

#### **Journal of Public Health and Diseases**

Volume 2(4), pages 67-75, December 2019 Article Number: E1943BC83 ISSN: 2705-2214 https://doi.org/10.31248/JPHD2019.053

https://integrityresjournals.org/journal/JPHD

Full Length Research

# The distribution pattern and feeding behaviour of malaria vectors in two selected communities of Karu Local Government Area of Nasarawa State

Hassan, S. C.1\*, Olayemi, I. K.2, Omalu, I. C. J.2, Adefolalu, F. S.3, Eke, S. S.2 and Affiku, I. J.1

<sup>1</sup>Department of Zoology, Nasarawa State University, Keffi, Nasarawa State, Nigeria. <sup>2</sup>Department of Animal Biology, Federal University of Technology, Minna, Niger State, Nigeria. <sup>3</sup>Department of Animal Biology, Federal University of Technology, Minna, Niger State, Nigeria.

\*Corresponding author. Email: hassans@nsuk.edu.ng.

Copyright © 2019 Hassan et al. This article remains permanently open access under the terms of the Creative Commons Attribution License 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received 10th December, 2019; Accepted 28th December, 2019

ABSTRACT: An entomological survey was conducted to determine the malaria vectors density and their distribution. The study was aimed at identifying the distribution and feeding behaviour of major malaria vectors. Mosquitoes were sampled using Pyrethroid Spray Collection (PSC) and CDC light trap methods to collect indoors and outdoors resting mosquitoes for a period of three months (April, May and June) and were identified morphologically. A total of 462(100%) mosquitoes were collected in the study areas, 238(51.5%) were collected in Gitata and 224(48.5%) were collected in Panda. Of the 462 (100%) mosquitoes collected, 433(93.7%) were Anopheline while 29(6.3%) were Culicine. Statistically, there was a statistical difference (p<0.05) in the distribution of malaria vectors encountered in the study areas. Out of the 433(100%) Anopheles mosquitoes collected, 279(64.4%) feed indoor while 154(35.6%) feed outdoor. The indoor resting density of the mosquitoes were also calculated, the result showed that Panda had the highest indoor resting density of 7.5 than Gitata 7.0. The human biting rate (HBR) of mosquitoes collected in each month at the study areas were also determine and the result showed a high biting rate of 2.515 in Panda compared to 2.321 in Gitata. The parity rate (PR) of the mosquitoes collected in Gitata and Panda for the three months were also analyzed, and the result showed that, out of the 433 Anopheles mosquitoes collected, 146(100%) were dissected, 85(58.2%) were parous and 61(41.8%) were nulliparous. This study therefore, will be used as a baseline data to help in designing strategies for the control of malaria vector diseases in Karu Local Government of Nasarawa State and its environs.

Keywords: Gitata, human biting rate (HBR), indoor, Karu LGA, malaria, outdoor, Panda, vectors.

# INTRODUCTION

Mosquitoes of the family Culicidae are considered a nuisance and a major public health problem, because their females feed on human blood and thus transmit extremely harmful diseases, such as malaria, yellow fever and filariasis (WHO, 2015). They are estimated to transmit diseases to more than 700 million people annually and responsible for the death of about 1 in 17 people (WECM and WHO, 2000). Effective transmission of mosquitoborne disease requires successful contact between female mosquitoes and their hosts (Xu et al., 2014). Among Anophelinae, the members of the genus Anopheles are best known for their role in transmitting malaria and

filariasis worldwide (Service, 2008; WHO, 2013). Of these diseases, malaria caused by Plasmodium parasite is one of the greatest killer diseases in the world (WHO, 2013). WHO (2013) reported an estimated 207 million cases of malaria in 2012 out of which 200 million cases (80.0 %) were in Africa continent? The distribution pattern, transmission and intensity of the disease are dependent on the degree of urbanization and the distance from vector breeding sites (CDC, 2015). The endemicity of malaria in any region is determined by indigenous *Anopheles* mosquitoes, abundance, feeding, resting behavior and their Plasmodium infectivity, among other factors (Molta,

2000; WHO, 2003).

Malaria infection is caused by five Plasmodium species: Plasmodium falciparum, P. vivax, P. ovale, P. malariae and P. knowlesi (zoonotic species mainly occurring in Asia) (Cox-Singh et al., 2008; Snow et al., 2005). P falciparum is the most fatal malaria parasite (Snow et al., 2005), threatening millions of lives primarily in Africa, south of the Sahara. An estimated 187 million clinical cases of P. falciparum were reported in Africa in 2015 (Bhatt et al., 2015). More than 90% deaths and 88% of cases occur in Africa (WHO, 2015), while some species of Anopheles are vectors of malaria (Cox, 2010). Anopheles gambiae, A. coluzzii, A. arabiensis and A. funestus are the major malaria vectors in Africa (Sinka et al., 2012).

