American Journal of Entomology
2017; 1(2): 31-38
http://www.sciencepublishinggroup.com/j/aje
doi: 10.11648/j.aje.20170102.12

Association of Meteorological Factors with Two Principal Malaria Vector Complexes in the University of Agriculture Makurdi Community, Central Nigeria

Manyi Manasseh Msugh-Ter[1, *], Dechi Aloysius Aondowase[2], Azua Emmanuel Terese[3]

[1]Applied Entomology and Parasitology Unit, Department of Biological Sciences, Federal University of Agriculture, Makurdi, Nigeria
[2]Department of Biology, College of Education, Katsina-Ala, Nigeria
[3]Environmental Science Unit, Department of Biological Sciences, Federal University of Agriculture, Makurdi, Nigeria

Email address:
manyimanasseh@rocketmail.com (M. M. Msugh-Ter), dechialoysius@gmail.com (D. A. Aondowase), tereseazua@gmail.com (A. E. Terese)
[*]Corresponding author

To cite this article:
Manyi Manasseh Msugh-Ter, Dechi Aloysius Aondowase, Azua Emmanuel Terese. Association of Meteorological Factors with Two Principal Malaria Vector Complexes in the University of Agriculture Makurdi Community, Central Nigeria. *American Journal of Entomology*. Vol. 1, No. 2, 2017, pp. 31-38. doi: 10.11648/j.aje.20170102.12

Received: May 29, 2017; **Accepted**: August 26, 2017; **Published**: October 9, 2017

Abstract: Association between meteorological indices and two major malaria vectors - *Anopheles gambiae* and *Anopheles funestus* complexes was determined in the Federal University of Agriculture Makurdi community, Nigeria, from July, 2015 to June, 2016. Meteorological data (Temperature, Rainfall and Relative Humidity) were obtained at the Nigerian Meteorological Agency, Tactical Air Command in Makurdi. Adult *Anopheles* mosquitoes (n = 3,053), comprising *Anopheles gambiae* s.l. [1,981(64.9%)] and *Anopheles funestus* complex [1,072(35.1%)], were collected indoors across four localities in the University Community and identified using standard keys and procedures. There were no marked fluctuations in mean atmospheric temperature throughout the study period, with the highest records of 35.9°C and 37.9°C for February and April, 2016 respectively. Relative humidity increased proportionally to rainfall, ranging from 46% - 89%. The *Anopheles* vector population was significantly ($P < 0.05$) higher during the wet season than the dry season. Pearsons's correlation showed strong negative and significant relationship ($r = -0.707, -0.653, P < 0.05$) between temperature and the *Anopheles* species across the localities. Rainfall and relative humidity correlated positively and significantly ($r = 0.735, 0.632, P < 0.05$) with the *Anopheles* species' population. Regression analysis showed strong linear relationships ($R^2 = 0.506465$, $R^2 = 0.526724$ and $R^2 = 0.665319$ for temperature, rainfall and humidity respectively) between meteorological indices and the *Anopheles* population. 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: Weather Parameters, Malaria, *Anopheles* Species, University Community, Makurdi, Nigeria

1. Introduction

The relationships between meteorological factors and both mosquito populations and their distribution as well as the parasites they transmit have been well documented [1-5]. Malaria and lymphatic filariasis's epidemiology depends on many factors including the environment (climate, topography and housing), and apart from the mosquito vectors themselves, the parasites they harbor and transmit have different temperature requirements for reproduction within the mosquito host [6]. This explains why *Plasmodium vivax* cannot reproduce below the temperature of 15°C, and *P. falciparum* does not reproduce when the temperature drops below 19°C.

[7] reported that incidence of malaria is influenced by weather, which affects the ability of the main carrier of malaria parasites and the female anopheline 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 mosquitoes [7]. [3] reported that optimum temperature of 32°C helps in the development and hatching of mosquitoes' eggs and this imply increased transmission of the malaria and lymphatic filarial parasites. Similarly, [4] stated that the higher the temperature,

the faster the gonotrophic cycle of mosquitoes and vice versa.

[1] reported that both mosquito population and their Entomological Inoculation Rate (EIR) are reduced by decreasing rainfall amounts. This has also been found to be true by the works of [8], who reported that *Anopheles* species were found to dominate in the wet season.

