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THE EFFECTS OF WEATHER PARAMETERS ON THE ABUNDANCE AND DISTRIBUTION OF LARVAL AND ADULT MOSQUITOES IN MAKURDI METROPOLIS

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Abstract: **In a bid to control malaria in Nigeria, this study was carried out to investigate the effects of weather parameters on the abundance and distribution of larval and adult mosquitoes in Makurdi metropolis, the capital of Benue State for a period of one year between November 2017 and October, 2018. Breeding sites were studies in five locations. Samples were collected twice per week both indoors and outdoors, using standard techniques. Three generic and four specific taxa of mosquito were identified: *Aedes aegypti, Anopheles gambiae, Anopheles funestus* and *Culex quiquefasciatus.* A total of 2,415 larvae were estimated in the five locations ranging from 345 (14.3%) larvae in Northbank to 615 (25.5%) in Wurukum. Average count was 483 in the five locations. *Culex quiquefasciatus* was the most abundant with a total of 1,384 and average of 276.8 larvae in the five locations where it was highest in Kanshio (303) and lowest in Northbank (183). Chi-square analysis showed a significant association between abundance of larvae and locations (χ^2 =83.46, P<0.05). The observed differences in the population of each species of mosquito across the locations are statistically significant (P<0.05). Mean seasonal weather temperature was 32.9°C while amount of rainfall and relative humidity were 127.59mm and 71.83% respectively. *Anopheles gambiae* larval population had significantly high positive correlations coefficients with rainfall (0.735) and relative humidity (0.815) but negative coefficient with temperature (-0.707). *Anopheles funestus* larval population had high positive correlations coefficients with relative humidity (0.738). Population of *Anopheles* mosquito was significantly affected by temperature (F=10.26, P<0.05; R^2 = 50.65%), rainfall (F=11.13, P<0.05, R^2 = 52.67%) and relative humidity (F=19.88, P<0.05, R^2 = 66.53%. On the basis of how weather parameters affected determined the population of *Anopheles* mosquito, relative humidity > rainfall >temperature. In conclusion, all weather parameters (temperature, rainfall and relative humidity had marked effects on the abundance and distribution of the malaria vectors. This work has added to the existing data on the relationship between malaria vectors and weather factors which may enhance knowledge on malaria entomology and future malaria control interventions in the study area and beyond.**

Keywords: **Mosquitoes, Abundance, Weather parameters, Malaria control.**

1. INTRODUCTION

Mosquitoes have been reported to be of public health importance as they constitute serious biting nuisance and transmit most deadly and life-threatening diseases such as malaria, dengue fever, yellow fever and filariasis (Gopalakrishnan *et al.*, 2013).These mosquito borne diseases, infecting more than 700 million people around the world each year, resulting in as many as two million deaths annually, thus establishing one of major health problems in almost all tropical and sub-tropical countries (Amarasingh and Dalpadado, 2014). The brunt of these diseases is mostly felt in Africa due to the poor socio-economic conditions and large expanse of the aquatic habitats which provide suitable breeding sites for mosquitoes (Adeleke *et al.*, 2010). For instance, in Sub- Saharan Africa (SSA), 76% of malaria related deaths take place since malaria is estimated to result in an annual loss of 70% of the deaths amongst children below five years of age (WHO, 2017).

Tropical areas, including Nigeria, have the best combination of adequate parameters such as temperature, rainfall and humidity that affect not only the geographical distribution of various vector borne diseases, but also is projected to have adverse effects on human health in view of infectious diseases, particularly malaria (Anil and Sandeep, 2017).

