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Malaria-Vector Dynamics in a Tropical Urban Metropolis, Nigeria

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ABSTRACT

Human malaria is a major cause of morbidity and mortality in sub-Saharan Africa. The present study explored the dynamics of malaria infection relative to *Anopheles* mosquito abundance, relative humidity and temperature in Nsukka, Nigeria. Hospital records from three hospitals in Nsukka town: Bishop Shanahan Hospital, University of Nigeria Medical Centre and Sadiq Hospital were examined for malaria prevalence and intensity from January to July 2015. Indoor biting *Anopheles* mosquitoes were collected by standard procedures within the study duration. Meteorological data on relative humidity and temperature was obtained from Centre for Basic Space Science, Nsukka, Enugu State. Overall recorded malaria prevalence at the hospitals from January to July was 72.8%. Malaria prevalence was highest in the month of July (90.3%) and least in February (55.4%). Majority of these infections were mild. Overall, more females compared to males were infected in the hospitals sampled ($p < 0.01$). Peak abundance of *Anopheles* mosquitoes was in July and lowest in January. Relative humidity increased from January to July while temperature declined in same direction. Malaria prevalence correlated positively with *Anopheles* mosquito abundance ($r = 0.863$, $p = 0.012$). Mosquito abundance and malaria prevalence strongly correlated negatively with temperature ($r = -0.799$, $p = 0.031$ and -0.869, $p = 0.011$, respectively). The positive correlation between relative humidity and malaria prevalence and mosquito abundance was not significant ($p < 0.05$). Malaria prevalence in Nigeria is influenced by *Anopheles* mosquito abundance. This association is affected by variation in temperature and relative humidity of the environment.

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IONA collected samples and laboratory records. GCO and CDN performed laboratory analyses and wrote the article. RNNO and ICO helped in sampling and analysis of data. All the authors helped in editing and revising the work.

Key words
Malaria, *Anopheles* mosquito, Prevalence, Relative humidity, Temperature.

INTRODUCTION

Human malaria, a parasitic disease caused by protozoa of the genus *Plasmodium*, is a major cause of morbidity and mortality globally. In 2013 alone, an estimated 198 million cases and 584 000 deaths were attributed to malaria worldwide (WHO, 2015). Majority of these morbidities and mortalities occur in sub-Saharan Africa where Nigeria is situated. Nigeria and Democratic Republic of Congo (DRC) account for 40% of malaria-associated deaths (WHO, 2013). The entire population of Nigeria which is over 180 million is at risk of malaria which accounts for 60% outpatient visits and 30% of hospitalizations annually (MPI, 2015).

The anthropophilic, haemophagic and nocturnal female anopheline mosquitoes transmit the blood-dwelling malaria parasite by inoculation into peripheral blood of human host during a blood meal. Over 40 species of *Anopheles* transmit human and zoonotic malaria, but *Anopheles gambiae, Anopheles funestus, Anopheles nili* and *Anopheles moucheti* are the primary vectors of human malaria in Africa and the most efficient globally (Sinka *et al*., 2010; Onyido *et al*., 2014; MAP, 2015). Survival of mosquitoes and transmission of malaria is affected by environmental and man-made factors and so, an elaborate exploration into the dynamics of environmental factors and vector cum human factors is vital to the control of malaria in any given population.

Environmental factors such as rainfall, temperature and humidity affect mosquito survival and *Plasmodium* transmission (Qasim *et al*., 2014). A seasonal variation in *Anopheles* mosquito abundance characterized by rise in the rainy season and decline in the dry season has been observed in Nigeria (Ayanda, 2009; Lamidi, 2009). The increased rainfall during rainy season creates more breeding sites for mosquitoes. The implication of the rise in mosquito abundance on malaria cases in a given population is not entirely a cause-effect relationship of more mosquito-more malaria. The species of mosquitoes, mosquito adaptation to environmental and man-made stressors, adaptation strategies of *Plasmodium* and human related factor may modify disease outcome (Paul *et al*., 2004; Russell *et al*., 2011; Deredec *et al*., 2016).