Reports from the National Institute of Allergy and Infectious Diseases [9] pointed out that climate affects both parasites and mosquito vectors and that, mosquitoes cannot survive in low humidity; rainfall expands breeding grounds, and in many tropical areas, malaria and other mosquito vector disease cases increase during the rainy season. Moreover, [4] opined that since mosquitoes must live long enough for the parasites to complete their development within them, environmental factors that affect their survival can influence disease incidence.

However, it has been recorded that extreme relative humidity retards the activity of mosquitoes, thereby making them stationary in their breeding, biting and resting places [2]. But they also corroborated that environmental factors such as high relative humidity and cool shade are preferred by mosquitoes for breeding.

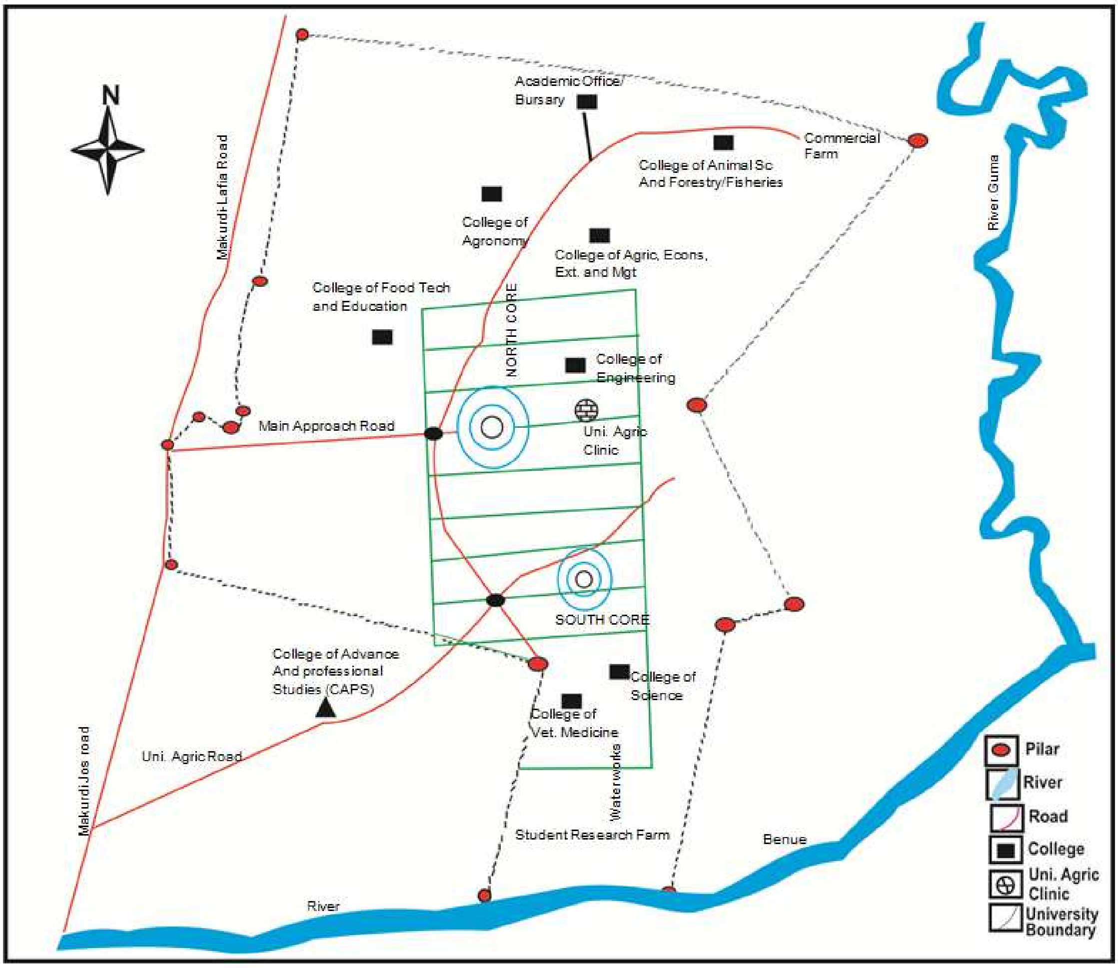
[10] also documented some interactions between weather and mosquito populations and reported that 'though, mosquitoes need water for reproduction and warm temperatures to be active, warmer and wetter conditions do not necessarily correspond to higher numbers of mosquitoes'.