Globally, the number of cases and deaths due to P. falciparum has substantially declined in Africa and elsewhere (Bhatt et al., 2015; WHO, 2015). Between 2000 and 2012, deaths due to malaria declined by 42% globally, and the reduction was higher (49%) in the World Health Organization's (WHO) African region (WHO, 2013). In 2013, malaria mortality rates declined by 47% globally and 54% in Africa compared to 2000, with malaria causing 584,000 deaths (WHO, 2014). Between 2000 and 2015, the malaria mortality rate was reduced by 60% worldwide and 66% in Africa among all age groups (WHO, 2015). The number of deaths due to malaria declined to 438,000 in 2015, from 839,000 in 2000 (WHO, 2015). The decline in the number of malaria cases and deaths is associated with the widespread use of long-lasting insecticidal nets (LLINs), indoor residual spraving (IRS), rapid diagnostic effective anti-malarial drug artemisinin tools and combination therapies (ACTs). It was reported that in 2015, more than 50% of people in Africa slept under LLINs compared to roughly 2% in 2000 (WHO, 2015). The interventions have averted an estimated 663 million clinical malaria cases since 2000, with insecticide treated bed nets being the largest contributors to reducing deaths, and followed by ACTs (Bhatt et al., 2015; WHO, 2015).

Malaria is one of the most significant infectious diseases in the world. Available statistics suggest that 2 to 5% of all human deaths in the 20th Century were attributed to the disease (Carter et al., 2002), and increasing evidence identifies malaria as the most significant recent selective pressure on the human genome (Kwiatkowski, 2005). In 2000, 20% of all deaths of children under 5 years in Sub-Saharan Africa were attributable to malaria (Black et al., 2003; WHO, 2006). In Nigeria, 18 million clinical malaria cases annually result in approximately 80,000 deaths (WHO, 2006). Most malaria cases in Nigeria are due to P. falciparum as in Tanzania (Mboera, 2000). P. falciparum is transmitted by female Anopheles mosquitoes during a blood meal. Gillies and Meillon (1968) defined 11 out of the 45 anopheline mosquito species as responsible vectors for malaria transmission. The most important malaria vectors in Nigeria as in Tanzania include A. gambiae and A. arabiensis (Mnzava and Kilama, 1986; Shiff et al., 1995; Kigadye et al., 2010) and A. funestus (Mboera et al., 1997,

2010).

A measure of entomological inoculation rates (EIR) is an important tool for estimation of malaria transmission intensity (Drakeley et al., 2003). It is one of the indicators of human exposure to malaria parasites (Killeen et al., 2000). In Nigeria, EIR has been shown to vary with season, altitude, proximity to breeding sites, socioeconomic status, agro-ecological systems (liumba et al., 2002; Kulkarni et al., 2006; Mboera et al., 2010). The knowledge on malaria transmission indices is important to its control through quantifying the potential risk of infection (Githeko et al., 1993). This calls for the need to accurately determine the mosquito population structure, spatial and temporal variations in malaria transmission within localized areas that will target specific needs in malaria interventions. This study was therefore carried out to determine mosquito population structure, its temporal variation and transmission indices in Karu Local Government Area of Nasarawa State.

#### MATERIAL AND METHOD

# Study area

Karu urban area is an urban area in central Nigeria. The urban area is majorly located in the Nigerian state of Nasarawa (Figure 1), but with some parts stretching into the boundaries of the Federal Capital Territory (FCT). It has an area of 40,000 hectares (400 km<sup>2</sup>) and a population of 2 million (Pell, 2009) with annual rainfall range of 1100 to 1600 mm. It is one of the fastest growing urban areas in the world, with a growth rate of 40 percent recorded annually (Tamuno, 2006). It consists of towns that developed as a result of urban sprawl from Abuja (Terkula, 2006). From west to east, the urban area includes towns like Kurunduma, New Nyanya, Mararaba, New Karu, Ado, Auta ba-laifi, Masaka and newer, fast-growing towns such as One Man Village (which contains over 1 million people (Turaki, 2011) and Gidan Zakara. Since the beginning of the 20th century, these districts have grown together into a large urban area and a major commercial centre of central Nigeria. The above locations were choosing due to high availability of breeding sites and high prevalence of malaria cases from previous reports. Karu Local Government Area of Nasarawa State was spotted by google satellite map at a geographical coordinate of 90 0' 39" North, 7º 34' 31" East and its original name (with diacritic) is Karu, situated in Abuja, FCT, Nigeria (Figure 2).

