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Seasonal Trends in Epidemiological and Entomological Profiles of Malaria Transmission in North Central Nigeria

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Abstract: The influence of seasonal changes on epidemiological and entomological indices of malaria transmission in North Central Nigeria was elucidated in a series of studies carried out between January 2004 and December 2009. The climate in the study area was divided into three seasonal periods namely, rainy (May-October), dry (December-March) and transitional (April and November), during which larval and adult anopheline mosquito collections were carried out and assessed for densities, sporozoite infection and parity rates and potentials for malaria transmission. The results indicated that the climate in the study area was clearly seasonal, with close similarities in the patterns of distribution of the climatic factors in the study sites. Mosquito densities, both at the adult and larval stages (i.e., 29.35±5.10 adult mosquitoes/man/night and 10.36±3.34 larvae/dip, respectively), were significantly ($p<0.05$) highest during the rainy season. However, while the former varied significantly in the three seasonal periods, the latter was not significantly different during the dry and transitional seasons. Malaria transmission risks, in terms of sporozoite rates and entomological inoculation rates, was significantly ($p<0.05$) least in the dry season (i.e., 2.89±1.25% and 0.37±0.21 infective bite/man/night, respectively) but the two variables were not significantly ($p>0.05$) different during the transitional and rainy seasons. Adult mosquito daily survival rate and adult longevity were least in the dry season (26.52±11.80% and 6.80 days, respectively) and significantly ($p<0.05$) highest during the rainy season (72.28±4.00% and 16.95±4.20 days, respectively). Parous rates of the mosquitoes and duration of sporogony had distinct distribution pattern from the other variables investigated. While, significantly highest parous rates were recorded in the transitional season (86.00±4.30%), duration of sporogony was not significantly ($p>0.05$) different during the three seasons. The epidemiology of urban malaria in North Central Nigeria was discussed from the view points of the these results and concluded that the findings should promote the development of informed temporally-targeted vector control programs for the area.

Key words: Entomological inoculation rate, human biting rate, mosquito density, parous rate, sporozoite rate

INTRODUCTION

Malaria is the leading cause of morbidity and mortality in Nigeria. Healthcare facility data indicate that more than 50% outpatient hospital attendance in all geo-political zones of the country, are due to malaria (Federal Ministry of Health, 2004), resulting in over 300,000 deaths every year (Odaibo, 2006). This heavy burden of malaria in the country has been sustained for decades by a complex inter-play of epidemiological and entomological drivers of disease transmission; the poor understanding of which has rendered well-meaning control interventions ineffective.

While, the epidemiological pattern of malaria transmission is influenced to a large extent by anthropogenic factors (Leighton and Foster, 1993), the vectorial capacity of the anopheline transmitters is determined by their human-biting rates and sporozoite-infection rates, as well as, the developmental and survival rates of the parasites and vectors, as influenced by climatic and ecologic factors (Githeko *et al*., 1993; Dossou-Yovo *et al*., 1995). However, local epidemiological patterns of malaria transmission vary considerably from region to region depending on factors ranging from differences in climatic, ecologic, socio-economic and cultural (WHO, 1975; Appawu *et al*., 2004),

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leading to the development of specific approaches in control strategies (Ahmed, 2007). Marked seasonality in the distribution of anopheline larvae have been reported in the tropics (Munga *et al*., 2006). According to Fillinger *et al*. (2004), rain pools and domestic containers constitute the most active anopheline breeding habitats in the wet season. However, in the dry season, significantly higher numbers of anophelines bred in lakes and swamps (Minakawa *et al*., 2001). Shililu *et al*. (2003) observed that the densities of anopheline larvae, in the breeding habitats, increased during the wet season and decreased in the dry season but the timing of peak densities was variable among habitat types. Similar observations have been made on the influence of seasons on sporozoite infection and entomological inoculation rates of anopheline mosquitoes (Awolola *et al*., 2002; Appawu *et al*., 2004).

Consequently, the importance of detailed knowledge of local determinants of malaria transmission is of primary importance in the development of area-specific control interventions that will effectively reduce the burden of the disease.