The present study was therefore, aimed at obtaining meteorological data in order to ascertain if there exist any association between them and *Anopheles* mosquito vector abundance in the Federal University of Agriculture community, with a view to providing a pre-control data that would be useful in any future mosquito control programs in the study area and beyond.

2. Materials and Methods

2.1. Study Area

This study was carried out between July, 2015 and June, 2016 and samples were collected from the University staff quarters, students' hostels, lecture halls, the surrounding village community, all in and around the Federal University of Agriculture Makurdi, in Benue State located in the middle belt region, North Central Nigeria [11].



Source: [16]

Figure 1. *Map of University of Agriculture Makurdi showing Proximity to River Benue.*

The University was established in 1988, following the recommendations of a 1987 Federal government White Paper on Higher Education curriculum and development in Nigeria [12]. The University is 10 km away from the Federal road leading to Lafia-Enugu across Benue State. It has a land mass of 8,048 hectares and share common boundaries with the river Benue and Makurdi town in the south, Federal Housing Estate in the west, Tyodugh village in the east, Agan village in the north and Guma Local Government Area in the North-east. One of the cardinal objectives of the University of Agriculture Makurdi was the generation of high-yielding crop varieties and livestock breeds as well as other efficient agricultural technologies that are sufficiently adapted and relevant to local environments.

The University is close to river Benue- a major source of water in the area with other networks of streams, standing pools, over filled and blocked drainages. Tall bushes, trees with thick canopies and overgrown fields are easily noticeable in the University of Agriculture Makurdi community, especially during the wet season, even around hostels, staff quarters and offices.

Recently, construction works have so many water holding ditches around the campus. These provide suitable breeding sites for mosquitoes throughout the wet and dry season periods.

Data from [13] show that the study area is characteristic of high temperatures, ranging between 30°C - 39°C, which is likely to be instrumental in the speedy development and hatching of mosquito eggs. It is thus suspected that temperature may have an impact on transmission of mosquito vector diseases in the study area throughout the year. Geographically, Makurdi is located between longitude 8°35'E and 8°41'E and latitude 7°45'N and 9°52'N respectively and has a climate typical of the middle belt of Nigeria with distinct wet and dry seasons in a year.

Meanwhile, [14] and [15] provided other detailed geographical and regional indices of the study area, and the map of the study area is depicted in Figure 1.

2.2. Ethical Consideration and Collection of Mosquito Samples

Informed consent was obtained verbally from the inhabitants (staff and students) of each of the randomly selected households before their houses were accessed for mosquito collection in all the study localities. Mosquito samples were collected using standard procedures as provided by the World Health Organisation [17]. Mosquito samples were collected from 0600-0900 hours at dawn and 1800-2100 hours at dusk from living rooms in the study localities.

These periods of sample collection were chosen because most mosquitoes are known to enter houses to feed at early hours of the night and struggle to go out at the early hours of the day to rest outdoors [4, 6]. The mosquitoes were collected from dark corners, walls, ceilings, clothing and other objects inside living rooms with the aid of mouth-aspirators, mosquito sweep nets, pyrethrum spray sheets and window trap method where applicable. The mosquito specimens were kept in holding tubes, inside cooling boxes, and carried to the laboratory on the same day or the following day for characterization and identification [17-19]. Those mosquito samples that could not be processed on the same day were refrigerated and worked upon the next day according to the methods of [20].

The mosquito populations for this study were only drawn from indoor-resting mosquitoes, with the expectation that they would only be females. However, some male mosquitoes were also caught along with the females and these were therefore, distinguished from the females using key morphological features as described by [4].

