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Spatial Monthly Distribution of Malaria Parasite and Anopheles Mosquitoes in Minna, Niger State, Nigeria

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ABSTRACT

Malaria is a life-threatening mosquito-borne tropical disease that continues to pose public health challenges in Nigeria. This study was conducted to evaluate the spatial monthly and seasonal distribution of *Anopheles* mosquito in Minna, Niger State, Nigeria. Mosquitoes were sampled using the Pyrethroid Spray Catch (PSC) technique and were identified morphologically using keys. A total of 3303 (100%) mosquito vectors were captured between June 2016 and May 2017. The total number of mosquitoes captured comprised, 791(23.95%) Anopheline and 2512(76.05%) Culicine. The highest number of mosquito vectors were captured in May 2017 with 528(15.99%) followed by 453(13.71%) in August 2016, while the least of 78(2.36%) were captured in November 2016 ($P<0.05$). Out of the 791(23.95%) *Anopheles* mosquitoes captured, the highest being 233 (44.13%) was recorded in May 2017. Seven (7) species of female *Anopheles* mosquitoes were encountered during the study period, namely: *Anopheles gambiae* (53.22%), *Anopheles funestus* (18.46%), *Anopheles squamosus* (4.55%), *Anopheles moucheti* (5.07%), *Anopheles coustani* (9.23%), *Anopheles nili* (7.21%) and *Anopheles pharoensis* (2.28%). This study revealed a high distribution of *Anopheles* mosquitoes in the study areas. The results of this study would be useful in planning an effective site-specific malaria vector control, as it highlights the need to give special consideration to the predominance of a single malaria vector, *Anopheles gambiae* in Minna, Niger State.

Keywords: Pyrethroid; *Anopheles*; Predominance; Minna; Niger State.

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INTRODUCTION

Malaria is a mosquito-borne disease in humans and animals [1, 2]. It is caused by parasitic protozoans of the genus *Plasmodium* with species P. *falciparum,* P.*vivax,* P*. malariae,* P*. knowlesi,* and P. *ovale.* The mosquitoes which act as vectors of this disease are female *Anopheles funestus, Anopheles moucheti, Anopheles gambiae, Anopheles arabiensis,* and other *Anopheles* species [3, 4].

Nigeria suffers the world's greatest malaria burden, with approximately 51 million cases and 207,000 deaths reported annually (approximately 30 % of the total malaria burden in Africa), while 97 % of the total population (approximately 173 million) is at risk of infection according to World Health Organization [5, 6, 7]. Moreover, malaria accounts for 60 % of outpatient visits to hospitals and leads to approximately 11 % maternal mortality and 30 % child mortality, especially among children less than 5 years old [5, 8]. Among the malaria parasites, *P. falciparum* is the most fatal species and exhibits complex genetic polymorphism which may explain its ability to develop multiple drug resistance and circumvent vaccines [9, 10, 11].

In Nigeria, malaria in pregnant women is a major public health concern because it is the major cause of maternal mortality. The major complications in pregnant women resulting from malaria are low birth weight in newborn babies, high placental plasmodia burden, foetal complications, and sometimes newborn death [12, 13].

Malaria is a fatal insect-borne tropical disease that continues to pose public health challenges with about 3.3 billion people at risk of being infected by the disease globally in 2023 [5]. This, however, was reduced to 3.2 billion people in 2015 probably as a direct result of the several global control efforts that eliminated malaria in some countries [6]. Africa carries the greatest burden of disease and it is one of the major causes of morbidity and mortality [14]. Globally, approximately 214 million cases of malaria occur annually [6] and 438,000 deaths were attributed to malaria in 2023, particularly in sub-Saharan Africa, where an estimated 90 % of all malaria deaths occur [6].

Malaria has been around for thousands of years and is still a major problem today. Despite efforts to eradicate malaria over the past 100 years, 149–274 million cases and 537,000–907,000 deaths from malaria occur in sub-Saharan Africa each year [15, 16]. Species of *Plasmodium* can infect reptiles, birds, and mammals. Of the more than 100 *Plasmodium* species, there are five (5) that infect humans. The transmission of the disease from one human to another involves mosquitoes of the genus *Anopheles* [17]. *Anopheles gambiae* is the principal vector of malaria in sub-Saharan Africa [18, 19] where more than 90% of the World's clinical cases are recorded [20, 21, 22]. According to recent World Health Organization's reports and statistics, malaria threatens the life and health status of about two-thirds of the world's human population, resulting in as much as 600 million clinical attacks and an estimated one million deaths annually [6]. The disproportionately high intensity of malaria transmission in sub-Saharan Africa is due to the widespread distribution and high vectorial capacity of the primary vector, i.e., *An. gambiae* in the region [23, 24]. Studies have established this anopheline species as one of the most efficient transmitters of *Plasmodium* parasites in the world. The epidemiological success of *An. gambiae* is largely dependent on its highly dynamic ecological behaviour [25] that has evolved over a long time due to certain tropical weather conditions that promote mosquito proliferation and human/vector contact.