Presently, there is a dearth of information on seasonal variations in malaria transmission indices in Nigeria and this study was therefore carried out to generate such data by comparing differences in the duration of sporogony of malaria parasites, as well as, densities, infection and survival rates of the vectors during the different weather seasons in two selected state capital cities in North Central Nigeria.

MATERIALS AND METHODS

Description of the study area: The study was carried out in North Central Nigeria which serves as a gate-way between the northern and southern parts of the country. Two state capital cities namely, Ilorin and Minna, generally representative of the eco-type of the area, were selected for data collection. While Ilorin is located within longitudes 4°30′ and 4°45′E and latitudes 8°25′ and 8°40′N, covering an estimated land area of 75 km^2 with about 1.4 million human population; Minna, on the other hand, lies within longitude 6°33′E and 9°37′N on a land area of 88 km^2 and having an estimated 1.2 million inhabitants . The climate in North Central Nigeria is that of a tropical continental region (Iloeje, 1992) which is characterized by relatively wide annual temperature range and a restricted rainfall. The mean annual temperature range from 27.00 to 30.20°C in Ilorin and Minna, respectively and mean annual relative humidity is higher in the former (76.00%) than the latter (61.00%) while, mean annual rainfall range from 1,334.00 mm in Minna to 1,800 mm in Ilorin.

The climate of the area is marked by two distinct weather seasons, i.e., rainy and dry. The rainy season starts in May and lasts till October, with June and August as the months of peak rainfall. The dry season, extending from December to March, is completely devoid of rains and characterized by harmattan with dust-laden cold winds informed by the Northeast Trade wind. The departure of harmattan, for the rains is informed by the arrival of moist tropical maritime air mass of the Southwest Trade wind. This point is usually marked by hot sunny days with temperature range of 34-40°C, the highest of which occur in March. The months of April and November, being transition periods at the beginning and end of the rainy season, respectively, usually record little amount of rainfall. The vegetation in North Central Nigeria reflects that of the Guinea Savanna zone, characterized by a predominance of tall grass species with scattered trees. This vegetation is frequently removed by bush burning in the dry season.

Mosquito collection, preservation and identification: Anopheline mosquitoes were collected monthly from the study area between January 2004 and December 2009. The larvae were sampled from randomly selected conventional mosquito breeding habitats, using standard 250 mL capacity ‘Dippers’ (Service, 1993; Azari-Hamidian *et al*., 2011) between the hours of 0700 and 1200. Twenty ‘Dipper’ samples were taken randomly from each breeding habitat type and the average of these samples was calculated. On the other hand, the adult female mosquitoes were collected from randomly selected sites using the Spread Sheet Pyrethrum Spray Catches (WHO, 1975; El-Badry and Al-Ali, 2010). Collected specimens were preserved using 4% formaldehyde solution and identification was done using the keys of Gillies and De Meillon (1968) and Gillies and Coetzee (1987).

Dissection of adult mosquitoes for sporozoite and parous rates: The adult anopheline mosquitoes were examined for Plasmodium sporozoites by investigating the salivary glands following the techniques of WHO (2002). The ovaries were dissected out of the abdomen at the region of the 6th and 7th sclerite under a dissecting microscope and examined for tracheation under a compound microscope using x40 objective (Holstein, 1954). Those ovaries in which the terminal skeins of the tracheoles had become uncoiled were considered to be parous.

Collection of meteorological data: Meteorological data of rainfall, temperature and relative humidity during the study period, for Ilorin, were obtained from the Records

Department of the weather station in Ilorin International Airport while, similar data for Minna were obtained from Minna Airport.

