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# Indoor Behaviour Responses of the Principal Malaria Vector, *Anopheles gambiae* (Diptera: Culicidae), in Relation to Micro-climatic Conditions in Minna, North Central Nigeria

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## ABSTRACT

This study elucidated the temporal dynamics of indoor-resting density and survivorship of *Anopheles gambiae* (Diptera: Culicidae) vectors of malaria, in relation to prevailing micro-climatic conditions in Minna, North Central Nigeria, between May 2008 and April 2009. Indoor-resting adult mosquitoes were collected bi-weekly using Pyrethrum Spread sheet Collection (PSSC), while daily survivorship and longevity were determined by monitoring indoor cages of *A. gambiae* mosquitoes for daily mortality. The results indicated significant ($p<0.05$) monthly and seasonal variations in micro-climatic and entomologic variables. Mean annual indoor temperature and relative humidity were 28.61±1.53°C and 58.88±16.57%, respectively. However, while temperature was significantly higher in the dry than rainy season, the reverse was the case for relative humidity. On the other hand, all entomologic variables investigated were significantly ($p<0.05$) higher in the rainy than dry season. Monthly indoor-resting density ranged from 38.50±15.50 mosquitoes/sample in March to 128.50±19.65 mosquitoes/sample in August. While, the mean annual daily survival rate of the mosquitoes was 73.24±18.28%, an average mosquito lived for 13.23±5.92 days. Though, all correlation coefficients between micro-climatic and entomological variables were strong, such correlations involving temperature were all negative while, those of relative humidity were positive. The implications of these results, regarding malaria transmission and vector control were highlighted and discussed. The findings of this study should guide the design of houses that will ensure inclement micro-climatic conditions for the survival of mosquito vectors.

**Key words:** Daily survival rates, longevity, mosquito density, relative humidity, temperature

## INTRODUCTION

Traditionally, malaria is considered the most important public health challenge, exerting heavy health and socio-economic burdens in many countries. Every year, as many as 500 million new infections and about 3 million deaths are due to malaria worldwide (Muturi *et al*., 2008). In Africa, the disease accounts for about 10% of hospital admissions and 50% outpatient visits (Schwartlander, 1997; USAID, 2005). Nigeria is one of the worst-hit African countries with respect to malaria endemicity, with an estimated several million cases and over 300,000 deaths per annum (Salako, 1997; Odaibo, 2006).

The high endemicity of malaria in Nigeria is due to its warm tropical climate which provides conditions that are favourable for reproduction and survival of malaria vectors. Also, urban land-use abuse, poor town planning and inadequate housing designs and structures in many Nigerian cities, ensure conducive indoor micro-climatic conditions for mosquito survival and extended longevity thus, encouraging anthropophily. According to Noutcha and Anumdu (2009), the intensity of malaria transmission in an area depends greatly on the density of vectors, degree of anthropophily and longevity of the adult mosquitoes. Longevity is particularly important because the incubation period of the plasmodial malaria parasites in anopheline hosts takes between 9 to 14 days, before they can be successfully transmitted to new human hosts (WHO, 1975; Olayemi and Ande, 2008a).

It has long been established that *A. gambiae* is the principal vector of malaria in sub-Saharan Africa, including Nigeria (Gillies and De Meillon, 1968; Gillies and Coetzee, 1987). In Nigeria, *A. gambiae* has been observed to have varied ecological and behavioural attributes, depending on the prevailing climatic and environmental conditions (Onyabe and Conn, 2001). Thus, a good understanding of the influence of these factors on vectorial potentials of *A. gambiae* is a pre-requisite in planning effective vector control measures (Black and Kondratieff, 2005). However, such an understanding will be more meaningful when it is made in the context of prevailing micro-climatic conditions.

Though malaria is hyper-endemic in Minna (Olayemi *et al*., 2009), very little is known of the entomological drivers of transmission in the area. The few studies on anopeline mosquitoes in the area, characterized larval breeding habitats in relation to mosquito abundance, as well as, determined the nocturnal biting regimen of malaria vectors (Olayemi, 2009; Olayemi *et al*., 2010). Therefore, in order to ameliorate the dearth of information on entomological drivers of malaria transmission, that presently characterizes most parts of Nigeria, this study was carried out to elucidate the temporal dynamics of indoor-resting density and survivorship of *A. gambiae* in relation to prevailing micro-climatic conditions in Minna, North Central Nigeria.