Although, *An. gambiae* is widely distributed in sub-Saharan Africa, its behaviour and ecological adaptability vary considerably from one locality to another, partly dictated by spatio-temporal differences in seasonal weather conditions [26, 27]. Such temporal variations in anopheline vector behaviour, in response to seasonal changes in weather conditions in an area, are responsible for enormous heterogeneity in the intensity of malaria transmission and the efficacy of control measures [28]. Studies have shown that in the rainy season, anopheline mosquitoes tend to be more endophagic, endophilic and anthropophagic, to avoid the harsh ecological conditions outdoors [29, 30, 31]. Also, these mosquitoes breed more in natural larval habitats, such as temporary sunlit ground pools in the rainy season due to the high proliferation of such sites during the period which guarantee faster developmental and higher survival rates [32]. The local interactions of combinations of these important entomological drivers of malaria transmission, occasioned by behavioural responses of anopheline mosquitoes to prevailing weather conditions, will go a long way in determining vectorial efficiency and hence, the patterns of malaria transmission, as well as the efficacy of implemented vector-control measures. Also, residual indoor spraying with insecticides such as Pyrethroids and the use of insecticide-treated bed nets are more effective at controlling malaria vectors when vectors prefer to feed and rest indoors [33].

METHODOLOGY

Study Area

The study was conducted in Minna, Niger State, Nigeria. Minna is bounded to the north by Kebbi, Sokoto, Kaduna, and Federal Capital Territory (FCT) to the east, Benin Republic to the west, and Kwara and Kogi to the south.

The metropolis spreads across two Local Government Areas (LGAs) namely: Bosso and Chanchaga. The mean annual rainfall of Minna is 1334 mm with August and September recording the highest monthly rainfall of about 300 mm. The highest

monthly temperature is recorded in March with an average daily temperature of 30°C and the lowest in August at about 22°C. Minna has a tropical wet and dry climate with a pronounced dry season. Ten (10) different locations were randomly selected, five (5) each from Bosso and Chanchaga LGAs. These study locations include Bosso Estate, Tudun Fulani, Rafin Yashi, Dutsen Kura, Shanu Village, Maikunkele, Kpakungu, Tunga, Maitumbi and Chanchaga (Table 1).

Table 1: Global Positioning System (GPS) coordinates of the study sites

S/No	Study Sites	Latitude	Longitude
1	Bosso Estate	9°38'52"N	6°32'35"E
2	Tudun Fulani	9°38'41"N	6°32'31"E
3	Rafin Yashi	9°38'56"N	6°32'50"E
4	Shanu Village	9°36'50"N	6°32'01"E
5	Maikunkele	9°36'48"N	6°32'49"E
6	Tunga	9°38'24"N	6°32'29"E
7	Dusten Kura	9°35'32"N	6°31'48"E
8	Kpakungu	9°38'36"N	6°32'24"E
9	Maitumbi	9°37'44"N	6°34'40"E
10	Chanchaga	9°39'13"N	6°32'20"E

Each of these houses was chosen based on the condition of windows, doors, and walls before they were examined, and whether the houses had closed or open eaves. The surroundings of the households were examined and any nearby water bodies, cattle sheds, or other animal sheds noted. Other environmental variables recorded included whether the houses were located at the edge or in the middle of the villages and whether people kept animals, such as cattle, pigs or chickens.

Pyrethrum Spray Collection (PSC)

A total of 10 houses per LGA per month were sampled using the Pyrethrum Spray Collection (PSC) method as described by WHO (2005, 2008) to sample indoor-resting mosquitoes. The houses were sampled by two persons, using an aerosol insecticide (Baygon) containing the active ingredients of 0.05 percent Imiprothrin, 0.05 percent Prallethrin, and 0.015 percent Cyfluthrin.