Data analysis: Mosquito Larval Density (LD) was determined as the average number of specimens collected per 'Dip'. Adult Mosquito Density, expressed as Human Biting Rate (HBR), was calculated as the total number of specimens collected from a room divided by the number of people that slept in the room the previous night (WHO, 1975). The proportions of adult mosquitoes infested with *Plasmodium* sporozoites in their salivary glands were noted as the Sporozoite Rate (SR) in percentage. The product of HBR and SR was noted as the Entomological Inoculation Rate (EIR) (Service, 1963; Githeko *et al*., 1993). The Parous Rates (PR) of the mosquitoes was estimated as the proportion of dissected specimens that were parous and expressed in percentage. The productivity of the larval breeding habitats was evaluated by estimating the relative densities of anopheline larvae in the different habitats during the seasonal periods. Malaria Incidence Rate (MIR) was determined as the proportion of tested blood samples that were positive in percentage. Estimation of the Duration of Sporogony (DS) was done using the formula:

$$n = b/c;$$

where, n = Duration of Sporogony, b = temperature degree-days and c = the difference between mean temperature per time and the threshold temperature for extrinsic development of Plasmodium parasites (WHO, 1975). Seasonal averages of all the variables investigated were calculated and compared for statistical differences using one-way ANOVA, at p = 0.05 level of significance.

RESULTS

The seasonal distribution of weather conditions in Ilorin and Minna during the study is given in Table 1. Though, the patterns of distribution of climatic factors in the two study sites were similar, local seasonal variations are apparent. Temperature was the most similar and was not significantly ($p>0.05$) different in the two sites in all seasons, with the lowest recorded in the rainy season. Rainfall was significantly ($p<0.05$) higher in Minna than Ilorin during the rainy season but vice versa in the transitional period and almost nil in the dry season. On the other hand, relative humidity was consistently significantly ($p<0.05$) higher in Ilorin than Minna during all the seasons.

Table 2 shows variations in entomological indices of malaria transmission intensity during the three seasonal periods characteristic of the study area. Mosquito densities, i.e., Larval Density and HBR (a proxy for adult density) were significantly ($p<0.05$) highest in the rainy season and lowest in the dry season though, Larval Densities in the dry and transitional seasons (4.94±1.81 and 5.60±1.10 larvae/dip, respectively) were not significantly ($p>0.05$) different. Sporozoite rates and entomological inoculation rates due to the mosquitoes and malaria incidence rate in the study area showed similar patterns of distribution whereby, values in the rainy and transitional seasons were not significantly ($p>0.05$) different but significantly ($p<0.05$) higher than in the dry season. Adult mosquito daily survival rate and adult longevity were least in the dry season (26.52±11.80% and 6.80 days, respectively) and significantly ($p<0.05$) highest during the rainy season (72.28±4.00% and 16.95±4.20 days, respectively). Parous rates of the mosquitoes and duration of sporogony had distinct distribution pattern from the other variables investigated, as significantly highest parous rates were recorded in the transitional season (86.00±4.30%) while, duration of sporogony (range = 8.98±0.80 to 10.14±1.32 days) was not significantly ($p>0.05$) different during the three seasons.

Table 3 highlights the relative productivity levels of the larval breeding habitats of anopheline mosquitoes in the area. While Household Containers (HC), Swamps (S) and Wells (W) were uniformly active during the three seasonal periods as indicated by the insignificantly ($p>0.05$) different larval densities during the periods, the remaining three habitats namely, Refuse Dump Containers (RDC), Ground Rain Pool (GRP) and Drains (D) were most productive in the rainy season and least active in the dry season. Larval densities varied significantly ($p<0.05$) among the breeding habitats, ranging from annual mean values of 0.67±0.09 larva/dip in W to 4.76±1.00 larvae/dip

Table 1: The Seasonal distribution of climatic factors in Ilorin and Minna

	Dry season (Dec.-Mar.)		Transitional season (Apr. and Nov.)		Rainy season (May - Oct.)		Annual (Jan.-Dec.)	
Climatic factors	Ilorin	Minna	Ilorin	Minna	Ilorin	Minna	Ilorin	Minna
Temperature	28.25±1.74	29.57±0.76	28.10±3.46	29.57±0.67	25.95±0.97	26.50±0.63	27.43±1.29	28.55±1.77
Rainfall	13.38±23.53	0.73±1.45	51.67±66.79	23.04±9.98	180.83±57.03	201.95±57.43	81.96±87.74	75.24±110.30
Relative humidity	63.00±2.48	27.94±5.12	74.75±1.77	42.63±6.35	83.58±2.99	70.58±1.97	73.76±10.32	47.05±21.66

Table 2: Seasonal variations in entomological indices of malaria transmission in North-Central Nigeria.