2.3. Identification of Anopheles Mosquitoes

Using morphological characters of [21] under x20 Zeiss light microscope, the identification focused on dark spots at the upper margins of the wings which is common to all *Anopheles* species. Specifically, palpi that is elongated and segmented into three, a pale spot on second dark area, a light spot between the two dark spots on vein 6, two dark spots on vein 6 and absence of fringes on vein 6 are features that were used for identification of *Anopheles funestus*; while peckles on the legs, third pre-apical dark area on vein 1 with a pale interruption and tarsi 1-4 with conspicuous pale bands are features that were used for identifying *Anopheles gambiae* sl.

2.4. Collection of Weather Data

Data on weather parameters (temperature, rainfall and relative humidity) for the twelve month study period, as they were perceived to have affected the population and distribution of the two major malaria vectors in the Federal University of Agriculture Makurdi community were collected with the help of trained personnel of the Nigerian Meteorological Agency (NMA), Tactical Air Command headquarters in Makurdi, Nigeria.

2.5. Data Analysis

The Predictive Analytical Software (PASW) Version 18 was used in running Chi-square (χ^2) statistic, correlation and regression analyses on the data collected. Significant levels were measured at 95% confidence level with significant differences considered at $P < 0.05$. Correlation analysis was also carried out both at 0.01 and 0.05 levels to determine whether there was any association between the mosquito populations and the weather parameters under consideration, while regression analysis was done to determine the strength of the association where it existed.

3. Results

This study provides data on the monthly relationship between weather parameters and two primary malaria vector populations in the University of Agriculture Makurdi community, a mosquito infested area in middle Nigeria (Tables 1 & 2). The results (Table 3) show that *Anopheles gambiae* s.l. and *Anopheles funestus* have strong negative and significant relationship (r = -0.707, -0.653, P < 0.05) with mean temperature measured in (°C). This means that an increase in temperature decreases *Anopheles* mosquito population in the study area while a decrease in temperature leads to a corresponding increase in *Anopheles* mosquito population. There also exist positive and significant correlations (r = 0.735, 0.0.632, P < 0.05) between *Anopheles gambiae* and *Anopheles funestus* with weather parameters such as mean rainfall and mean relative humidity. This implies that increasing mean rainfall or mean relative humidity would lead correspondingly to increase in *Anopheles* mosquito population in the study area.

The results presented in Table 4 show the output of a linear regression model describing the relationship between mean temperature and *Anopheles* mosquito population in the University of Agriculture Makurdi community. The results show that the intercept of the regression line is positive and statistically significant (P < 0.01) at 1% marginal significance level. This means that the total *Anopheles* mosquito population in the study area will be approximately 1257 with a standard error of 313.8791 when the independent variable (mean temperature) is held constant. The slope coefficient of the independent variable is -30.28371, which is negative and significant (P < 0.01) with a standard error of 9.453526. The implication is that every 1°C increase in mean temperature will reduce *Anopheles* mosquito population in the study area by approximately 30 units.

The value of R^2 is 0.506465 meaning that about 50.65% of the variations in the dependent variable have been explained by the regression model. The Durbin Watson (DW) statistic 0.643544 is greater than R^2-adjusted indicating that the model is non-spurious. The F-statistic measures the overall significance of the regression model with a significant P-value of 0.009437 meaning that our model is a good fit.

The estimates of a linear regression model describing the relationship between mean rainfall and *Anopheles* mosquito population in the University of Agriculture Makurdi community are provided in Table 5. The result shows that the constant parameter is positive and statistically significant (P < 0.01). This implies that the total *Anopheles* mosquito population in the study area will be approximately 173 when the independent variable (mean rainfall) is kept constant. The slope coefficient of the independent variable is 0.637680, which is positive and significant with a standard error of 0.191148. This implies that a 1mm increase in mean rainfall will increase *Anopheles* mosquito population in the study area by approximately 0.64 units. The model indicates that about 52.67% of the variations in the dependent variable have been explained by the independent variable. The Durbin Watson (DW) statistic 0.823519 is greater than R^2-adjusted indicating that the model is not spurious. The F-statistic, which measures the overall significance of the regression model is F=11.12932 with a significant P-value of 0.007540 meaning that our model is a good fit.