### methods

# Pyrethrum Spray Collection (PSC)

A total of thirty houses (15 houses in two communities of Karu Local Government Area) were randomly selected for

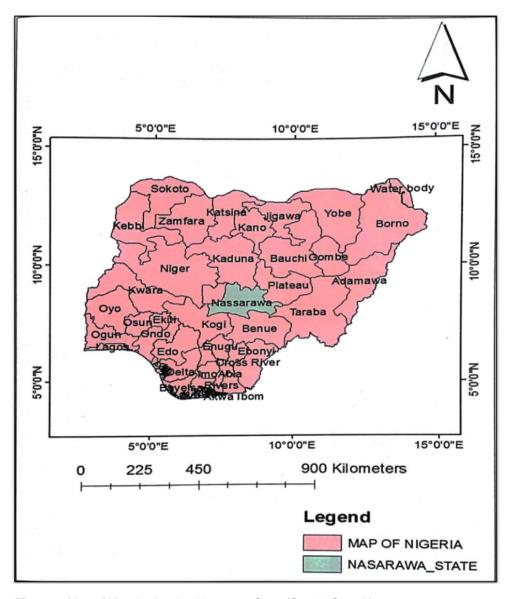


Figure 1. Map of Nigeria showing Nasarawa State (Google Search).

sampling using Pyrethrum Spray Collection (PSC) method as described by WHO (2005, 2008) to sample indoorresting 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.

Prior to 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 will enter and collect mosquitoes. Mosquitoes that were knocked down were collected from the white cloth that was laid down prior to spraying. The spraying commenced at 6:00 to 9:30 am.

The mosquitoes were collected using feather weight

forceps and then placed in petri dishes or paper cups containing damp filter paper. Anopheline mosquitoes were preserved on damp absorbent paper in a cool box, transported to the Department of Zoology Laboratory, Nasarawa State University, Keffi, Nasarawa State and later identified to the species level by morphological criteria (Gillies and De Meillon 1968; Gillet, 1972; Gillies and Coetzee 1987; Kent, 2006).

# **CDC** light trap collection

Centre for Disease Control light trap methods (baited traps, was placed indoors and outdoors) in two different houses monthly for three (3) nights per site to measure mosquito biting time. The light trap bag was replaced every

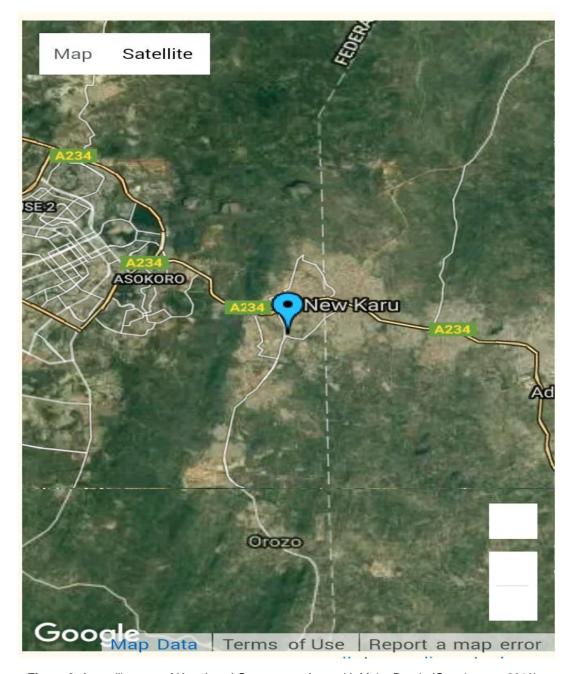


Figure 2. A satellite map of Karu Local Government Area with Major Roads (Google map, 2016).

hour by two mosquito collectors from 18:00 to 06:00 per house per night in order to have proxy estimate on the peak biting time. One collector worked from 18:00 to 24:00 and was replaced by a second collector both indoor and outdoor from 24:00 to 06:00 following the methods of Yohannes and Boelee (2012). The trap was placed close to the legs of a person sleeping under an untreated bed net as bait both indoors and outdoors with the cups changed hourly. The mosquitoes collected were kept in separate labeled paper cups for identification and further analysis as the Indoor resting *Anopheles* were collected

using Pyrethrum spray insecticide. Prior to spraying of the rooms, all materials were removed from the rooms to be sampled. All openings like windows, doors, eaves among others were closed. A white sheet was spread to completely cover the whole floor. The pyrethrum insecticide (Raid) was sprayed in a clockwise direction towards the ceiling until the whole room was filled with a fine mist of the insecticide. The door was closed and left for 15 minutes. Thereafter the door was opened and starting from the doorway, the sheets were folded and carried outside. All the mosquitoes on the sheet were

Site/ Comm.	April		May		June			
	Anopheline (%)	Culicine (%)	Anopheline (%)	Culex (%)	Anopheline (%)	Culex (%)	Total (%)	
Gitata	81(49.4)	3(42.9)	72(50.7)	6(66.7)	69(54.3)	7(53.8)	238(51.5)	
Panda	83(50.6)	4(57.1)	70(49.3)	3(33.3)	58(45.7)	6(46.2)	224(48.5)	
Total	164(35.5)	7(1.5)	142(30.7)	9(2.0)	127(27.5)	13(2.8)	462(100)	

Table 1. The distribution pattern of the malaria vector in two communities of Karu L.G.A.