Malaria remains a major cause of neonatal and maternal mortality in Nigeria. Studies on malaria epidemiology and malaria vector dynamics remain an integral part of public health research in Nigeria. The importance of information about vector abundance and

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malaria cases in Nigeria where *Plasmodium falciparum* endemicity is a major public health concern is integral to public welfare. This informed this research enquiry.

MATERIAL AND METHODS

Study area

The study was conducted in Nsukka town which is situated in Nsukka Local Government Area, Enugu State, Nigeria. Nsukka LGA lies between latitude 6º43' - 7º00' and longitude 7º13' - 7º35' covering a land area of 1810km in Southeastern Nigeria (Ezeh and Ugwu, 2010; Ozor and Ozioko, 2015). Nsukka LGA has a population of over 309 448 (NPC, 2010) and the people engage in farming, trading and civil service as their main occupations. Climatic condition of Nsukka is the characteristic wet and dry seasons of West Africa. The dry season usually commences in November and recedes in March while the rainy season starts and recedes in April and October respectively. The average annual rainfall, temperature and relative humidity in Nsukka were 1579mm, 24.9ºC, and 75% respectively (Climate-data.org).

Ethical considerations

Ethical approval for this study was obtained from Enugu State Ministry of Health. Additional approval was obtained from the Chief Medical Officers at the three hospitals where hospital records were assessed.

Sampling sites

Bishop Shanahan Hospital, University of Nigeria Medical Centre and Sadiq Hospital were randomly chosen for this study using lottery method. All three hospitals were situated in Nsukka, and have high outpatient and inpatient calls. They also maintained good patient records keeping arrangements. Malaria records were obtained for patients admitted either as outpatient or inpatient at the three hospitals from January to July 2015. Special care was taken to exclude patients not resident in Nsukka.

The intensities of malaria cases for each month, were recorded as follows; +, mild infection; ++, moderate infection; +++, heavy infection. Sex of patients was also recorded.

Mosquito collection and identification

Adult mosquitoes were collected from the residential houses using pyrethroid-based insecticide knock down approach (PKC) (Onyido *et al*., 2011). Indoor-biting and resting adult mosquitoes were collected from student hostels within University of Nigeria Nsukka, in houses within 15km from each hospital and within Nsukka metropolitan. Sixty residential houses were randomly selected, twenty each in closer proximity to any one of the hospitals. From each of the houses, 2 rooms were randomly selected, indoor-biting and resting adult mosquitoes were collected from the 120 rooms in the 60 houses.

In each of the rooms that had sheltered at least one person the previous night, white spread sheets were laid on the floor from wall to wall and covering all immovable objects. Mortein insecticides were sprayed in the room, all doors and windows were shut and the room was vacated for 20 min. No special consideration for ceiling was made as all the rooms were properly sealed. At the end of 20 min, the rooms were opened. The white spread sheets were gently folded to enclose all weakened and killed mosquitoes. The sheets were taken outside, opened and all mosquitoes were collected with the aid of a forceps into petri dishes lined with a filter paper placed on cotton wool moistened with 2% formalin (Lamidi, 2009; Onyido *et al*., 2011).

The mosquitoes were identified by observation of gross morphology of the species by a trained entomologist and taxonomist aided by Gilies *et al*. (1968) and Gillet (1971) and (1972).

Meteorological data

Meteorological data for the duration of the study were obtained from the Centre for Basic Space Science Nsukka, Enugu State, Nigeria.

Statistical analysis

Data was analyzed using Microsoft Office Excel (Microsoft Inc.) and Statistical package for Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, Illinois). Chi-Square analysis was carried out for comparison of malaria prevalence and *Anopheles* mosquitoes for the duration of the study. Significance level (α) was set at 95% ($p < 0.05$).

RESULTS

The overall recorded prevalence of malaria in the hospitals studied was 72.8% (Table I). A monthly representation of malaria prevalence at the three hospitals showed that the highest (87.8%) prevalence was in July. This was followed by the month of June (77.6%) while the least prevalence was observed in February (58.4%). A steady rise in prevalence was noted from March to July in the three hospitals excluding a slight decline in March at Sadiq hospital. Malaria prevalence at each of the hospitals varied significantly with month ($p = 0.000$).