The results as contained in Table 6 shows the output of a simple linear regression model describing the relationship between mean relative humidity and *Anopheles* mosquito population in the University of Agriculture Makurdi community. The result shows that the intercept of the regression line is negative and statistically insignificant, implying that the total *Anopheles* mosquito population in the study area will be less than unity when the independent variable (mean relative humidity) is held constant. The slope coefficient of the independent variable is 6.321158, which is positive and significant. The implication is that a 1% increase in mean relative humidity will increase *Anopheles* mosquito population in the study area by approximately 6 units. The R^2 value of 0.665319 indicates that about 66.53% of the variations in the dependent variable have been explained by the regression model. The Durbin Watson (DW) statistic value of 1.632422, which is greater than R^2-adjusted, indicates that the model is non-spurious. The F-statistic measures the overall significance of the regression model with a significant P-value of 0.001219 shows that our model is a good fit.

The scatter plots of total *Anopheles* mosquitoes and mean temperature, rainfall and relative humidity are depicted in Figures 2-4 respectively.

Table 1. *Monthly Relationship between Weather Data and Anopheles Mosquito Population in the University of Agriculture Makurdi community.*

	***Anopheles* species and Number collected (%)**			**Data on Weather Parameters**		
Sample Months	***Anopheles gambiae* s.l.**	***Anopheles funestus***	**Monthly Total (%)**	**Mean Tempt (°C)**	**Mean Rainfall (mm)**	**Mean RH (%)**
July, 2015	226 (59.8)	152 (40.2)	378 (12.4)	31.2	89.0	83
Aug., 2015	305 (73.7)	109 (26.3)	414 (13.6)	29.7	215.8	89
Sept., 2015	251 (67.5)	121 (32.5)	372 (12.2)	30.5	271.4	88
Oct., 2015	153 (65.4)	81 (34.6)	234 (7.7)	30.6	296.4	79
Nov., 2015	71 (54.2)	60 (45.8)	131 (4.3)	33.1	0.00	62
Dec., 2015	60 (51.7)	56 (48.3)	116 (3.8)	33.5	0.00	46
Jan., 2016	72 (60.0)	48 (40.0)	120 (3.9)	34.3	0.00	47
Feb., 2016	79 (69.9)	34 (30.1)	113 (3.7)	36.8	0.60	68
March, 2016	116 (60.1)	77 (39.9)	193 (6.3)	37.9	0.00	62
April, 2016	211 (66.6)	106 (33.4)	317 (10.4)	34.2	141.2	73
May, 2016	220 (67.7)	105 (32.3)	325 (10.6)	32.6	162.5	80
June, 2016	217 (63.8)	123 (36.2)	340 (11.1)	30.4	354.2	85
Total/Mean	1,981 (64.9)	1,072 (35.1)	3,053 (100.0)	32.9	127.59	71.83

Table 2. *Anopheles gambiae s.l. and Anopheles funestus abundance from the University of Agriculture Makurdi Community.*

Locality/Number of mosquitoes collected (%)					
Anopheles **species**	**Staff Quarters**	**Hostels**	**Lecture Halls**	**Village**	**Total (%)**
Anopheles gambiae s.l.	291 (79.7)	582 (62.7)	296 (62.6)	812 (63.1)	1,981 (64.9)
Anopheles funestus	74 (20.3)	346 (37.3)	177 (37.4)	475 (36.9)	1,072 (35.1)
Total	365 (11.9)	928 (30.4)	473 (15.5)	1,287 (42.2)	3,053 (100)

$P < 0.05$

Table 3. *Correlation between Anopheles species and Weather Parameters from the University of Agriculture Makurdi Community.*

Correlations	**Correlation Coeff.**	**P-value**
Anopheles gambiae Vs Mean Temperature (°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 (°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 the University of Agriculture Makurdi Community.*

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 the University of Agriculture Makurdi Community.*

Dependent variable: Total *Anopheles*				
Variable	Coefficient	Std. Error	t-statistic	P-value
Intercept	173.3250	34.23941	5.062148	0.0005
MRainfall	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

Table 6. *OLS Parameter Estimates of Total Anopheles and Mean Relative Humidity from the University of Agriculture Makurdi Community.*