Before spraying, the floors were covered with clean white bed sheets, outlets were closed, and the two sprayers began spraying as they moved in opposite direction, spraying inside the room after which the door was closed for 15 minutes and then opened so the sprayers would enter and collect mosquitoes. Mosquitoes that were knocked down were collected from the white cloth that was laid down before spraying. The spraying was done between 6:00 am and 9:00 am.

The mosquitoes were collected using feather-weight forceps and then placed in Petri dishes or paper cups containing a damp filter paper. Anopheline mosquitoes were preserved on damp absorbent paper in a cool box, transported to the Department of Animal Biology Laboratory, Federal University of Technology, Minna, Niger State and later identified to the species level by morphological criteria [18, 34, 35, 36].

Morphological Identification of Mosquito Samples

All mosquitoes collected were identified and sorted out under a stereomicroscope (Leica model NSW series IMNS 210) and Olympus Tokyo VT-II 225329 Entomological microscope. All mosquitoes were identified using the morphological keys of Gillies and De Meillion [34], and Gillies and Coetzee [18] by sex and whether they were anophelines or culicines.

Data Analysis

Data generated were analyzed using the SPSS software version 20.0 and Excel package. The monthly spatial distribution patterns of the malaria vector species and the Culicine genera, i.e. *Culex* spp. mosquitoes were presented graphically. The graph was also used to represent the environmental data obtained from the study areas. The relationship between the seasonal relative abundance of mosquito vector individuals in the study was evaluated using Chi-Square analysis. The relationship between *Anopheles* species and months/season was analyzed using one-way ANOVA. Statistical analyses on abundance data of predominant species and environmental variables to species distributions were analyzed. Pearson correlation coefficients were computed for the dominant species using SPSS 20.0 to assess the correlations between mosquito abundance and environmental variables.

RESULTS

This study established that seven (7) species of *Anopheles* mosquitoes were encountered during the study period; *Anopheles gambiae, An. funestus, An. squamosus, An. moucheti, An. coustani, An. nili* and *An. pharoensis*. The highest *Anopheles* mosquito species population was recorded in May. The distribution of *Anopheles* mosquito species varies significantly (P<0.05) monthly. *Anopheles gambiae* was the dominant species throughout the study period while the least was *An. pharoensis*. The highest number of *An. gambiae, An. funestus, An. coustani*, and *An. nili*, were recorded in May, while *An. squamosus* was highest in August, *An. moucheti* and *An. Pharoensis* was highest in April.

Monthly relative abundance of mosquito vector individuals in Minna

A total of three thousand, three hundred and three (3303) mosquito vectors were sampled between the period of June 2016 and May 2017. Of the 3303 mosquitoes sampled, 791 (23.95%) were Anopheline while 2512 (76.05%) were Culicine. The highest number of mosquitoes were sampled in May, 2017 528 (15.99%), followed by 453 (13.71%) in August 2016 while the least number of 78 (2.36%) mosquitoes were sampled in November 2016. Out of the 791 (23.95%) Anopheline mosquitoes sampled, the highest number of 233 (44.13%) was recorded in May 2017, followed by August 2016 with 111 (24.50%) mosquitoes while the least was recorded in November 2016 with 8 (10.26%) mosquitoes. Conversely, of the 2512 (76.05%) Culicine mosquitoes sampled, the highest number of 350 (80.46%) mosquitoes were sampled in June 2016, followed by August 2016 with 342 (75.50%) mosquivtoes while the least numbers of Culicine mosquitoes 70 (89.74%) were sampled in November 2016. There was a statistically significant (p<0.05) difference in the monthly relative abundance of mosquito vectors in Bosso and Chanchaga Local Government Areas (Figure 2).

Seasonal relative abundance of mosquito vector individuals in Minna

On seasonal basis, a total of 1209 (36.60%) mosquito vectors were sampled in the dry season period while 2094 (63.40%) mosquitoes were sampled during the rainy season period. Of the 1209 (36.60%) mosquitoes collected during the dry season period, 257 (21.26%) were Anopheline while 952 (78.74%) were Culicine. In the same vein, a total of 534 (25.50%) Anopheline and 1560 (74.50%) Culicine mosquitoes were collected during the rainy season period. The relative abundance of mosquito vector genera varies significantly (P<0.05) based on the two seasons in Bosso and Chanchaga Local Government Areas as shown in Table 2. The environmental data collected and populations of Anopheles mosquitoes collected are shown in Table 3. Correlation analysis also determined the relationship between *Anopheles* mosquito species and the environmental data (Supplementary Table 1). The record showed that the abundance of *Anopheles* mosquito species in the study area is dependent on rainfall and temperature. Certainly, rainfall and temperature directly affect mosquito breeding, survival, behavior and malaria transmission. More so, the development and survival rates of both the *Anopheles* mosquitoes and the *Plasmodium* parasites that cause malaria depend on temperature, making this a potential driver of mosquito population dynamics and malaria transmission. There was a significant correlation between *Anopheles* mosquito species and the environmental data collected.