Generally, environmental factors have contributed significantly to malaria prevalence and thereby affect its distribution, seasonality, and transmission intensity (Esther *et al.*, 2017). Although several other factors account for its occurrence and incidence, diseases seem to have a significant association with climatic variables (Alemu *et al.*, 2011). Malaria has been identified as the most climate sensitive disease hence changes in temperature, rainfall, and humidity due to climatic change are expected to influence malaria prevalence directly (modifying the behaviour and geographical distribution of malaria vectors as well as changing the length of the cycle of the malaria parasite) and indirectly (changing ecological relationships important to the organisms). Precisely, population of malaria is influenced by weather, which affects the ability of the main carrier of malaria parasites, *Anopheles* mosquitoes, to survive or otherwise. Tropical areas including Nigeria have the best combination of adequate rainfall, temperature and humidity allowing for breeding and survival of *Anopheles* mosquitoes (Kuhe and Jenkwe, 2015; Manyi *et al.*, 2015).

The effects of weather factors on both immature and adult mosquito populations and their distribution as well as on the parasites they transmit have been documented (Manyi *et al*., 2015). Also, Valdeza *et al*. (2017) found that the distribution of a mosquito population depends heavily on climatic variables such as temperature, precipitation and humidity. These parameters affect ecology, development, behaviour, and survival of insects and the diseases they transmit. They are associated with the dynamics of malaria vector population and therefore with the spread of the disease (Maya *et al*., 2015; Valdeza *et al*., 2017). This study is necessary due to the fact that Benue State is blessed with large and small water bodies that have been known to serve as breeding sites for mosquitoes which further constitute serious biting nuisance and transmit most deadly and life-threatening diseases such as malaria, yellow fever and filariasis. Serial cases of malaria incidence have been reported in Benue State both in adults, children and pregnant women which often leads to economic hardship and to some extend death if adequate measures are not taken. It is on this premise that the study aims at determining the effects of weather parameters on the survival, abundance and distribution of both larval and adult mosquito species in the study area

2. MATERIALS AND METHODS

Study Area

Studies on the effects of weather parameters on the abundance and distribution of larval and adult mosquitoes in Makurdi metropolis, Nigeria was carried out in Makurdi town, the capital of Benue State, using five major localities: Kanshio, Wurukum, Gboko-road, North- bank and Wadata, for a period of one year between November 2017 and October, 2018. Benue State is located between longitude 8°37ˈE and latitude 7°41ˈN. The local government shares boundaries with Guma Local Government Area to the North-East, Gwer to the South, Gwer-West to the West and Doma local government area of Nasarawa State to the North-West. The local government area is divided into two major blocks by River Benue hence the North and South Banks. It has a population of 300,377 comprising 154,138 male, 146,239 female (National Bureau of Statistics, 2011) with a landmass of 820 km². Makurdi town, the headquarters of the Local Government also serves as the State capital. Its location can best be described as the "Gateway" of the state to both the North and South (Government of Benue State, 2016). Makurdi is characterized with high temperature in ranging from (30^{O}C-39^{O}C) (Nigeria Meteorological Agency 2017).

Ethical Consideration

Verbal informed consent was obtained from the head of each household before their houses were accessed for mosquito collection in all the study localities.

Collection of Adult Mosquito Samples

A total of twenty-five (25) sampling units or houses, five (5) for each locality were randomly selected from the four localities. Mosquito samples were collected twice per week. Indoor resting mosquitoes were collected using the Pyrethrum

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Spray Catch (PSC) between the hours 06:00 – 09:00 am and 05:00 – 08:00 pm in the study localities either alive or dead as described by Dandalo (2007). Individual samples were each preserved dry over silica gel in well labeled Eppendorf tubes (1.5ml) prior to identification. This was to ensure preservation of delicate significant features that were needed for morphological identification in the laboratory (Celina *et al.*, 2016). Outdoor sampling was done twice weekly using a sweep net up to a maximum of five sweeps was taken along the edges of each habitat depending on its surface area and size. Sweep net contents were emptied into a white tray to enhance visibility and identification of sampled organisms. The period of mosquito collection was carefully selected to suit the biting period of the vector species (dusk and dawn) as reported by WHO (2017) and as adopted by (Manyi *et al.*, 2015).