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

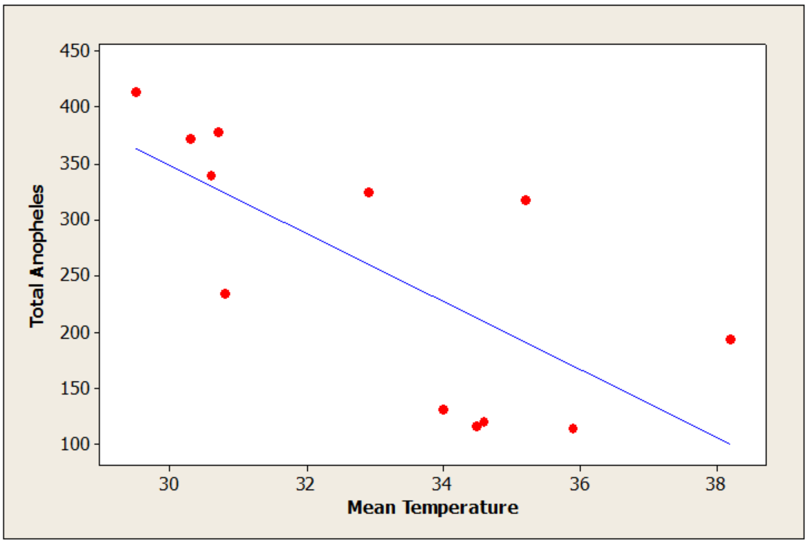


Figure 2. *Scatter Plot of Total Anopheles mosquitoes and Mean Temperature.*

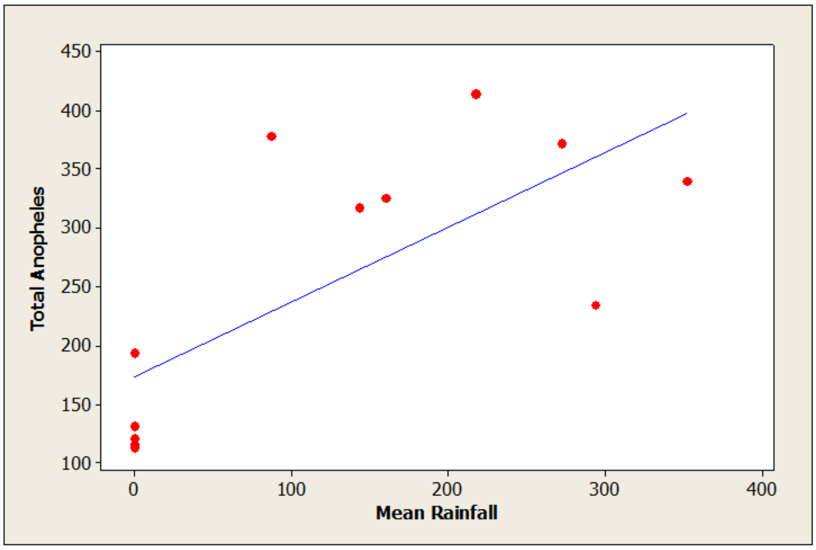


Figure 3. *Scatter Plot of Total Anopheles mosquitoes and Mean Rainfall.*

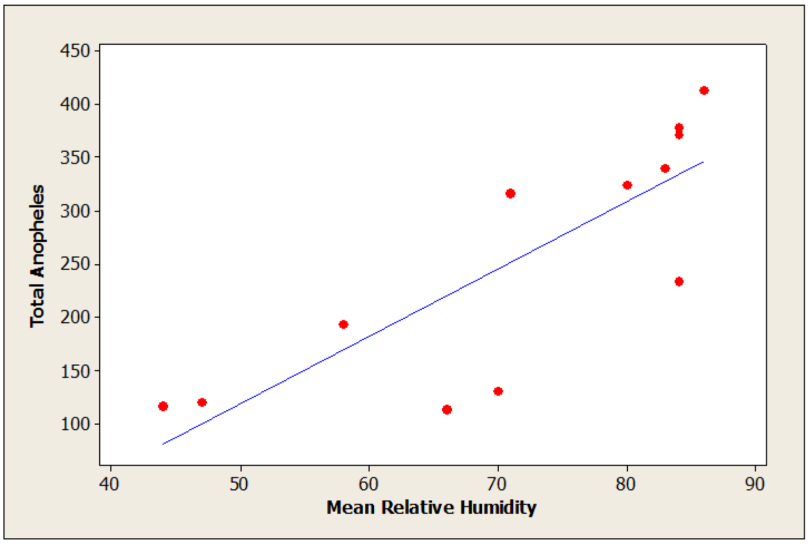


Figure 4. *Scatter Plot of Total Anopheles mosquitoes and Mean Relative Humidity.*