Table 2: Seasonal Relative Abundance of Mosquito Vector Genera in Minna

Seasons	Anopheline (%)	Culicine (%)	Total (%)
Dry season	257 (21.26)	952 (78.74)	1209 (36.60)
Rainy season	534 (25.50)	1560 (74.50)	2094 (63.40)
Total	**791 (23.95)**	**2512 (76.05)**	**3303 (100)**

χ^2 Cal = 7.58; χ^2 tab = 3.84; df = 1

Table 3: Environmental Data collected and *Anopheles* mosquitoes Population.

		Environmental Data		
Months	***Anopheles* species**	**Relative Humidity (%)**	**Temperature (°C)**	**Rainfall (mm)**
January	70	81.2	27.8	1.4
February	12	81.8	29.8	5.4
March	35	80.6	27.4	11.9
April	102	83.0	27.3	60.9
May	233	84.0	25.4	153.9
June	85	86.3	25.2	174.5
July	48	88.2	24.3	206.6
August	111	85.0	25.4	261.7
September	21	78.1	27.2	234.9
October	36	73.2	28.5	96.4
November	8	70.3	28.0	1.1
December	30	64.5	29.2	0.3
Total	**791**	**956.3207**	**325.4908**	**1209**
Average		79.7	27.12	100.75

Monthly distribution of *Anopheles* mosquito species in Minna

The monthly distribution of *Anopheles* mosquito species in Bosso and Chanchaga Local Government Areas is presented in Table 4. Seven (7) species of *Anopheles* mosquito were encountered during the study period; *Anopheles gambiae complex, An. funestus, An. squamosus, An. moucheti, An. coustani, An. nili* and *An. pharoensis*. The highest *Anopheles* mosquito species population recorded in May was 116.50±24.75 (29.46%). The distribution of *Anopheles* mosquito species varies significantly (P<0.05) monthly. *Anopheles gambiae* complex was the dominant 210.50±47.35 (53.22%) species throughout the study period while the least was *An. pharoensis* with 9.00±5.66 (2.28%). The highest number of *An. gambiae* complex*, An. funestus, An. coustani*, and *An. nili* (74.00±15.56, 17.50±2.12, 10.50±2.12 and 6.50±2.12) respectively, were recorded in May, while *An. squamosus* was highest (7.00±1.41) in August, *An. moucheti* and *An. pharoensis* (5.50±2.12, 2.00±1.41) respectively were highest in April.

ANOVA analysis showed that there was no statistically significant difference (p>0.05) between and within the *Anopheles* species encountered during the study period (Supplementary Table 2).

Spatial monthly and seasonal distribution of *Anopheles* mosquitoes in Minna

The spatial monthly distribution of *Anopheles* mosquitoes in Bosso and Chanchaga Local Government Areas is presented in Table 5. The *Anopheles* mosquito population encountered in the study areas varied significantly (P<0.05) among the months of collection and between the seasons. Throughout the collection period and in the sampling locations, the highest *Anopheles* mosquito population was recorded in the month of May except for Maikunkele and Tunga where the highest *Anopheles* mosquito population was recorded in the month of August and April, respectively. As the collection moved down from January to February, the *Anopheles* mosquito population collected fell significantly (P<0.05), thereafter the *Anopheles* mosquito population sampled increased from March to May, where the highest *Anopheles* mosquito population was observed. However, in most of the sampling areas, after the month of May, the *Anopheles* mosquito population encountered fell drastically/significantly (P<0.05). Additionally, the highest percentage distribution was recorded in the month of May (29.46%) while the least was recorded in the month of November (0.88%).