## MATERIALS AND METHODS

**Description of the study area:** The study was carried out in Minna, the capital city of Niger state, Nigeria. Minna is located within longitude 6°33´E and latitude 9°37´N, on an estimated land area of 88 km$^2$, with a human population of about 1.2 million. The climate in the area is tropical with mean annual temperature, relative humidity and rainfall of 30.20°C, 61.00% and 1334 mm, respectively. Two distinct seasons namely, rainy (May-October) and dry (November-April) characterize the area, with peak periods in August and March, respectively. Minna, being a state capital city, is dominated by fairly good housing structures and town planning. Thus, the houses used for this study were of fairly high standard. Essentially, the rooms selected for mosquito collection were spacious with plastered walls and asbestos ceiling. The roofs were made of iron corrugated materials and each room had at least a standard window.

**Indoor-resting mosquito collection, preservation and identification:** Four houses in different parts of Minna, were selected as mosquito collection sites. Specimen collection was carried out bi-weekly using Pyrethrum Spread Sheet Catches (PSSC) techniques following standard procedures (WHO, 1975, 2008; Service, 1993), between May 2008 and April 2009. Collected mosquitoes were preserved in 10% formaldehyde solution and identification was done using the keys of Gillies and Coetzee (1987).

**Indoor-rearing and determination of survivorship rates of *A. gambiae* mosquitoes:** Mosquitoes used for this experiment were obtained from wild populations of *A. gambiae* breeding in rain pools in the city. The mosquitoes were subsequently colonized and maintained in the laboratory of the Department of Biological Sciences, Federal University of Technology Minna, Nigeria, following recommended techniques for rearing *A. gambiae* (Das *et al.*, 2007; Olayemi and Ande, 2009). Starting from the $F_2$ generation of the mosquito colony, on a monthly basis, four groups of about 400 mosquitoes each (approximately 1:1 sex ratio) were prepared in screened cages measuring 60×60×60 cm. Two mosquito cages were then suspended in each room, about 1 meter from the ceiling, in 4 different parts of the city. The adult mosquitoes were fed *ad libitum* with 10% glucose solution. The mosquito cages were monitored twice daily (at 0900 and 1800 h) for daily mortality, until all the specimens in a cage died. The entire experiment was repeated for each period investigated.

**Measurement of indoor micro-climatic conditions:** The temperature and relative humidity within the mosquito cages were monitored daily, between 1200 and 1300 h, using mercury bulb thermometer and hygrometer, respectively.

**Data analysis:** Daily survival rate was calculated as the average of the proportions of mosquito in a cage tat survived till the next day. Longevity of the mosquitoes was determined by calculating the mean number of days lived by the individual mosquito. Data from the four sites were analyzed and found not to be significantly different hence, they were polled as representative of the entire study area. All statistical analyses were carried out using SPSS 16.0 software Computer Program. While, differences in seasonal variations of the variables were compared using student's t-test, those of monthly variations were analyzed using Chi-square test; both tests were carried out at $p = 0.05$ level of significance. Te relationships among the micro-climatic and entomologic variables were established using Linear coefficient correlation.

## RESULTS

Temporal variations in indoor temperature and relative humidity in Minna, during the study period are highlighted in Table 1. Mean indoor temperature was significantly ($p<0.05$) higher during the dry (31.12±1.09°C) than rainy season (27.67±1.27°C). Monthly variations in indoor temperature though varied within narrow limits in a season, ranged from 25.90±0.82°C in July to 32.46±1.33°C in February. With a mean annual value of 58.88±16.57%, relative humidity had a different pattern of temporal distribution from temperature (Table 1). Significantly ($p<0.05$) higher relative humidity was recorded during the rainy (Mean = 69.51±12.44%) than dry (Mean = 44.01±7.02%) and monthly variations ranged from 37.51±1.39% in December to 79.44±2.19% in August.

Also, the entomologic parameters investigated showed significant ($p<0.05$) seasonal variations, with much higher values recorded in the rainy than dry season (Table 2). Indoor mosquito density ranged from 38.50±15.50 mosquitoes/sample in March to 128.50±19.65 mosquitoes/sample in August. The monthly distribution of mosquitoes density exhibited two peaks, the largest in August and the smaller peak in October. Incidentally, the largest peak of indoor mosquito density coincided with that of relative humidity. While, the mean annual daily survival rate of the mosquitoes was 73.24±18.28%, an average mosquito lived for about 13.23±5.92 days, during the study period.