Identification of Adult Mosquito Samples

Standard dissecting microscope was used for identification of the mosquitoes with particular reference to the head, thorax, wings and hind - legs according to Gilles and Coetzee (1987). Morphological characteristics such as length of maxillary palps, wing spots, leg shape, mouth parts and abdominal end model as presented by Oguoma *et al.* (2010) and Service (2012) was used to identify adult mosquito that were collected in the study area. Observation of the morphological features were made at the advanced Biology laboratory, Department of Biological Sciences Federal University of Agriculture Makurdi.

Mosquito Larval Sampling

Accessible breeding sites in the study area were sampled for mosquito larvae including Kanshio, Wadata, Wurukum, North bank and Gboko road. The mosquito larvae were collected with the use of plastic dippers sieves of 0.55 mm mesh -seize into labeled sample bottles. The larvae were collected by skimming plastic scoopers and sieves through the water or lowering the deeper slowly into the water at an angle of 45° just below the water surface so that water will flow in together with any larvae that was present as described by Adeleke *et al*. (2010). In occasions that the larvae was not identified immediately, they were preserved using 4% formaldehyde solution (Okorie *et al*,. 2014).

Identification of Mosquito Larval Specimens

The specimens were identified as fast as possible using keys provided by Gillies and Coetzee (1987). The larvae were viewed and identified using taxonomic features as; absence or presence of siphon, pectin, comb, sub -ventral tuffs, gills, metal - pleural spines and tergal plate as described by Service (2012).

Collection of Data on Weather Factors

Tropical areas including Nigeria have the best combination of adequate rainfall, temperature and humidity allowing for breeding and survival of mosquitoes (Kuhe and Jenkwe, 2015).Therefore, in order to ascertain correlations with the problem of mosquito proliferation and subsequent vector disease transmission in Makurdi metropolis, data on weather parameters (temperature, rainfall and relative humidity) were obtained during the study period with the help of the personnel Nigerian Meteorological Agency (NMA), Tactical Air Command Makurdi.

3. DATA ANALYSES

Statistical correlation analysis and ANOVA was used to analyse the weather parameters on larval and adult mosquito distribution, Regression analysis was done to determine the strength of the association where it may exist, using SPSS version17.0. Significant levels were measured at 95% confidence level with significant differences considered at P< 0.05.

4. RESULTS AND DISCUSSION

Three generic and four specific taxa of mosquito were identified: *Aedes aegypti*, *Anopheles gambiae*, *Anopheles funestus* and *Culex quiquefasciatus* (Table 1). A total of 2,415 larvae were estimated in the five locations ranging from 345 larvae in Northbank to 615 in Wurukum. Average count was 483 in the five locations. *Culex quiquefasciatus* was the most abundant with a total of 1,384 and average of 276.8 larvae in the five locations where it was highest in Kanshio (303) and lowest in Northbank (183). This was followed by *Anopheles gambiae* with a total number of 880 larvae and average of 176 larvae, ranging from 97 in Gboko Road to 285 in Wurukum. Other identified mosquito species and their total counts were *Aedes aegypti* (61 larvae) and *Anopheles funestus* (90 larvae). The hierarchical order of abundance mosquito larvae in the five locations is given as: Wurukum>Kanshio>Wadata>Gboko Road>Northbank. Chi-square analysis showed a significant association between abundance of larvae and locations (χ^2 =83.46, P<0.05).

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Table 2 describes the monthly weather parameters and *Anopheles* mosquito population of the study area. Mean weather temperature recorded between November 2017 and October 2018 was 32.9ºC while amount of rainfall and relative humidity were 127.59mm and 71.83% respectively. The lowest mean temperature reading of 29.7ºC was recorded in December 2017 (dry season) and the highest was recorded in July 2018 (rainy season) with value of 37.9ºC. There was no rainfall observed from March to July. Highest mean rainfall recorded was 354.2mm in October and the lowest was 89.0mm in November. Mean relative humidity varied between 46% in April and 89% in December. An average of 80 *Anopheles* larval was recorded ranging from a total count of 21 larvae in March 2018 to 117 in October 2018. The month of November to May (dry season) recoded low larval population while June to October (rainy season) had higher larval population.