Seasonally, *Anopheles* mosquito distribution varied likewise significantly, and the *Anopheles* mosquito population was higher in the rainy season 267.00±96.15 (67.51%) than in the dry season 128.00±54.45 (32.36). This is not the same for *Anopheles* mosquitoes sampled in Tunga and Kpakungu where no significant difference (P>0.05) was observed in the mosquito distribution for the two seasons

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Table 2: Monthly Distribution of *Anopheles* Mosquito Species

Months/An. species	*An. gambiae* complex	*An. funestus*	*An. Squamosus*	*An. moucheti*	*An. coustani*	*An. Nilli*	*An. pharoensis*	Total (%)
June	$24.50\pm2.12_{d}^{d}$	$6.50\pm2.12_{c}^{b}$	$3.00\pm1.41_{b}^{b}$	$2.50\pm0.71_{ab}^{ab}$	$3.50\pm2.12_{b}^{bc}$	$1.50\pm0.71_{a}^{abc}$	$1.00\pm1.41_{a}^{ab}$	42.50±10.6 (10.75)
July	$10.50\pm3.53_{c}^{abc}$	$4.50\pm2.12_{b}^{ab}$	$2.50\pm0.71_{b}^{b}$	$1.00\pm0.00_{b}^{a}$	$2.00\pm1.41_{b}^{abc}$	$3.50\pm2.12_{b}^{bcd}$	$0.00\pm0.00_{a}^{a}$	24.00±9.89 (6.07)
August	$20.50\pm2.12_{e}^{bcd}$	$12.50\pm1.12_{d}^{c}$	$7.00\pm1.41_{c}^{c}$	$1.00\pm1.41_{a}^{a}$	$9.00\pm1.41_{c}^{d}$	$4.50\pm0.71_{b}^{de}$	$1.00\pm0.00_{a}^{ab}$	55.50±8.18 (14.03)
September	$5.50\pm2.12_{c}^{a}$	$2.50\pm2.12_{b}^{ab}$	$0.00\pm0.00_{a}^{a}$	$0.50\pm0.71_{a}^{a}$	$1.00\pm1.41_{ab}^{ab}$	$0.50\pm0.71_{a}^{a}$	$0.50\pm0.71_{a}^{ab}$	10.50±7.78 (2.65)
October	$8.00\pm1.41_{d}^{ab}$	$5.50\pm2.12_{c}^{b}$	$0.00\pm0.00_{a}^{a}$	$0.50\pm0.71_{a}^{a}$	$3.00\pm1.41_{b}^{abc}$	$1.00\pm0.00_{ab}^{ab}$	$0.00\pm0.00_{a}^{a}$	18.00±5.56 (4.55)
November	$2.00\pm1.41_{b}^{a}$	$1.00\pm1.41_{ab}^{a}$	$0.00\pm0.00_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	$0.50\pm0.71_{a}^{ab}$	$0.50\pm0.71_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	4.00±4.24 (1.01)
December	$9.50\pm3.53_{c}^{abc}$	$2.50\pm0.71_{b}^{ab}$	$0.50\pm0.00_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	$2.00\pm1.41_{b}^{abcd}$	$0.50\pm0.71_{a}^{ab}$	15.00±6.36 (3.79)
January	$19.50\pm4.95_{d}^{bcd}$	$6.00\pm1.41_{c}^{b}$	$0.00\pm0.00_{a}^{a}$	$4.50\pm2.12_{c}^{bc}$	$1.50\pm0.71_{b}^{ab}$	$2.00\pm0.00_{b}^{abcd}$	$1.50\pm0.71_{b}^{ab}$	35.00±9.90 (8.85)
February	$3.00\pm1.41_{b}^{a}$	$1.00\pm0.00_{a}^{a}$	$0.50\pm0.71_{a}^{a}$	$0.50\pm0.71_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	$1.00\pm1.41_{a}^{ab}$	$0.00\pm0.00_{a}^{a}$	6.00±4.24 (1.52)
March	$11.00\pm2.83_{c}^{abc}$	$3.00\pm1.41_{b}^{ab}$	$0.50\pm0.71_{a}^{a}$	$0.00\pm0.00_{a}^{a}$	$0.50\pm0.71_{a}^{ab}$	$1.50\pm0.71_{ab}^{abc}$	$1.00\pm0.00_{ab}^{ab}$	17.5±6.37 (4.42)
April	$22.50\pm6.36_{d}^{cd}$	$10.50\pm2.12_{c}^{c}$	$1.50\pm0.71_{b}^{ab}$	$5.50\pm2.12_{b}^{c}$	$5.00\pm1.41_{b}^{c}$	$4.00\pm1.41_{b}^{cde}$	$2.00\pm1.41_{a}^{b}$	51.00±15.54 (12.90)
May	$74.00\pm15.56_{e}^{e}$	$17.50\pm2.12_{d}^{d}$	$2.50\pm0.71_{a}^{b}$	$4.00\pm1.41_{b}^{bc}$	$10.50\pm2.12_{c}^{d}$	$6.50\pm2.12_{b}^{e}$	$1.50\pm0.71_{a}^{ab}$	116.50±24.75 (29.46)
Annual	**210.50±47.35 (53.22)**	**73.00±18.78 (18.46)**	**18.00±6.37 (4.55)**	**20.00±9.90 (5.07)**	**36.50±13.42 (9.23)**	**28.50±12.02 (7.21)**	**9.00±5.66 (2.28)**	**395.50±113.5 (100)**