Table 1: Mean monthly and seasonal variations in indoor temperature and relative humidity in Minna, between May 2008 and April 2009

| Month | Temperature (°C) | Relative humidity (%) |
|---|---|---|
| May | 27.40±1.50$^{ab}$ | 69.16±2.50$^{d}$ |
| June | 26.25±0.47$^{a}$ | 74.70±3.69$^{e}$ |
| July | 25.90±0.82$^{a}$ | 76.36±2.66$^{e}$ |
| August | 27.56±0.70$^{ab}$ | 79.44±2.19$^{e}$ |
| September | 28.91±0.86$^{b}$ | 75.95±3.21$^{e}$ |
| October | 28.64±1.02$^{b}$ | 68.13±2.63$^{d}$ |
| November | 29.05±0.59$^{b}$ | 42.83±2.75$^{ab}$ |
| December | 29.65±0.84$^{b}$ | 37.51±1.39$^{a}$ |
| January | 31.35±1.09$^{c*}$ | 42.56±3.57$^{ab}$ |
| February | 32.46±1.33$^{c}$ | 40.28±2.94$^{a}$ |
| March | 31.65±0.90$^{c}$ | 43.89±2.46$^{b}$ |
| April | 30.47±0.68$^{b}$ | 55.80±3.21$^{c}$ |
| Dry season | 31.12±1.09$^{c}$ | 44.01±7.02$^{b}$ |
| Rainy season | 27.67±1.27$^{ab}$ | 69.51±12.44$^{d}$ |
| Annual | 29.11±2.10$^{b}$ | 58.88±16.57$^{c}$ |

*Values followed by same superscript alphabets in a column are not significantly different at p = 0.05

Table 2: Mean monthly and seasonal variations in indoor adult density and survival attributes of *Anopheles gambiae* in Minna, between May 2008 and April 2009

| Month | Density (No. collected/sample) | Daily survival rate (%) | Longevity (days) |
|---|---|---|---|
| May | 61.00±14.90$^{e}$ | 78.64±10.61$^{d}$ | 14.93±4.71$^{d}$ |
| June | 77.50±20.50$^{d}$ | 86.90±9.20$^{e}$ | 19.20±3.34$^{ef}$ |
| July | 102.00±15.50$^{f}$ | 94.14±2.99$^{f}$ | 18.44±3.16$^{e}$ |
| August | 128.50±19.65$^{g}$ | 89.06±4.50$^{e}$ | 21.23±4.08$^{f}$ |
| September | 75.50±16.80$^{d}$ | 92.68±5.20$^{e}$ | 17.39±2.11$^{e}$ |
| October | 98.00±21.00$^{f}$ | 86.39±4.76$^{ef}$ | 18.70±3.92$^{e}$ |
| November | 62.00±17.30$^{e}$ | 63.70±11.25$^{b}$ | 12.46±3.40$^{c}$ |
| December | 57.50±18.40$^{e}$ | 71.89±6.33$^{c}$ | 8.41±4.37$^{b}$ |
| January | 42.50±13.90$^{a*}$ | 43.25±9.00$^{a}$ | 5.34±2.29$^{a}$ |
| February | 43.00±18.00$^{a}$ | 41.57±12.49$^{a}$ | 4.80±1.62$^{a}$ |
| March | 38.50±15.50$^{a}$ | 58.19±8.16$^{b}$ | 6.22±2.85$^{a}$ |
| April | 56.00±9.50$^{c}$ | 72.45±8.93$^{d}$ | 11.69±3.67$^{c}$ |
| Dry season | 47.50±8.64$^{b}$ | 57.47±14.90$^{b}$ | 7.29±2.82$^{b}$ |
| Rainy season | 86.36±24.46$^{g}$ | 84.50±10.46$^{e}$ | 17.48±2.92$^{e}$ |
| Annual | 70.17±27.45$^{d}$ | 73.24±18.28$^{d}$ | 13.23±5.92$^{d}$ |

*Values followed by same superscript alphabets in a column are not significantly different at p = 0.05

Monthly variations of mosquito daily survival rates and longevity had, more or less, the same pattern of distribution. Generally, these variables increased steadily from February/March to indistinct peaks between July and September/October.

Table 3 shows cross-correlation coefficients among the indoor micro-climatic and entomological variables in Minna, during the study period. Though, all such correlations were strong (r>0.60), temperature correlated negatively with all the entomologic variables while, relative humidity did so positively.