Table 2. Feeding behavior of mosquitoes collected indoor and outdoor in the two communities of Karu L.G.A.

Site/Comm.	April		May		June		T-1-1 (0/)	
	Indoor (%)	Outdoor (%)	Indoor (%)	Outdoor (%)	Indoor (%)	Outdoor (%)	Total (%)	
Gitata	53(51.5)	28(45.9)	41(47.1)	31(56.4)	47(52.8)	22(57.9)	222(51.3)	
Panda	50(48.5)	33(54.1)	46(52.9)	24(43.6)	42(47.2)	16(42.1)	211(48.7)	
Total	103(23.8)	61(14.1)	87(20.0)	55(12.7)	89(20.6)	38(08.8)	433(100)	

transferred into petri dishes containing damp cotton wool and filter paper to maintain the physiological status of the mosquitoes.

#### **Entomological investigation**

#### Mosquito identification

Each adult raised from the larvae caught indoors and outdoors was individually identified to species and species complex level, using morphological characters of Gillett (2012) and Gillies and Coetzee (1987) under 20x Zeiss light microscope within 24 hour of post emergence.

# Identification of feeding status of the vector

Anophelines were first grouped based on their abdominal conditions. They were generally grouped as unfed, freshly fed, half gravid and gravid (WHO, 2003).

#### Data analysis

Data generated were analyzed using the SPSS software version 22.0 and excel package. Chi-square ( $\chi^2$ ) test was used to compare the distribution of malaria vectors between collection sites and months. p<0.05 was considered indicative of a statistically significant difference.

#### **RESULTS**

# The Distribution of malaria vectors in two communities of Karu L.G.A

A total of 462(100%) mosquitoes were collected in the study areas, 238(51.5%) were collected in Gitata and

224(48.5%) were collected in Panda. 433(93.7%) were *Anopheles* species while 29(6.3%) were *Culex*, which shows that *anopheles* are more distributed in the study area. Table 1 showed the distribution pattern of *anopheles* species over *culex* in the two sites sampled. In month April, 81(49.4%) *anopheles* dominates the *culex* 3(42.9%) in Gitata and 83(50.6%) *anopheles* dominates the *culex* 4(57.1) in Panda. In month of May, 72(50.7%) *anopheles* dominates the *culex* 6(66.7) in Gitata and 70(49.3%) *anopheles* dominates the *culex* 3(33.3%) in Panda. In month of June, 69(54.3%) *anopheles* dominates the *culex* 7(53.8%) in Gitata and 58(45.7%) *anopheles* dominates the *culex* 6(46.2%) in Panda. Statistically, there was a statistical difference (p<0.05) in the distribution of malaria vectors encountered in the study areas.

# Feeding behavior of mosquitoes collected indoor and outdoor in the two communities of Karu L.G.A

Table 2 showed that, of the 433 anopheles species of mosquitoes collected, 53(51.5%) feeds indoor and 28(45.9%) feeds outdoor in Gitata, while 50(48.5%) feeds indoor and 33(54.1%) feeds outdoor in Panda for April. 41(47.1%) feeds indoor and 31(56.4%) feeds outdoor in Gitata, while 46(52.9%) feeds indoor and 24(43.6%) feeds outdoor in Panda for May. 47(52.8%) feeds indoor and 22(57.9%) feeds outdoor in Gitata, while 42(47.2%) feeds indoor and 16(42.1%) feeds outdoor in Panda for June. These analysis shows that, there is a high feeding behavior of the malaria vector Indoor than outdoor.