Also among the sexes, prevalence of malaria was higher in females than males except for the months of January at Bishop Shanahan Hospital, April at Sadiq Hospital and University of Nigeria Medical Centre where prevalence of malaria was higher among the males (Table II). The total prevalence of malaria infection in females compared to males was significant at Bishop Shanahan Hospital and University of Nigeria Medical Centre ($p < 0.05$).

Most of the patients that were positive for malaria had mild infection with the exception of Sadiq hospital where moderate level of parasitaemia was higher (53.7%) than mild (24.0%) (Table III) Overall, heavy parasitaemia was only observed in Bishop Shanahan Hospital (0.5%) and Sadiq Hospital (5.6%) but totally absent at University of Nigeria Medical Centre throughout the period of study.

Table I.- Monthly prevalence of malaria at the three hospitals

Month	Bishop Shanahan		Sadiq Hospital		Medical Centre		Total	
	No. examined	No. infected (%)	No. Examined	No. infected (%)	No. examined	No. infected (%)	No. examined	No. infected (%)
January	249	176 (70.7)	169	119 (70.4)	269	190 (70.6)	687	485 (70.6)
February	267	148 (55.4)	147	83 (56.5)	377	231 (61.3)	791	462 (58.4)
March	251	167 (66.5)	143	75(52.4)	383	261 (75.8)	777	503 (64.7)
April	236	168 (71.2)	138	95 (68.8)	318	241 (77.4)	692	504 (72.8)
May	296	234 (79.1)	133	95 (71.4)	314	243 (81.2)	743	572 (77.0)
June	286	231 (80.8)	93	68 (73.1)	457	371 (83.0)	836	670 (68.8)
July	278	251 (90.3)	182	163 (89.6)	218	181 (83.0)	678	595 (87.8)
Total	1863	**1375 (73.8)**	1005	**698 (69.5)**	2336	**1718 (73.5)**	5204	**3791 (72.8)**
χ^2		106.044		66.799		63.069		216.133
p		0.000		0.000		0.000		0.000

Table II.- Recorded prevalence of malaria by sex in the three hospitals examined.

		January	February	March	April	May	June	July	Total
Bishop Shanahan Hospital									
Male	No. Examined (%)	96 (38.6)	116(43.4)	103(41.0)	98(41.5)	104(35.1)	124(43.4)	102(36.7)	743(39.9)
	No. infected (%)	85(88.5)	50(43.1)	53(51.5)	65(66.3)	81(77.9)	94(75.8)	89(87.3)	517(69.6)
Female	No. Examined (%)	153(61.4)	151(56.6)	148(59.0)	138(58.5)	192(64.9)	162(56.6)	176(63.3)	1120(60.1)
	No. infected (%)	91(59.5)	98(64.9)	114(77.0)	103(74.6)	153(79.7)	137(84.6)	162(92.0)	858(76.6)
	P value*	0.000	0.000	**0.000**	0.165	0.719	0.062	0.194	0.001
Sadiq Hospital									
Male	No. Examined (%)	79 (46.7)	64(43.5)	65(45.5)	60(43.5)	63(47.4)	33(35.5)	87(47.8)	451(44.9)
	No. infected (%)	42(53.2)	36(56.2)	34(52.3)	45(75.0)	35(55.6)	26(78.8)	83(95.4)	301(66.7)
Female	No. Examined (%)	90(53.3)	83(56.5)	78(54.5)	78(56.5)	70(52.6)	60(64.5)	95(52.2)	554(55.1)
	No. infected (%)	77(85.6)	47(56.6)	41(52.6)	50(64.1)	60(85.7)	42(70.0)	80(84.2)	397(71.7)
	P value*	0.000	0.964	0.976	0.171	0.000	0.360	0.014	0.092
Medical Centre									
Male	No. Examined (%)	125(46.5)	177(46.9)	168(43.9)	122(38.4)	123(39.2)	200(43.8)	82(37.6)	997(42.7)
	No. infected (%)	73(58.4)	66(37.3)	94(56.0)	99(81.1)	86(69.9)	148(74.0)	65(79.3)	631(63.3)
Female	No. Examined (%)	144(53.5)	200(53.1)	215(56.1)	196(61.6)	191(60.8)	257(56.2)	136(62.4)	1339(57.3)
	No. infected (%)	117(81.2)	165(82.5)	167(77.7)	142(72.4)	157(82.2)	223(86.8)	116(85.3)	1087(81.2)
	P value*	0.000	0.000	**0.000**	0.078	0.011	**0.001**	0.251	0.000

*p value compares the prevalence of malaria between male and female.