4. Discussion

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 the University of Agriculture Makurdi community during the study period were optimum for the mosquitoes' breeding, growth and survival in consonance with the reports of [3-6, 22, 23]. 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 [3]. The high temperature values recorded in this study would accelerate the reproductive process in the mosquito vector populations in the University of Agriculture, Makurdi community, in line with the findings of [4], who reported that optimum temperature of 32°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 [6, 7] 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.

[1, 8] separately but 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, 2015 to March, 2016 (dry season) and higher values were recorded from July to October, 2015 (wet season) and then April to June, 2016 (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 [24, 25], India [26] and in the Eastern part of Kenya [27] respectively. 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 [28] 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 the University community as corroborated by [9] 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 [4]. Weather data in correlation to the mosquito distribution data obtained in the present study are therefore, in line with the report of [9]; 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 [30] 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 [29] 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 four 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 [1] in Western Kenya who reported no significant correlation between the monthly rainfall totals and relative densities of *Anopheles gambiae* s.l. and *Anopheles funestus* respectively.

5. Conclusion

The results of this investigation have shown that temperature had no adverse effect on the *Anopheles* mosquito population and distribution in the study area during the study period. However, 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. It is therefore, recommended that the environment of the University of Agriculture Makurdi should be properly kept clean, drainage channels should be constructed around student's hostels, lecture halls and staff quarters to eliminate logged waters that serve as breeding sites for these vectors.

References

[1] J. I. Shililu, W. A. Maier, H. M. Seitz, A. S. Orago. (1998). Seasonal density, sporozoite rates and entomological inoculation rates of *Anopheles gambiae* and *Anopheles funestus* in a high-altitude sugarcane growing zone in Western Kenya. *Tropical Medicine and International Health,* 3(9): 706–710.

[2] G. R. A. Okogun, B. E. B. Nwoke, A. N. Okere, J. C. Anosike, A. C. Esekhegbe. (2003). Epidemiological Implications of preferences of Breeding sites of mosquito species in Mid-Western Nigeria. *Annals of Agricultural and Environmental Medicine*, 10: 217–222.

[3] A. K. Githeko, S. W. Lindsay, U. E. Confalonieri, J. A. Patz. (2000). Climate Change and Vector-Borne Diseases: A regional Analysis. *Bulletin of the World Health Organization,* 78(9): 1136-1147.

[4] M. W. Service. (2012). Medical Entomology for Students. 5^{th} edn, Cambridge University Press, New York. 303Pp.

[5] M. M. Manyi, J. T. Akaahan, E. T. Azua,. (2015). Relationship between Weather Parameters and Female Mosquito Abundance and Distribution in Makurdi – a mosquito Infested area in North Central Nigeria. *International Journal of Sciences*, 4: 44–54.

[6] V. Laumann. (2010). Environmental Strategies to replace DDT and control Malaria. 2^{nd} extended edition: *Pestizid Aktions-Netzwerk (PAN) e.V.* 40Pp.

[7] O. I. Ayanda. (2009). Relative Abundance of Adult Female Anopheline Mosquitoes in Ugah, Nasarawa State, Nigeria. *Journal of Parasitology and Vector Biology,* 1(1): 005-008.

[8] S. Kasili, F. Oyieke, C. Wamae, C. Mbogo. (2009). Seasonal Changes of Infectivity Rates of Bancroftian Filariasis Vectors in Coast Province, Kenya. *Journal of Vector Borne Diseases*, 46: 219-224.

[9] NIAID. (2007). National Institute of Allergy and Infectious Diseases. Understanding Malaria. U. S. Department of Health and Human Services. *National Institute of Heath Pulication,* No. 07-7139. www.niaid.nih.gov 32 Pp.

[10] National Environmental Education Fund. (NEEF, 2008). National Environmental Education Foundation: Weather, Climate and Mosquitoes. Earth Gauge, www.earthgauge.net 2Pp.