Table 3 showed the total number of fed, unfed, gravid and half-gravid mosquitoes collected in the two sides (Gitata and Panda). In month of April, 66(39.52%), in May, 48(28.74%) and in June, 53(31.74%) fed mosquitoes, bringing the total to 167(100%) fed mosquitoes for the three months. In month of April, 98(36.8%), in May, 94(35.4%)

Table 3. Shows the total fed and unfed mosquitoes in the two-study area of Karu L.G.A

Months	Gitata	Panda	Total	Fed	Unfed	Half-Gravid	Gravid
April	81	83	164	66	98	30	36
May	72	70	142	48	94	27	21
June	69	58	127	53	74	30	23
Total	222	211	433	167	266	87	80

**Table 4.** Indoor resting density of mosquitoes in two communities of Karu L.G.A.

Site/ Comm.	Indoor collection		No. of o	ccupants	IRD = (n/N of occ.)	
	Gitata	Panda	Gitata	Panda	Gitata	Panda
April	53	50	23	20	2.3	2.5
May	41	46	20	19	2.1	2.4
June	47	42	18	16	2.6	2.6
Total	141	138	61	55	7.0	7.5

**Table 5.** Human biting rate of mosquitoes in two communities of Karu L.G.A.

Site/ Comm.	Indoor collection		No. of Occupants		No. of	HBR=n/Occu./days	
	Gitata	Panda	Gitata	Panda	Days/Month	Gitata	Panda
April	53	50	23	20	3	0.768	0.833
May	41	46	20	19	3	0.683	0.807
June	47	42	18	16	3	0.870	0.875
Total	141	138	61	55	9	2.321	2.515

Table 6. Number of parous mosquitoes dissected from the two communities of Karu L.G.A.

Site/comm. No. of mosq. collected		No. dissected	No parous (%)	No. nulliparous (%)	(%)	
Gitata	222	76	47(55.3)	29(47.5)	0.618	
Panda	211	70	38(44.7)	32(42.5)	0.543	
Total	433	146	85(58.2)	61(41.8)	1.161	

and in June, 74(27.8%) unfed mosquitoes, bringing the total to 266(100%) unfed mosquitoes for the three months. In month of April, 30(35.0%), in May, 27(30.0%) and in June, 30(35.0%) half-gravid mosquitoes, bringing the total to 87(100%) half-gravid mosquitoes for the three months. In month of April, 36(45.0%), in May, 21(26.2%) and in June, 23(28.8%) gravid mosquitoes, bringing the total to 80(100%) gravid mosquitoes for the three months.

Table 4 shows the indoor resting density of mosquitoes collected in each month for the two sites. 2.3 indoor resting density rate in Gitata and 2.5 indoor resting density rate in Panda for the month of April. 2.1 indoor resting density rate in Gitata and 2.4 indoor resting density rate in Panda for the month of May. 2.6 indoor resting density rate in Gitata and 2.6 indoor resting density rate in Panda for the month of June. This result shows that Panda has the highest indoor resting density of 7.5 totals than Gitata 7.0.

Table 5 showed the human biting rate (HBR) of mosquitoes collected in each month for the two sites. 0.768 HBR in Gitata and 0.833 HBR in Panda for the month of April. 0.683 HBR in Gitata and 0.807 HBR in Panda for the month of May. 0.870 HBR in Gitata and 0.875 HBR in Panda for the month of June.

Table 6 showed the parity rate (PR) of mosquitoes collected in Gitata and Panda for the three months. Out of the 76 mosquitoes dissected, 47(55.3%) were parous and 29(47.5%) were nulliparous in Gitata. Out of the 70 mosquitoes dissected, 38(44.7%) were parous and 32(42.5%) were nulliparous in Panda.

# DISCUSSION

The heterogenic nature and behavior of malaria vectors,

the *Anopheles* mosquitoes has caused a lot of hindrances to malaria control strategies and interventions deployed as noticed in this research work with high abundance of mosquito species of malaria vector parasites among the individuals within the study areas as indicators of malaria transmission. Anopheles mosquito's distribution pattern was very high than the culex though the use of some insecticides and usage of long lasting insecticide treated nets can reduce vector infectivity as well as vector survival rate and the length of the sporogonic cycle. Both Gitata and Panda had high 433(93.7%) Anopheles species than the *culex* 29(6.3%) in their distribution pattern which may be due to the availability of temporary breeding sites as reported by Angerilli (1980) and some of the environmental practices within the study areas which include disposing of containers, receptacles, water storage jars, unused tyres, abandoned cans etc. Also, the anopheles species found in this study areas were also reported by Coluzzi et al. (2002) which is the most important vector of the malaria parasites in the Sub-Saharan Africa, in connection with certain climatic factors most especially the annual precipitation appears to influence the range and the relative abundance of the mosquito species.