Values with the same superscript within a row are not significantly different at P>0.05
Values with the same subscript within a column are not significantly different at P>0.05

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Table 3: Spatial Monthly Distribution of *Anopheles* Mosquitoes in Minna

	BES	TDF	RFY	SHAV	MAIK	TUN	DUT	KPA	MAIT	CHA	**Aggregate**
Jun	4.50±2.12$_{c}^{a}$	7.50±2.12$_{cd}^{d}$	3.00±1.41$_{bc}^{ab}$	8.50±2.12$_{c}^{b}$	2.50±0.71$_{b}^{ab}$	1.50±0.71$_{a}^{ab}$	3.00±1.41$_{bc}^{a}$	1.00±1.41$_{a}^{a}$	3.50±0.71$_{bc}^{b}$	7.50±2.12$_{b}^{d}$	42.50±14.84
Jul	2.50±0.71$_{b}^{b}$	0.50±0.71$_{a}^{a}$	2.00±0.00$_{b}^{abc}$	2.00±1.41$_{b}^{a}$	2.50±0.71$_{b}^{ab}$	1.00±1.41$_{a}^{ab}$	5.50±2.12$_{c}^{de}$	4.50±2.12$_{bc}^{a}$	2.50±0.71$_{b}^{ab}$	1.00±1.41$_{a}^{a}$	24.00±11.31
Aug	5.00±1.41$_{c}^{c}$	5.50±2.12$_{bc}^{c}$	3.00±1.41$_{b}^{abc}$	7.50±2.12$_{d}^{b}$	10.00±1.41$_{e}^{c}$	3.00±1.41$_{b}^{bc}$	2.00±1.41$_{a}^{ab}$	1.50±0.71$_{a}^{a}$	11.50±2.12$_{e}^{c}$	6.50±2.12$_{b}^{d}$	55.50±16.24
Sept	5.00±1.41$_{c}^{c}$	0.50±0.71$_{a}^{b}$	0.50±0.71$_{b}^{a}$	0.00±0.00$_{a}^{a}$	1.00±0.00$_{b}^{a}$	1.00±1.41$_{b}^{ab}$	0.50±0.71$_{b}^{ab}$	0.50±0.71$_{b}^{a}$	1.00±0.00$_{b}^{ab}$	0.50±0.71$_{b}^{a}$	10.50±6.37
Oct	1.50±0.71$_{b}^{a}$	5.00±2.83$_{bc}^{d}$	0.50±0.71$_{ab}^{a}$	1.50±0.71$_{b}^{a}$	0.00±0.00$_{a}^{a}$	1.50±0.71$_{b}^{ab}$	2.50±0.71$_{ab}^{a}$	1.00±0.00$_{ab}^{a}$	1.50±0.71$_{b}^{ab}$	3.00±1.41$_{b}^{a}$	18.00±8.50
Nov	0.50±0.71$_{b}^{a}$	0.00±0.00$_{a}^{a}$	0.50±0.71$_{b}^{a}$	0.00±0.00$_{a}^{a}$	0.00±0.00$_{a}^{a}$	1.00±0.00$_{b}^{ab}$	0.00±0.00$_{a}^{a}$	0.50±0.71$_{b}^{a}$	0.50±0.71$_{b}^{a}$	0.50±0.71$_{b}^{a}$	3.50±3.55
Dec	2.50±0.71$_{b}^{b}$	0.50±0.71$_{a}^{a}$	0.50±0.71$_{b}^{a}$	1.50±0.71$_{a}^{a}$	2.00±0.00$_{ab}^{a}$	1.00±1.41$_{a}^{ab}$	0.50±0.71$_{a}^{ab}$	2.00±0.00$_{ab}^{a}$	2.00±0.00$_{ab}^{ab}$	3.00±0.71$_{b}^{a}$	15.50±5.67
Jan	4.50±2.12$_{c}^{c}$	2.00±1.41$_{ab}^{a}$	4.00±2.83$_{c}^{bc}$	1.50±0.71$_{a}^{a}$	3.00±0.00$_{b}^{ab}$	4.00±1.41$_{c}^{c}$	4.00±1.41$_{c}^{e}$	6.50±0.71$_{d}^{d}$	3.50±2.12$_{bc}^{b}$	1.50±2.12$_{a}^{a}$	34.50±14.84
Feb	0.50±0.71$_{ab}^{a}$	1.00±0.00$_{b}^{a}$	1.00±1.41$_{b}^{ab}$	1.00±0.00$_{b}^{a}$	0.00±0.00$_{a}^{a}$	0.00±0.00$_{a}^{a}$	1.50±0.71$_{c}^{b}$	0.50±0.71$_{ab}^{a}$	0.00±0.00$_{a}^{a}$	0.50±0.71$_{ab}^{a}$	6.00±4.25
Mar	1.00±0.00$_{a}^{a}$	2.00±1.41$_{ab}^{b}$	2.50±0.71$_{b}^{b}$	1.00±1.41$_{a}^{a}$	1.50±0.71$_{a}^{a}$	2.00±0.00$_{b}^{ab}$	1.00±1.41$_{a}^{a}$	3.50±2.12$_{c}^{ab}$	2.00±141$_{b}^{ab}$	1.00±0.00$_{a}^{a}$	17.50±9.18
Apr	4.00±1.41$_{d}^{b}$	6.50±2.12$_{c}^{c}$	4.50±2.12$_{d}^{bc}$	8.50±2.12$_{e}^{b}$	5.00±1.41$_{d}^{b}$	11.50±2.12$_{f}^{e}$	3.50±2.12$_{c}^{b}$	2.50±2.12$_{b}^{ab}$	3.50±0.71$_{ab}^{b}$	1.50±0.71$_{a}^{a}$	51.00±16.96
May	16.0±11.31$_{bc}^{b}$	10.50±2.12$_{b}^{d}$	13.00±1.411$_{d}^{b}$	8.50±2.12$_{ab}^{b}$	8.50±3.54$_{a}^{c}$	8.50±0.71$_{a}^{d}$	6.50±0.71$_{a}^{e}$	8.00±4.24$_{a}^{c}$	15.50±2.12$_{bc}^{d}$	21.50±10.61$_{d}^{c}$	116.50±38.89
Annual	**47.50±23.33**	**41.50±16.26**	**35.00±14.14**	**41.50±13.43**	**36.00±8.49**	**36.00±11.30**	**30.50±13.43**	**32.00±15.56**	**47.00±11.32**	**48.00±23.34**	**395.50±150.6**

