Lafia and in a peri-urban community were blood-fed, at 72 (69.2%) and 308 (67.10%), respectively. Kawada *et al.* (2021) in their study also reported that blood-fed mosquitoes were most abundant compared to other physiological conditions. Additionally, a study in the southern part of Gombe State, Northeast Nigeria, revealed that most endophagic *Anopheles gambiae* fed on human blood (Maikenti *et al.,* 2025). However, Njila *et al.* (2022b) in their study on the gonotrophic stages of indoor resting mosquitoes in the lecture halls of the University of Jos also found that unfed female mosquitoes were the majority, at 1,441 (78.10%). Similarly, another study reported that unfed female mosquitoes were very high in number, at 2098 (45.9%), compared to other abdominal conditions (Ebenezer *et al.,* 2013).

CONCLUSION

This study identifies *Anopheles gambiae* as the primary vector in Qua'an-pan, with transmission risk peaking in July. Targeted indoor spraying and net distribution before July are hereby recommended. The findings of this study provide a baseline for evaluating vector control interventions in agriculturally active regions of North Central Nigeria.

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