Correlation between weather parameters and population of Anopheles species is given in Table 3. *Anopheles gambiae* larval population had high positive correlations coefficients with rainfall (0.735) and relative humidity (0.815) but negative coefficient with temperature (-0.707). *Anopheles funestus* larval population had high positive correlations coefficients with relative humidity (0.738); moderate positive coefficient with rainfall (0.632) but moderate negative coefficient with temperature (-0.653). All coefficients values are statistically significant ($P<0.05$). From regression analysis, effect of mean temperature on population of *Anopheles* mosquito was significant ($F=10.26$, $P<0.05$). Coefficient of determination R^2 (variability explained) between the two variables was 50.65% (Table 4). Effect of mean rainfall on population of *Anopheles* mosquito was significant ($F=11.13$, $P<0.05$). Coefficient of determination R^2 (variability explained) between the two variables was 52.67% (Table 5). Effect of mean relative humidity on population of *Anopheles* mosquito was significant ($F=19.88$, $P<0.05$). Coefficient of determination R^2 (variability explained) between the two variables was 66.53% (Table 6). On the basis of how weather parameters affected determined the population of *Anopheles* mosquito, relative humidity > rainfall >temperature. Table 7 describes the monthly weather parameters and combined population of *Culex quinquefasciatus* and *Aedes aegypti*. A total of 1405 larvae was counted with average count of 117.08 larva within 12 months. The lowest count was recorded in February 2018 (48 larvae) while the highest count was 209 larvae as recorded in October 2018.

Table 1: Mosquito larval abundance and distribution at five Localities in Makurdi.

Species, Number /Location	Kanshio	Gbk Road	Nor N/Bank	Wurukum	Wadata	Total	Mean
Aedes aegypti	15	13	11	10	12	61	12.2
Anopheles gambiae	165	97	141	285	192	880.	176
Culex quiquefasciatus	303	294	183	318	286	1,384	276.8
Anopheles funestus	46	29	1 0	2	3	90	18
Total	529	433	345	615	493	2,415	483

Table 2: Monthly Relationship between Weather Data and *Anopheles* Mosquito Population in the Localities of Makurdi between November, 2017 and October, 2018.

	Mosquito species and Number collected (%)			**Data on Weather Parameters**		
Sample Months	*Anopheles gambiae*s.l.	*Anopheles funestus*	Monthly Total (%)	Mean Tempt (ºC)	Mean Rainfall (mm)	Mean RH (%)
Nov, 2017	63	1	64	31.2	89.0	83
Dec., 2017	54	2	56	29.7	215.8	89
Jan., 2018	43	6	49	30.5	271.4	88
Feb., 2018	23	5	28	30.6	296.4	79
Mar., 2018	18	3	21	33.1	0.00	62

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Apr., 2018	65	6	71	33.5	0.00	46
May.,2018	72	8	80	34.3	0.00	47
June., 2018	83	12	95	36.8	0.60	68
July, 2018	116	9	125	37.9	0.00	62
Aug, 2018	124	15	139	34.2	141.2	73
Sept, 2018	104	11	115	32.6	162.5	80
Oct.,2018	105	12	117	30.4	354.2	85
Total/Mean	**870**	**90**	**960**	**32.9**	**127.59**	**71.83**

Table 3: Correlation between *Anopheles* species and Weather Parameters from the Localities of Makurdi between Nov. 2017 to Oct. 2018

Correlations	Correlation Coeff.	P-value
Anopheles gambiae Vs Mean Temperature (^{O}C)	-0.707*	0.010
Anopheles gambiae Vs Mean Rainfall (mm)	0.735**	0.006
Anopheles gambiae Vs Mean Relative Humidity	0.815**	0.001
Anopheles funestus Vs Mean Temperature (^{O}C)	-0.653*	0.021
Anopheles funestus Vs Mean Rainfall (mm)	0.632*	0.027
Anopheles funestus Vs Mean Relative Humidity	0.738**	0.006

Note: * means correlation is significant at 0.05 level while ** means correlation is significant at 0.01 level.