For the feeding behaviour of these mosquitoes, of the 433 anopheles species of mosquitoes collected, 53(51.5%) feeds indoor and 28(45.9%) feeds outdoor in Gitata, while 50(48.5%) feeds indoor and 33(54.1%) feeds outdoor in Panda for April, 41(47.1%) feeds indoor and 31(56.4%) feeds outdoor in Gitata, while 46(52.9%) feeds indoor and 24(43.6%) feeds outdoor in Panda for May, 47(52.8%) feeds indoor and 22(57.9%) feeds outdoor in Gitata, while 42(47.2%) feeds indoor and 16(42.1%) feeds outdoor in Panda for, which shows that, there is a high feeding behavior of the malaria vector Indoor than outdoor. The indoor feeding behaviour was very high than outdoor feeding behaviour which makes the occupants living in those houses more quick at risk of infection of the malaria vector in the study area. This result is similar to the findings of Atting et al. (2016) who reported higher feeding behaviour of mosquitoes indoor than outdoor in Uyo, Akwa Ibom State, Nigeria.

The indoor resting density of mosquitoes collected in each month for the two sites shows that there were 2.3 indoor resting density in Gitata and 2.5 indoor resting density in Panda for April, 2.1 indoor resting density in Gitata and 2.4 indoor resting density in Panda for May. 2.6 indoor resting density rate in Gitata and 2.6 indoor resting density rate in Panda for June. This result shows that Panda has the highest indoor resting density of 7.5 totals than Gitata 7.0, therefore individuals or occupants should be prompt on using long lasting insecticides treated mosquitoes net and other approved insecticides by the Centre for Disease Control and Prevention (CDC). The findings of this research work disagree with the work of Umar et al. (2015) who reported IRD during the dry season in Bauchi State, Nigeria.

The human biting rate (HBR) of mosquitoes collected in

each month for the two sites shows that there is 0.768 HBR in Gitata and 0.833 HBR in Panda for April, 0.683 HBR in Gitata and 0.807 HBR in Panda for May, 0.870 HBR in Gitata and 0.875 HBR in Panda for June, which shows that occupants do not really use the LLIN given to them. This result is similar to the findings of Atting et al. (2016) who in their own research recorded a higher HBR in Uyo, South – South Nigeria.

The parity rate (PR) of mosquitoes collected in Gitata and Panda for the three months however shows that out of the 76 mosquitoes dissected, 47(55.3%) were parous and 29(47.5%) were nulliparous in Gitata and out of the 70 mosquitoes dissected from Panda, 38(44.7%) were parous and 32(42.5%) were nulliparous which shows that these mosquitoes feeds and lay eggs most frequently in the study area unlike in other studies in Ghana and even Lagos State in South West Nigeria (Appawu et al., 2004 and Awolola et al., 2003). It showed that anopheles mosquitoes selected in the study areas are effective vectors of malaria transmission.

The distribution pattern of the mosquito species within the study areas was also associated with the availability of suitable breeding habitats within the locations as described by Minakawa et al. (2005). The breeding sites ranges across the various types of water bodies such as temporary ground pools to large permanent water bodies found within the study areas. More so, the high rate of malaria infection within the study area could be attributed to the fact that the infection is already a looming endemic problem in Nigeria, including Nasarawa State as the sampling and surveying period coincided with the peak of raining season when mosquitoes are breeding due to the amount of rainfall, Moreover, Karu and its environment including the study areas are relatively water logged and poorly drained areas, gutters and other drainages are also routinely clogged with wastes as a result of an inefficient public waste disposal system. All these provide good breeding sites for mosquitoes which help to fuel stable and continuous malaria transmission, even beyond the peak rainy season in the months of November and December respectively.

#### Conclusion

In conclusion, the morphological identification of these mosquitoes shows that, *Anopheles* is the most predominant genera than *Culex* in the study area. The vector is anthropophilic (preference for humans) and endophagic (bites indoors) than exophagic (bites outdoors). This may help narrow down vector control measures in Karu Local Government Area to a selective, targeted, site specific, ecologically sound and cost effective (malaria) vector control strategy suited to the local environment and epidemiological conditions of Karu Local Government.

The findings of this study also indicates that both the

entomological and parasitological indices of malaria transmission which includes their Species Distribution, Feeding Behavior and the sporozoites found in the salivary glands of the female Anopheles as well as their parous nature and the Plasmodium parasites found in the blood samples of the patients are well established in the study areas, thus explaining the endemicity of malaria in Karu Local Government Area of Nasarawa State and its environment.

# **CONFLICT OF INTEREST**

Authors declare that they have no conflict of interest.