[11] Federal Republic of Nigeria Official Gazette. (2007). Legal Notice on Publication of the Details of the Breakdown of the National and State Provisional Totals, 2006 Census, 94: B175-B198.

[12] O. E. Anyanwu, (2011). The Politics of Access: University Education and Nation-Building in Nigeria, 1948-2000. University of Calgary Press. Pp 174-177.

[13] NMA. (2011). Nigerian Meteorological Agency, Tactical Air Command Head Quarters Makurdi.

[14] K. R. Udo. (1981). Geographical Regions of Nigeria. London, Morrison and Gibb Ltd. Pp 133–149.

[15] J. L. Nyagba. (1995). The geography of Benue State. In: A Benue Compendium. Denga, D. I. (ed) Calabar, Rapid Educational Publishers Ltd. Pp 85–97.

[16] Ministry of Land and Survey, Makurdi (2011). Map of Benue State showing Makurdi Local Government Area.

[17] World Health Organization, (1975). Manual on Practical entomology in Malaria. Part I And II. Methods and Techniques. World Health Organization Offset Publication 13, Geneva, Switzerland. Pp 160.

[18] D. S. Goodman, J. N. Orelus, J. M. Roberts, P. I. Lammie, T. G. Streit. (2003). PCR and mosquito dissection as tools to monitor filarial infection levels following mass treatment, *Filaria Journal,* 2: Pp11.

[19] F. I. Aigbodion and H. C. Nnoka. (2008). A Comparative study of the activities of *Anopheles gambiae, Culex quinque-fasciatus* and *Aedes aegypti* (Diptera: Culicidae) by Pyrethrum spray collection in Benin City, Nigeria. *Bioscience Research Communications,* 20(3): 147-151.

[20] E. M. Ungureanu. (1972). Methods for Dissecting Dry Insects and Insects Preserved in Fixative Solutions or by Refrigeration. *Bulletin of the World Health Organization* 47: 239-244.

[21] M. T. Gillies and M. Coetzee. (1987). *A supplement to the Anophelinae of Africa, South of the Sahara*. Johannesburg: Sought African Institute of Medical Research. 143Pp.

[22] L. M. Beck-Johnson, W. A. Nelson, K. P. Paaijmans, A. F. Read, M. B. Thomas, et al. (2013) The Effect of Temperature on *Anopheles* Mosquito Population Dynamics and the Potential for Malaria Transmission. PLoS ONE 8(11): e79276. doi: 10.1371/ journal. pone.0079276.

[23] S. I. Efe and C. O. Ojoh. (2013). Climate Variation and Malaria Prevalence in Warri Metropolis. *Atmospheric and Climatic Sciences*, 3: 132-140.

[24] E. C. Uttah and C. Uttah. (2009). Human settlement and behavioual triggers of sustained endemic filariasis in Eastern Nigeria. *Paper presented at the 2009 Annual Conference of Parasitology and Public Health Society of Nigeria hosted at Usman Danfodio University Sokoto, Nigeria.*

[25] E. C. Uttah, D. Ibe, and G. N. Woken. (2013). Filariasis control in Coastal Nigeria: Predictive.

[26] A. Gajanana, R. Rajendran, P. P. Samuel. (1997). Japanese encephalitis in South Arcot district, Tamil Nadu, India. A three year longitudinal study of vector abundance and infection frequency, *Journal of Medical Entomology,* 34(6): 651-659.

[27] J. M. Mwngangi, E. J. Muturi, C. M. Mbogo. (2009). Seasonal Mosquito larval Abundance and Composition in Kibwezi, lower eastern Kenya, *Journal of Vector Borne Diseases,* 46(10): 65-71.

[28] F. Masaninga, C. Daniel, W. Nkhuwa, M. Fastone, C. S. Goma, E. Chanda, M. Kamuliwo, E. C. Kawesha, S. Siziya, O. Babaniyi. (2012). Mosquito biting and malaria situation in an urban setting in Zambia. *Journal of Public Health and Epidemiology*, 4(9): 261–269.

[29] World Health Organisation (2000). World Health Organization Expert Committee on Malaria. Technical Report Series. 892 Geneva.