Table III.- Monthly intensity of malaria at the three hospitals.

Month	Malaria intensity cases (%)								
	Bishop Shanahan Hospital			Sadiq Hospital			Medical Centre		
	Mild (+)	Moderate (++)	Heavy (+++)	Mild (+)	Moderate (++)	Heavy (+++)	Mild (+)	Moderate (++)	Heavy (+++)
January	140 (79.5)	33 (18.8)	3 (1.7)	45 (37.8)	64 (53.3)	10 (8.4)	173 (91.1)	17 (8.9)	0 (0.0)
February	108 (73.0)	40 (27.0)	0 (0.0)	34 (41.0)	43 (51.8)	6 (7.2)	209 (90.5)	22 (9.5)	0 (0.0)
March	123 (73.7)	40 (27.0)	0 (0.0)	36 (48.0)	37 (49.3)	2 (2.7)	220 (84.3)	41 (15.7)	0 (0.0)
April	119 (70.8)	48 (28.0)	2 (1.2)	43 (45.3)	48 (50.5)	4 (4.2)	238 (98.8)	3 (1.2)	0 (0.0)
May	172 (73.5)	62 (26.5)	0 (0.0)	43 (45.3	47 (49.5)	5 (5.3)	229 (94.2)	14 (5.8)	0 (0.0)
June	172 (74.5)	56 (25.5)	0 (0.0)	23 (33.8)	42 (61.8)	3 (4.4)	359 (96.8)	12 (3.2)	0 (0.0)
July	204 (81.3)	46 (18.3)	1 (0.4)	60 (36.8)	94 (57.7)	9 (5.5)	176 (97.2)	5 (2.8)	0 (0.0)
Total	1038 (75.5)	330 (24.0)	**7 (0.5)**	284 (40.7)	357 (53.7)	**39 (5.6)**	1604 (93.4)	116 (6.6)	**0 (0.0)**
χ^2		20.120			9.457			62.345	
P		0.065			0.664			0.000	

Table IV.- Monthly abundance of *Anopheles* mosquitoes.

Month	Mosquito abundance (%)		
	Anopheles gambiae	***Anopheles funestus***	**Total**
January	30 (37.5)	50 (62.5)	80 (8.2)
February	40 (39.2)	62 (60.8)	102 (10.5)
March	38 (33.3)	76 (66.7)	114 (11.8)
April	50 (36.2)	88 (63.8)	138 (14.2)
May	82 (46.1)	96 (53.9)	178 (18.4)
June	104 (93.7)	7 (6.3)	111 (11.4)
July	210 (85.0)	37 (15.0)	247 (25.5)
Total	554 (57.1)	416 (42.9)	**970 (100)**

df = 6; χ^2 = 224.830; p = 0.000.

A total of 970 *Anopheles* mosquitoes (554 *A. gambiae* and 416 *A. funestus*) were collected within the duration of the study. Mosquito abundance increased steadily from January to July except in June where number decreased to 111 (11.4%) (Table IV). The overall abundance of *A. gambiae* and *A. funestus* were 57.1% and 42.9% respectively. The peak abundance (93.7%) for *A. Gambiae* was in June and lowest (33.3%) in March. *A. funestus* also showed increase in abundance from January to May but declined drastically (6.3%) to its lowest in June.

A plot of mosquito abundance and malaria prevalence (Fig. 1) revealed that the *Anopheles* mosquitoes abundance increased gradually from January to July and only dropping slightly in the month of June. The same trend was observed in malaria prevalence where a steady monthly rise in mosquito abundance was accompanied by rise in malaria prevalence. The high prevalence of malaria in June was, however, accompanied by a peak abundance of *A. gambiae*.