Table 4: OLS Parameter Estimates of Total *Anopheles* and Mean Temperature from Makurdi Community (Nov. 2017 to Oct. 2018).

Dependent variable: Total *Anopheles*				
Variable	Coefficient	Std. Error	t-statistic	P-value
Intercept	1256.808	313.8791	4.004113	0.0025
MTempt.	-30.28371	9.453526	-3.203431	0.0094
R-squared				0.506465
Adjusted R-squared				0.457111
DW statistic				0.643544
F-statistic		10.26197	Probability	0.009437

Table 5: OLS Parameter Estimates of Total *Anopheles* mosquitoes and Mean Rainfall from Makurdi Community (Nov. 2017 to Oct. 2018).

Dependent variable: Total *Anopheles*				
Variable	Coefficient	Std. Error	t-statistic	P-value
Intercept	173.3250	34.23941	5.062148	0.0005
M Rainfall	0.637680	0.191148	3.336063	0.0075
R-squared				0.526724
Adjusted R-squared				0.479396
DW statistic				0.823519
F-statistic		11.12932	Probability	0.007540

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Table 6: OLS Parameter Estimates of Total *Anopheles* and Mean Relative Humidity from Makurdi Community (Nov. 2017 to Oct. 2018).

Dependent variable: Total *Anopheles*				
Variable	Coefficient	Std. Error	t-statistic	P-value
Intercept	-197.0194	103.2611	-1.907973	0.0855
MRH	6.321158	1.417743	4.458606	0.0012
R-squared				0.665319
Adjusted R-squared				0.631851
DW statistic				1.632422
F-statistic		19.87917	Probability	0.001219

Table 7: Monthly Relationship between Weather Data and other Mosquito Population in the Localities of Makurdi between November, 2017 and October, 2018.

	Mosquitospecies and Number collected (%)				Data on Weather Parameters		
Sample Months	*Culexquinquefasciatus*	*Aedesaegypti*	Monthly (%)	Total	Mean Tempt (°C)	Mean Rainfall (mm)	Mean RH (%)
Nov, 2017	73	0	73		31.2	89.0	83
Dec., 2017	64	1	65		29.7	215.8	89
Jan., 2018	53	2	55		30.5	271.4	88
Feb., 2018	43	5	48		30.6	296.4	79
Mar., 2018	58	3	61		33.1	0.00	62
Apr., 2018	105	5	110		33.5	0.00	46
May., 2018	112	5	117		34.3	0.00	47
June., 2018	133	6	139		36.8	0.60	68
July, 2018	166	7	173		37.9	0.00	62
Aug, 2018	174	8	162		34.2	141.2	73
Sept, 2018	184	9	193		32.6	162.5	80
Oct, 2018	199	10	209		30.4	354.2	85
TOTAL/MEAN	**1364**	**61**	**1405**		**32.9**	**127.54**	**71.83**

The results of this study revealed a proportional relationship between the Anopheles mosquito abundance, their distribution and, the meteorological parameters measured. Data on temperature obtained in Makurdi metropolis during the study period were optimum for the mosquitoes' breeding, growth and survival in consonance with the findings of Laumann (2010). The temperature values were consistently high throughout the study period with peaks in February and March, 2016, just before the steady rains in April of the same year. The highest and lowest monthly mean temperature values during the study period imply that temperature had no adverse effect on the two primary malaria vectors' abundance in the study area for both dry and wet seasons. This might be attributed to the fact that the mean temperature values were within the optimum temperature range for insects, particularly mosquitoes which is in agreement with the report of Githeko *et al.* (2000).The high temperature values recorded in this study would accelerate the reproductive process in the mosquito vector populations Makurdi metropolis, in line with the findings of (Service, 2012) who reported that optimum temperature of 32 ^{0}C helps in the development and hatching of mosquitoes' eggs and this signify increased transmission of the malaria and lymphatic filarial parasites.