Values with the same superscript within a row are not significantly different at P>0.05
Values with the same subscript within a column are not significantly different at P>0.05
Keys: BES = Bosso Estate, TDF = Tudun Fulani, RFY = Rafin Yashi, SHAV = Shanu Village, MAIK = Maikunkele, TUN = Tunga
DUT = Dutsen Kura, KPA = Kpakungu, MAIT = Maitumbi and CHA = Chanchaga

DISCUSSION

In this study, two mosquito vector genera were encountered. A total of 3303 (100%) mosquitoes consisting of Anopheline 791 (23.95%) and Culicine 2512 (76.05%). However, the results of this study are higher than that reported by Olayemi *et al*. [47]. Seven (7) species of *Anopheles* mosquito were encountered during the study period; *Anopheles gambiae complex, An. funestus, An. squamosus, An. moucheti, An. coustani, An. nili* and *An. pharoensis*.

Based on monthly collection, mosquito vectors were most abundant in the month of May for Anopheline species (44.13%) and June for Culicine (80.46%). There was no positive relation between the abundance of mosquito vectors with rainfall and the majority of the anopheline species. We did not find any significant correlation between rainfall, and the known malaria vector; *An. gambiae complex*. It may be because of the association with rice fields and irrigated cropland, where the females deposit their eggs on moist soil [37]. Also, Rahman *et al*. [38] did not find a correlation between mosquito vector abundance and rainfall in Malaysia. The observed diversity of species in this study may be due to favourable breeding sites in the study area. Ye' *et al.* [39] and Thomson *et al.* [40] reported that soil moisture is a major factor affecting the abundance of some species. However, measurements of soil moisture were not included in this study.