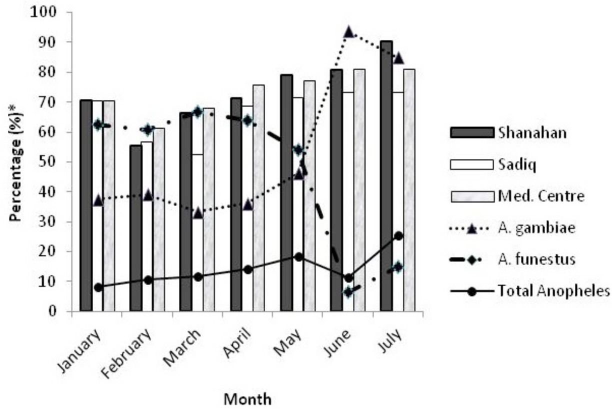

Fig. 1. Monthly prevalence of malaria at the three hospitals and associated *Anopheles* abundance.*, malaria prevalence and mosquito abundance.

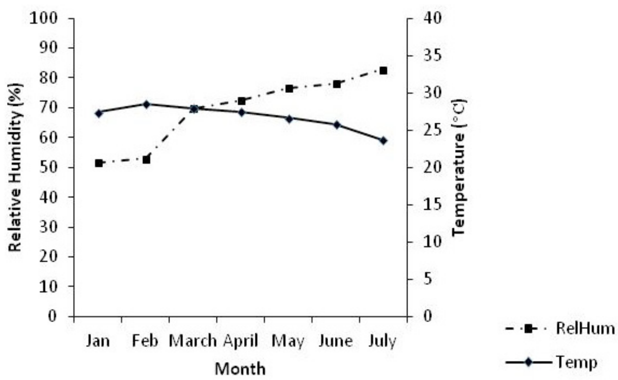

Fig. 2. Relative humidity and temperature at Nsukka, Enugu State, Nigeria for the duration of the study. RelHum, relative humidity; Temp, temperature.

Meteorological data on the relative humidity and temperature of the study area throughout the period of study indicated a progressive rise in relative humidity from January to July while temperature declined in the same direction (Fig. 2). Malaria prevalence and mosquito abundance increased in a similar pattern as the relative humidity (Fig. 3). The decline in mosquito abundance and malaria prevalence in June was however contrary to slight rise in relative humidity for same month. Malaria prevalence and mosquito abundance peaked when relative humidity was 83% and temperature 24ºC. The result from Pearson correlation analysis (Table V) indicated a strong negative correlation between temperature and *Anopheles* mosquito abundance and malaria prevalence. The positive association between relative humidity, malaria prevalence and mosquitoes abundance was however not significant. Malaria prevalence correlated significantly positive with *Anopheles* mosquito abundance (p = 0.012).

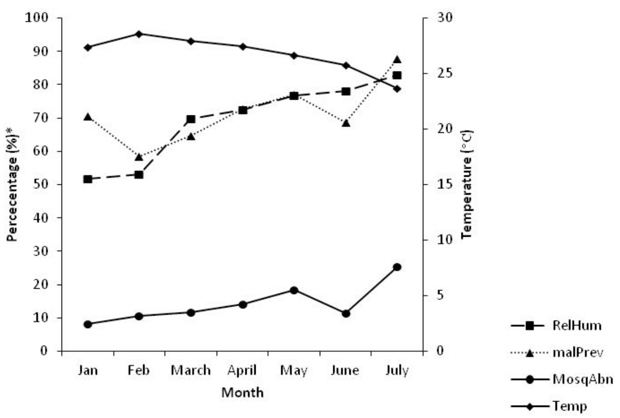

Fig. 3. Relationship between malaria prevalence and mosquito abundance to relative humidity and temperature in the study area from January to July. RelHum, relative humidity; Temp, temperature; MosqAb, mosquito abundance; malPrev, malaria prevalence. *, Prevalence for malaria, relative abundance for mosquito and percentage for relative humidity.

Table V.- Pearson correlation (r) and p values for mosquito abundance, malaria prevalence, temperature and relative humidity.

		Temperature	Relative humidity
	Mosquito abundance	-0.799*	0.747
		0.031	**0.054**
Malaria prevalence	0.863*	-0.869*	0.678
	0.012	**0.011**	**0.094**

*, Correlation significant at $p < 0.05$. p values in bold font.