Entomological indices	Dry season (Dec.-Mar.)	Transitional season (Apr. and Nov.)	Rainy season (May-Oct.)	Annual (Jan.-Dec.)
Larval density (larvae/350 mL)	4.94±1.81^{a}	5.60±1.10^{a}	10.36±3.34^{b}	6.97±2.96
Human biting rate (mosquitoes/man/night)	12.44±1.96^{a}	18.40±6.38^{b}	29.35±5.10^{c}	20.06±8.58
Sporozoite rate (%)	2.89±1.25^{a}	5.89±3.71^{b}	5.18±1.90^{b}	4.65±1.57
Entomological inoculation rate (infective bites/man/night)	0.37±0.21^{a}	0.87±0.53^{b}	1.24±0.88^{b}	0.83±0.44
Parous rate (%)	48.90±6.34^{a}	86.00±4.30^{c}	74.39±7.22^{b}	69.76±18.98
Adult daily survival rate (%)	26.52±11.80^{a}	43.40±7.19^{b}	72.28±4.00^{c}	47.40±23.14
Adult longevity (days)	6.80±1.46^{a}	8.44±2.60^{a}	16.95±4.20^{b}	10.73±5.45
Duration of sporogony (days)	8.98±0.80^{a}	9.20±0.50^{a}	10.14±1.32^{a}	9.44±0.62

*Values followed by same superscript alphabet in a row are not significantly different at $p = 0.05$ level of significance

Table 3: Seasonal variations in anopheline larval habitat productivity in North-Central Nigeria.

Larval breeding habitat	Dry season (Dec.-Mar.)	Transitional season (Apr. and Nov.)	Rainy season (May-Oct.)	Annual (Jan.-Dec.)
Drains	0.58±0.35^{a*}	1.11±0.42^{a}	4.17±2.20^{b}	1.95±1.94^{a}
Ground rain pools	0.00±0.00^{a}	5.49±2.61^{b}	7.33±2.80^{c}	4.27±3.81^{b}
Household containers	4.14±1.06^{a}	3.05±1.46^{a}	2.68±0.80^{a}	3.29±0.76^{a}
Refuse dump containers	0.20±0.13^{a}	2.86±1.40^{b}	5.04±1.39^{c}	2.70±2.42^{b}
Swamps	5.90±1.69^{a}	4.02±1.25^{a}	4.35±1.84^{a}	4.76±1.00^{a}
Wells	0.76±0.09^{a}	0.66±0.40^{a}	0.59±0.21^{a}	0.67±0.09^{a}
Aggregate	1.93±2.47^{a}	2.87±1.80^{a}	4.03±2.27^{b}	2.94±1.05^{a}

*Values followed by same superscript alphabet in a row are not significantly different at $p = 0.05$ level of significance

in S. Overall, S and GRP were the most productive anopheline larval habitats followed by HC, RDC and D while the W produced the least mosquitoes. The anopheline mosquitoes in the area showed significant seasonal preferences from larval breeding habitats. During the dry season, the mosquitoes bred most actively in S (5.90±1.69 larvae/dip), but shifted to GRP during the transitional and rainy seasons (5.49±2.61 and 7.33±2.80 larvae/dip, respectively).

DISCUSSION

The similarities noted in the seasonal distribution patterns of climatic factors in Ilorin and Minna may be attributed to the fact that both areas are located within the same geographical region, i.e., North Central Nigeria (Iloeje, 1992)and hence subject to common weather conditions. However, on the whole, Ilorin was wetter than Minna reflecting the fact that while the former borders the tropical rainforest in the south, the latter marks the beginning of the Savanna to the north.