#### **REFERENCES**

- Angerilli, N. P. (1980). Influences of extracts of freshwater vegetation on the survival and oviposition by Aedes aegypti (Diptera: Culicidae). *The Canadian Entomologist*, 112(12), 1249-1252.
- Appawu, M., Owusu-Agyei, S., Dadzie, S., Asoala, V., Anto, F., Koram, K., Rogers, W., Nkrumah, F., Hoffman, S. L., & Fryauff, D. J. (2004). Malaria transmission dynamics at a site in northern Ghana proposed for testing malaria vaccines. *Tropical Medicine & International Health*, 9(1), 164-170
- Atting, I. A., akpan, M. E., & udoidung, n. i. (2016). morphological and molecular characterization of *anopheles* mosquitoes and their behavioural patterns in uyo, nigeria. *international journal of tropical disease and health*, 14(2), 1-11.
- awolola, t. s., ibrahim, k., okorie, t., koekemoer, I. L., Hunt, R. H., & Coetzee, M. (2003). Species composition and biting activities of anthropophilic Anopheles mosquitoes and their role in malaria transmission in a holo-endemic area of southwestern Nigeria. *African entomology*, 11(2), 227-232.
- Bhatt, S., Weiss, D. J., Cameron, E., Bisanzio, D., Mappin, B., Dalrymple, U., Battle, K. E., Moyes, C. L., Henry, A., Eckhoff, P. A., Wenger, E. A., Briët, O., Penny, M. A., Smith, T. A., Bennett, A., Yukich, J., Eisele, T. P., Griffin, J. T., Fergus, C. A., Lynch, M., Lindgren, F., Cohen, J. M., Murray, C. L., Smith, D. L., Hay, S. I., Cibulskis, R. E., & Gething, P. W. (2015). The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature*, *526*(7572), 207-211.
- Black, R. E., Morris, S. S., & Bryce, J. (2003). Where and why are 10 million children dying every year? *The Lancet*, 361(9376), 2226-2234.
- Carter, R., & Mendis, K. N. (2002). Evolutionary and historical aspects of the burden of malaria. *Clinical microbiology Reviews*, 15(4), 564-594.
- Centre for Disease Control (CDC) (2015). Ecology of malaria. Centers for Disease Control and Prevention (CDC). Retrieved 20th July, 2014 from https://www.cdc.gov/malaria/about/biology/ecology.html.
- Coluzzi, M., Sabatini, A., Della Torre, A., Di Deco, M. A., & Petrarca, V. (2002). A polytene chromosome analysis of the Anopheles gambiae species complex. *Science*, 298(5597), 1415-1418.
- Cox, F. E. (2010). History of the discovery of the malaria parasites and their vectors. *Parasites and Vectors*, 3, 5.
- Cox-Singh, J., Davis, T. M., Lee, K. S., Shamsul, S. S., Matusop,

- A., Ratnam, S., Rahman, H.A., Conway, D. J., & Singh, B. (2008). Plasmodium knowlesi malaria in humans is widely distributed and potentially life threatening. *Clinical Infectious Diseases*, 46(2), 165-171.
- Drakeley, C., Schellenberg, D., Kihonda, J., Sousa, C. A., Arez, A. P., Lopes, D., Lines, J., Mshinda, H., Lengeler, C., Schellenberg, J. A., & Tanner, M. (2003). An estimation of the entomological inoculation rate for Ifakara: a semi-urban area in a region of intense malaria transmission in Tanzania. *Tropical Medicine & International Health*, 8(9), 767-774.
- Gillett J. D., (2012). Common African Mosquitoes and Their Medical Importance. Willem Hellmann Medical Books Ltd: London. 50:731-855.
- Gillies, T. M., & de Meillon, D. B. (1968). The Anopheles of Africa South of Sahara (Ethiopian Zoogeographic Region). 1968, Johannesburg, Republic of South Africa. *Publication of the South African Institute for Medical Research*, 54(2).
- Githeko, A. K., Service, M. W., Mbogo, C. M., Atieli, F. K., & Juma, F. O. (1993). Plasmodium falciparum sporozoite and entomological inoculation rates at the Ahero rice irrigation scheme and the Miwani sugar-belt in western Kenya. *Annals of Tropical Medicine & Parasitology*, 87(4), 379-391.
- Ijumba, J. N., Mosha, F. W., & Lindsay, S. W. (2002). Malaria transmission risk variations derived from different agricultural practices in an irrigated area of northern Tanzania. *Medical* and Veterinary Entomology, 16(1), 28-38.
- Kigadye, E. S. P., Nkwengulila, G., Magesa, S. M., & Abdulla, S. (2010). Diversity, spatial and temporal abundance of Anopheles gambiae complex in the Rufiji River basin, southeastern Tanzania. *Tanzania Journal of Health Research*, 12(1), 68-72.
- Killeen, G. F., McKenzie, F. E., Foy, B. D., Schieffelin, C., Billingsley, P. F., & Beier, J. C. (2000). A simplified model for predicting malaria entomologic inoculation rates based on entomologic and parasitologic parameters relevant to control. *The American Journal of Tropical Medicine and Hygiene*,
- Kulkarni, M. A., Kweka, E., Nyale, E., Lyatuu, E., Mosha, F. W., Chandramohan, D., Rau, M. E., & Drakeley, C. (2006). Entomological evaluation of malaria vectors at different altitudes in Hai district, northeastern Tanzania. *Journal of Medical Entomology*, 43(3), 580-588.
- Kwiatkowski, D. P. (2005). How malaria has affected the human genome and what human genetics can teach us about malaria. *The American Journal of Human Genetics*, 77(2), 171-192
- Mboera, L. E. G. (2000). *Fifty Years of Health Research in Tanzania* (1949 1999). Annotated Bibliography, DUP (1996) Ltd., 373pp.
- Mboera, L. E. G., Pedersen, E. M., Salum, F. M., Msuya, F. H., & Sambu, E. Z. (1997). Transmission of malaria and bancroftian filariasis in Magoda, North-East Tanzania. *Malaria and Infectious Diseases in Africa*, 7, 61-67.
- Mboera, L. E., Senkoro, K. P., Mayala, B. K., Rumisha, S. F., Rwegoshora, R. T., Mlozi, M. R., & Shayo, E. S. (2010). Spatiotemporal variation in malaria transmission intensity in five agroecosystems in Mvomero district, Tanzania. *Geospatial Health*, 4(2), 167-178.
- Minakawa, N., Sonye, G., & Yan, G. (2005). Relationships between occurrence of Anopheles gambiae sl (Diptera: Culicidae) and size and stability of larval habitats. *Journal of Medical Entomology*, 42(3), 295-300.
- Molta, N. B. (2000). Burden of malaria in Africa. A paper presented at the African Summit on Roll Back Malaria, Abuja