The finding of this study also corroborates Laumann (2010) who reported that the incidence of malaria is influenced by weather factors which specifically determine the ability of the main carrier of malaria parasites, female *Anopheles* mosquitoes, to survive or otherwise. Kasili *et al.* (2009) similarly reported that both mosquito populations and their Entomological Inoculation Rates (EIR) were reduced by decreasing rainfall amounts; and that *Anopheles* species were found to dominate in the wet season. Results of the present study have similarly revealed that rainfall had a marked effect on the *Anopheles* mosquito vector populations in the study community as more mosquitoes were obtained in the wet season than the dry season. Meanwhile, the relative humidity values ranged from 46% to 89% with lowest values recorded from December, 2017 to March, 2018 (dry season) and higher values were recorded from July to October, 2017 (wet season) and then April to June, 2018 (second wet season) respectively.

A similar seasonality trend as observed in terms of the relative abundance of mosquitoes for all the localities in this study has been reported in Southern Nigeria (Uttah, 2009) and in the Eastern part of Kenya (Mwngangi *et al.*, 2009). The meteorological data obtained in this study were strongly observed to have influence on *Anopheles* mosquito distribution in the study area, contrary to the report of Masaninga *et al.* (2012) who reported that these factors had no significant roles on the mosquito distribution in "an urban setting in Zambia". Therefore, it is evident that malaria and other mosquito vector disease cases are likely to increase during the wet season in Makurdi metropolis as corroborated by NIAID (2007) for tropical areas. Since female *Anopheles* mosquitoes must live long enough for *Plasmodium* species to complete their development within them, environmental factors that affect their survival can influence disease incidence (Service, 2012)**.** Weather data in correlation to the mosquito distribution data obtained in the present study are therefore, in line with the report of NIAID (2007). the mosquito population increased with increase in rainfall. In a similar manner, temperature values throughout the period of this investigation did not show adverse effect on the mosquito vector population. This coincides with the report of WHO (2017) on malaria seasonality in the tropics which holds that temperature is normally in favour of mosquito vectors throughout the year in these areas. This report of WHO (2017) also related mosquito vector disease transmission with the availability of breeding sites, which in turn depends on the annual rainfall patterns. In the present study, temperature had favourably enhanced the population of the vector species across the five localities throughout the study period.

Meanwhile, annual rainfall and the corresponding relative humidity were observed to have proportional effects on the mosquito vector population in the area (i. e the higher the amount of rainfall and relative humidity, the more the number of mosquitoes). There was a strong relationship between mean monthly rainfall totals and the relative abundance of the three major mosquito species identified in the study area. This is however, parallel to the findings of Shililu *et al.* (1998) in Western Kenya who reported no significant correlation between the monthly rainfall totals and relative densities of *Anopheles gambiae*s and *Anopheles funestus* respectively. This study was also carried out to identify the mosquito species that are predominant in Makurdi metropolis. The present result correlates with the findings of Okorie *et al*. (2014) who reported similar findings in Ibadan and Manzoor *et al*. (2020) in Pakistan.

5. CONCLUSION

Culex quiquefasciatus was the predominant among the four species of mosquito identified in the study area. The Wurukum location recorded the most abundant larvae. All weather parameters (temperature, rainfall and relative humidity had marked effects on the abundance and distribution of the malaria vectors. Wet season months had more mosquitoes across the study localities than dry season period of the study, since there were more breeding sites during the wet season than the dry season. This work has added to the existing data on the relationship between malaria vectors and weather factors which may enhance knowledge on malaria entomology and future malaria control interventions in the study area and beyond. The city of Makurdi and its environment should be properly kept clean at all times while drainage channels should be constructed within and around the metropolis to eliminate logged waters that serve as breeding sites for these vectors.

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