Table 3: Cross-correlation among indoor micro-climatic conditions and entomological variables of *Anopheles gambiae* in Minna

| | Temperature | Relative humidity | Density | Daily survival rate | Longevity |
|---|---|---|---|---|---|
| Temperature | 1.0000 | | | | |
| Relative humidity | -0.7416 | 1.0000 | | | |
| Density | -0.6550 | 0.7997 | 1.0000 | | |
| Daily survival rate | -0.6780 | 0.8713 | 0.7936 | 1.0000 | |
| Longevity | -0.6792 | 0.8970 | 0.8288 | 0.9266 | 1.0000 |

## DISCUSSION

Mean annual indoor temperature in Minna was 29.11±2.10°C. This temperature is within the optimal range for mosquito adult activities including, blood meal digestion and egg development thus, perhaps, explaining the all-year-round collection of mosquitoes in appreciable numbers in the area. However, indoor temperature was significantly higher during the dry than rainy season. This may mean increased metabolic activities during the dry season which, may wear out the mosquitoes quickly and coupled with the less than favourable relative humidity during the period, perhaps, explains the significantly lower densities of mosquitoes collected during the dry season. According to McMichael and Martens (1995), adult mosquitoes require a relative humidity of at least 60% to survive long enough to nurture malaria parasites to maturity. The mean annual relative humidity (i.e., 58.88±16.57%) recorded in Minna is below this threshold, therefore, explains the relatively short life span of the mosquitoes recorded in this study, especially, during the dry months. Elsewhere, indoor-maintained mosquitoes survived for much longer periods, i.e., about 20 days (Olayemi and Ande, 2009).

Like the climatic variables, entomological parameters investigated equally varied significantly with seasons, with peak in monthly relative humidity coinciding with peak indoor mosquito density. This result agreed with those of earlier studies and suggests that mosquito density and survival rates are seasonally influenced by changes in weather conditions. For example, significantly higher densities of mosquitoes were collected in the rainy than dry season. According to WHO (1975) and Minakawa *et al.* (2001, 2002) etc., rainfall provides suitable breeding sites for anopheline mosquitoes and raises relative humidity above 60%, optimally suited for mosquito survival and reproductive activities (McMichael and Martens, 1995). However, Olayemi and Ande (2008a) observed an upsurge in the density of indoor-biting mosquitoes in Ilorin, Nigeria, during the rainy season, due principally to the incessant nocturnal rainfall which disrupted mosquito activities outdoors thus, compelling them to withdraw indoors. The mean annual daily survival rate and longevity of the mosquitoes indoor during the study period were 73.24±18.28% and 13.23±5.92 days, respectively. These results, while they agreed with estimated data obtained in Ilorin, Nigeria (Olayemi and Ande, 2008b), they contradicted those of Detinova (1962), who puts the mean life expectance of anopheline mosquitoes in nature between 6 to 9 days. Differences in anopheline mosquito survival rates and longevity have been attributed to variations in climatic conditions of different localities, as well as, differences in the ecologic and biologic requirements of anopheline mosquito populations (WHO, 1975).

The strong correlations recorded between the micro-climatic and entomologic variables, re-inforces the significant influence of weather conditions on mosquito activities, especially population density and survivorship, as has been severally alluded to in literature (WHO, 1975; McMichael and Martens, 1995). However, of the two micro-climatic conditions, i.e., temperature and relative humidity, investigated in relation to indoor density and survival rates of *A. gambiae* in

Minna, it seems the latter is the best predictor of indoor mosquito activity in the area, as it correlated strongly and positively with the entomologic variables. Thus, it may be possible to disrupt indoor mosquito activities and shorten their lifespan, below that necessary for the completion of plasmodium sporogony, by significantly reducing indoor humidity below the optimal range for mosquito activities and survival. This, of course, will entail designing houses with improved ventilation which will ultimately reduce temperature and humidity thus, making the interior of our homes unsuitable for mosquitoes to thrive. This, perhaps, explains the recommendations of good housing structure as an effective means of reducing malaria transmission.

## CONCLUSION

Indoor resting density and survivorship of *A. gambiae*, the principal vector of malaria in north central Nigeria, were significantly influenced by variations in micro-climatic conditions. Though, the mean annual indoor temperature in the area was within the optimal range for adult mosquito activities, the life span of the indoor-maintained mosquitoes was relatively low, indicating that relative humidity (which was below the threshold for mosquito activities) is a more potent factor in regulating survivorship. Thus, improving housing structures in a way that will ensure good ventilation, thereby reducing indoor humidity, will go a long way in reducing malaria transmission by discouraging indoor vector activities.

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