DISCUSSION

Malaria is reported as the most prevalent tropical disease with high morbidity and mortality rates (WHO, 2001). The disease is endemic in sub-Saharan Africa with over 60% prevalence in Nigeria and other sub-Saharan countries (Onyido *et al*., 2011; Umar, 2014). Globally, malaria clinical cases have been estimated to be 300–500 million, resulting to over 881,000 deaths annually (WHO, 2008). This ranked malaria as the world's most important parasitic disease. Despite the reports of decline in malaria prevalence in many parts of the world, there are still areas in some countries of sub-Saharan Africa where malaria prevalence is over 70% as observed from records of some hospitals studied in Nsukka metropolis, Enugu State, Nigeria. This finding is in line with the works of Amadi and Ebenizer (2009), who reported high prevalence of haemoparasites in Yenagoa, Nigeria. Also high (93.7%) prevalence of malaria infection in the month of July observed in this study agrees with the works of Amadi *et al*. (2011). This high prevalence may be attributed to a moderately high rainfall in Nsukka during this period coupled with poor drainage systems which encourage the breeding of the disease vector.

Endemicity of a disease is usually characterised by presence of certain level of the disease condition in the population. It is not unusual that majority of the patients records in the hospitals studied for malaria infection had mild intensity of parasitaemia and females were more infected with malaria parasites than males. This observation is contrary to the reports of Mandel and White (1984) and Amadi *et al*. (2011) where males had more malaria infection. The higher prevalence in females may be due to the characteristic female wears that expose some parts of their body to malaria vectors during outdoor activities. Majority of these mild cases which are usually asymptomatic (Laishram *et al*., 2012; Gudo *et al*., 2013), sometimes come from patients whose complaints necessitate the diagnosis of malaria and typhoid infections as a measure to exclude both cases before further tests and treatment are recommended. This is because most individuals in endemic areas acquire immunity to malaria even when the infective agents are present. This helps to prevent misdiagnosis of the actual cause of morbidity and neglect of the real cause of disease state.

Anopheles gambiae strict lacto and *Anopheles funestus*, the major vectors of malaria in Africa are known to vary in abundance in relation to environmental parameters such as rainfall, temperature and humidity (Lamidi, 2009; Umar, 2014). Rainfall provides suitable breeding ground for mosquitoes. Habitat expansion during periods of rainfall favour mosquito reproduction and survival which also is dependent on temperature and relative humidity (Impoinvil *et al*., 2007; Yamana and Eltahir, 2013). It has been observed that relative humidity plays a significant role in mosquito survival and malaria transmission dynamics (Yamana and Eltahir, 2013). A strong negative correlation between temperature and mosquito abundance and a positive correlation between relative humidity and mosquito abundance were reported recently by Jemal and Al-Thukair (2016). This conforms to the observation in this work of a positive correlation between *Anopheles* mosquito abundance in the rainy months (May to July) and peak malaria prevalence. The observed increased in malaria prevalence may have resulted from the abundance of malaria vectors at that same period.

The changes in *A. gambiae* and *A. funestus* monthly abundance in relation to malaria prevalence in the study population highlight evolutionary adapted efficiency of these vectors of *Plasmodium.* In the drier months of January, February and March, *A. funestus* was higher in abundance than *A. gambiae*. When the population of *A. funestus* dropped drastically during the wet season, the population of *A. gambiae* rose much higher augmenting the effect of the drop in *A. funestus* population thus maintaining *Anopheles* species population and malaria transmission all year round. This conforms to the sub-species synergy reported by Russell *et al*. (2011) where increase in the abundance of outdoor biting *A. funestus* complemented decline in indoor biting *A. gambiae* and *A. funestus*.

The present study highlights that besides the direct target of *Plasmodium*, a comprehensive knowledge of malaria vector dynamics is essential in malaria eradication. This goes to show that efforts and strategies for malaria control in Nsukka, and possibly Nigeria as a whole need to be re-evaluated and intensified. Also an integrated approach to malaria control is especially required in sub-Saharan Africa where political, social and environmental factors confound control efforts.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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