Anopheline mosquitoes were most abundant, in north central Nigeria, during the rainy season; results consistent with those obtained elsewhere in the country and other African localities with similar eco-climatic conditions (Awolola *et al*., 2002; Hamad *et al*., 2002; Shililu *et al*., 2003). Such phenomena have been attributed to the high precipitation during the rainy season which results in the proliferation of anopheline breeding habitats, in addition to providing favourable humidity for the survival and dispersal of adult mosquitoes (WHO, 1975; Devi and Jauhari, 2005; Vandyk, 2006). According to Minakawa *et al*. (2001, 2002), *Anopheles gambiae*, the dominant vector of malaria in North Central Nigeria (Molyneaux and Gramiccia, 1980; Onyabe and Conn, 2001), breeds preferably in temporary sunlit ground pools created by rainfall and, therefore, the graph of the population density of the species fits that of precipitation very closely, usually with a lag period of one to two weeks, been the duration of larval and pupal development.

The close similarities in the seasonal distribution of Sporozoite Rates (SR) and Entomological Inoculation Rates (EIR), as indicated by the results of this study, suggests that SR is a good indicator of the intensity of malaria transmission, especially, when data on human infection rates are not available. Though, the results of this study indicate that malaria transmission in North Central Nigeria is seasonal, with very high transmission likely to occur in the rainy season, aggressive malaria vector control interventions must be extended to the other seasons when, appreciable levels of malaria transmission are equally likely. Significantly lower SR, EIR and Parous Rates (PR) were recorded in the dry than the other seasons of the year. This finding agrees with those of Beier *et al.* (1990), who observed that the heaviest malaria transmission, in certain Kenyan villages, occurred towards the end of the rainy season and Faye *et al.* (1995), in Senegal, who recorded significantly lower Entomological Inoculation Rates in the dry than rainy season. However, the similarity in patterns of seasonal distribution of SR, EIR and Parous Rates (PR) obtained in this study, may not be unconnected with the fact these variables are greatly influenced by the age structure of the mosquito populations. Mosquitoes live longer in the rainy season as a result of the favourable humidity provided by rains and thus, are more likely to become infected during blood meals and hence, parous, as a result of ovipositional activities. The shortest duration of sporogony recorded in the dry season is due to the significantly higher temperature during the period. However, it could not reduce the duration of sporogony significantly because even the lowest temperature recorded in the rainy season (25.95±0.97°C) in Ilorin, was still within the optimal range for the development of malaria parasites.

Most of the larval habitats were particularly active in the rainy season thus, further explaining the preponderance of mosquitoes and highest EIR recorded during this period. This finding suggest that elimination or deactivation of these mosquito breeding sites, during the rainy season, will go a long way in reducing the population density of anopheline mosquitoes and hence, the intensity of malaria transmission during its naturally peak period. The reason for the more or less equal levels of mosquito production from certain habitats, i.e., swamps, wells and household containers, during the three seasonal periods, in North Central Nigeria, may not be far-fetched; for example, been large and constantly supplied with water from domestic sources, respectively, may mean the availability of the swamps and household containers for mosquito breeding purposes throughout the year (Minakawa *et al*., 2001, 2002, 2005). However, for the mosquitoes to have continued breeding equally well in the Swamps and Household Containers even in the rainy season, when small sunlit temporary ground pools are ubiquitous, buttress the fact that while *Anopheles gambiae*, the principal vector of malaria in sub-Saharan Africa, breeds preferentially in rain pools, other important anopheline vectors of malaria have adapted to breeding mostly in other unconventional larval habitats (Sattler *et al*., 2005; Balakrishnan *et al*., 2011), to avoid competition with the better adapted *An. gambiae*. Several studies in Africa, have reported *An. funestus, An. nili, An. pharaoensis*, etc, as breeding preferentially in such unconventional larval habitats. Thus, for maximum impact, anopheline larval control interventions must be selective and seasonally-targeted; while control efforts are directed particularly at refuse dump containers, ground rain pools and drains, in the rainy season, such efforts must be evenly spread in the swamps and household containers throughout the year. The Wells appear not to pose serious threat to human health regarding the transmission of malaria.

CONCLUSION

The climate in North Central Nigeria is clearly seasonal and similarly influences malaria transmission in the area, as indicated by the results of the entomological indices investigated. The rainy season provided optimal conditions for the breeding, human biting activity and survival of anopheline mosquitoes thus, significantly enhancing the intensity of malaria transmission during the period. These findings should provide a better understanding of the epidemiology of malaria in North Central Nigeria and promote the development of informed temporally-targeted vector control programs.

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