We did not find any significant association with temperature, mosquito density and malaria incidence in our study. Certainly, the temperature directly affects mosquito breeding, survival, and behavior and malaria transmission as earlier reported [41]. We were unable to detect a significant relationship with this factor because the temperature ranges in this region are always suitable for mosquito breeding and development. Moreover, statistical significance alone does not always explain the complex biological dynamics of mosquitoes and temperature.

The result of this study is similar to the report of Atting and Akpan [42] in Uyo, Nigeria, where *Anopheles* mosquitoes were most abundant between the months of May to October. More so, mosquito vectors were more abundant in the rainy season (63.40%) than in the dry season (36.40%). This seasonal variation in the mosquito vector genera abundance was also documented by Mgbemena et al. [43].

The highest *Anopheles* mosquito population was recorded in the month of May except in Maikunkele and Tunga where the highest *Anopheles* mosquito population was recorded in the month of August and April, respectively. Environmental and climatic factors could play a role but most vital is the availability of host settlement. The reason why a higher mosquito population was recorded in the months of August and April in Tunga and Maikunkele could be due to the onset of rains that the mosquito eggs hatch immediately due to the aestivation period, while in August could be due to the availability of suitable breeding sites created by the rains. In the results section, it was mentioned that in Tunga and Kpakungu no significant difference (P>0.05) was observed in the mosquito distribution for the two seasons. This could be due to the settlement within the locations and the availability of breeding sites in those areas.

Anopheles mosquito relative abundance was moderately high (23.95%) in the study areas, although, the use of some insecticides and the usage of Long Lasting Insecticidal Treated Nets can reduce vector infectivity as well as vector survival rate and the length of the sporogonic cycle [44]. This result revealed that *Anopheles* mosquito abundance was high in Bosso Estate (47.50±23.33), Maitumbi (47.00±11.32) and Chanchaga (48.00±23.34). This could be due to the availability of temporary breeding sites and favourable environmental factors such as rainfall and temperature as earlier reported by Anumudu *et al.* [45] and Paaijmans *et al.* [46]. Some of the environmental practices within the study areas include disposing of containers, receptacles, water storage jars, unused tyres, abandoned cans etc. also play a major role in the distribution of *Anopheles* mosquitoes in the study areas [27, 30, 47]. Also, the *Anopheles* mosquito encountered in this study area was reported by Coluzzi *et al.* [48] as the most important vector of the malaria parasites in the sub – Saharan Africa, in connection with certain climatic factors most especially the annual precipitation that appears to influence the range and the relative abundance of *Anopheles* mosquitoes.

Interestingly, a similar result was earlier reported by Omalu *et al.* [49] who recorded a high relative abundance of *Anopheles* mosquitoes in the Gidan Kwano and Maikunkele areas of Minna, Niger state, Nigeria. However, a low relative abundance of *Anopheles* mosquitoes was recorded in Rafin Yashi (35.00±14.14), Maikunkele (36.00±8.49), Tunga (36.00±11.30), Dutsen Kura (30.30±13.43) and Kpakungu (32.00±15.56). This could be because of over-flooding of the temporary breeding sites during the peak of the rainy season when most of the mosquito larvae are washed away [42, 50].

CONCLUSION

This study demonstrates that the spatial distribution of *Anopheles* mosquitoes all year-round in Minna was due to the favourable environmental conditions. Therefore, an integrated vector management system covering year-round should be adopted to reduce malaria morbidity and mortality in Minna.

We recommend that vector ecologists cautiously consider the complex nature of the relationship between malaria vectors and climate variables. Detailed studies

of vector bionomics, continuous monitoring, and malaria transmission dynamics are essential for predicting outbreaks of disease and, if necessary, control of the vector mosquitoes in Minna, Niger State, Nigeria.

LIST OF ABBREVIATIONS

ANOVA: Analysis of Variance
CDC: Centre for Disease Control and Prevention
DNA: Deoxyribonucleic Acid
FCT: Federal Capital Territory
FMOH: Federal Ministry of Health
PCR: Polymerase Chain Reaction
PSC: Pyrethrum Spray Collections
WHO: World Health Organization
LGAs: Local Government Areas

ETHICAL APPROVAL

The study protocol was approved by the Niger State Ministry of Health (Niger State Hospital Management Board) (HMB/GHM/STA/136/VOL.III/440). Individual informed consent was also obtained from all the participants after the aim and objectives of the study were fully explained to them. Verbal consent was also taken from Fall the household heads for the study because the majority of them were illiterate.

CONFLICT OF INTEREST

The authors declared that they have no competing interests.

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