- Technical Session, 25th April 2000, World Health Organization, Geneva.
- Pell, F. (2009). Pell Frischmann Consulting Engineers LTD. British Expertise. Retrieved 5 May 2011.
- Shiff, C. J., Minjas, J. N., Hall, T., Hunt, R. H., Lyimo, S., & Davis, J. R. (1995). Malaria infection potential of anopheline mosquitoes sampled by light trapping indoors in coastal Tanzanian villages. *Medical and Veterinary Entomology*, 9(3), 256-262.
- Sinka, M. E., Bangs, M. J., Manguin, S., Rubio-Palis, Y., Chareonviriyaphap, T., Coetzee, M., Mbogo, C. M., Hemingway, J., Patil, A. P., Temperley, W. H., & Gething, P. W. (2012). A global map of dominant malaria vectors. *Parasites & vectors*, 5(1), 69.
- Snow, R. W., Guerra, C. A., Noor, A. M., Myint, H. Y., & Hay, S. I. (2005). The global distribution of clinical episodes of Plasmodium falciparum malaria. *Nature*, 434, 214-217.
- Tamuno, A. (2006). Nearer to peace (PDF). Academic Associates Peace Work. Retrieved 4 May 2011.
- Terkula, I. (2006). The Double Lives of Abuja Workers. Daily Trust. All Africa. Retrieved 4 May 2011.
- Turaki, A. H. (2011). Voters registration: Jega appears before Reps today. Daily Trust Daily Trust Online. Retrieved 5 May 2011.
- Umar, A., Kabir, B. G. J., Abdullahi, M. B., Barde, A., Misau, A. A., Sambo, M. L., Babuga, U. & Kobi, M. (2015). Assessment of Indoor Resting Density of female Anopheline mosquitoes dwelling at malaria vector sentinel sites in Bauchi State, Nigeria. Advanced Studies in Biology, 7(7), 323 333.

- World Health Organization (WHO) (2000). Management of severe Malaria: A practical handbook 47-48.
- World Health Organization (WHO) (2003). Malaria entomology and vector control learner's guide. Document WHO/CDS/CPE/SMT/2002. 18. World Health Organization Geneva.
- World Health Organization (WHO) (2006). Global programme to eliminate lymphatic filariasis. *Weekly Epidemiological Record*, 81(22), 221-232.
- World Health Organization (WHO) (2013). World malaria report. World Health Organization, Geneva, Switzerland.
- World Health Organization (WHO) (2014). World malaria report. World Health Organization, Geneva, Switzerland.
- World Health Organization (WHO) (2015). World malaria report. World Health Organization, Geneva, Switzerland.
- Xu, T., Zhong, D., Tang, L., Chang, X., Fu, F., Yan, G., & Zheng, B. (2014). Anopheles sinensis mosquito insecticide resistance: comparison of three mosquito sample collection and preparation methods and mosquito age in resistance measurements. Parasites and Vectors, 7(1), 54.
- Yohannes, M., & Boelee, E. (2012). Early biting rythms in the afro-tropical vectors of malaria, *Anopheles arabiensis* and challenges for its control in Ethiopia. *Medical and veterinary Entomology*, 26, 103-105.