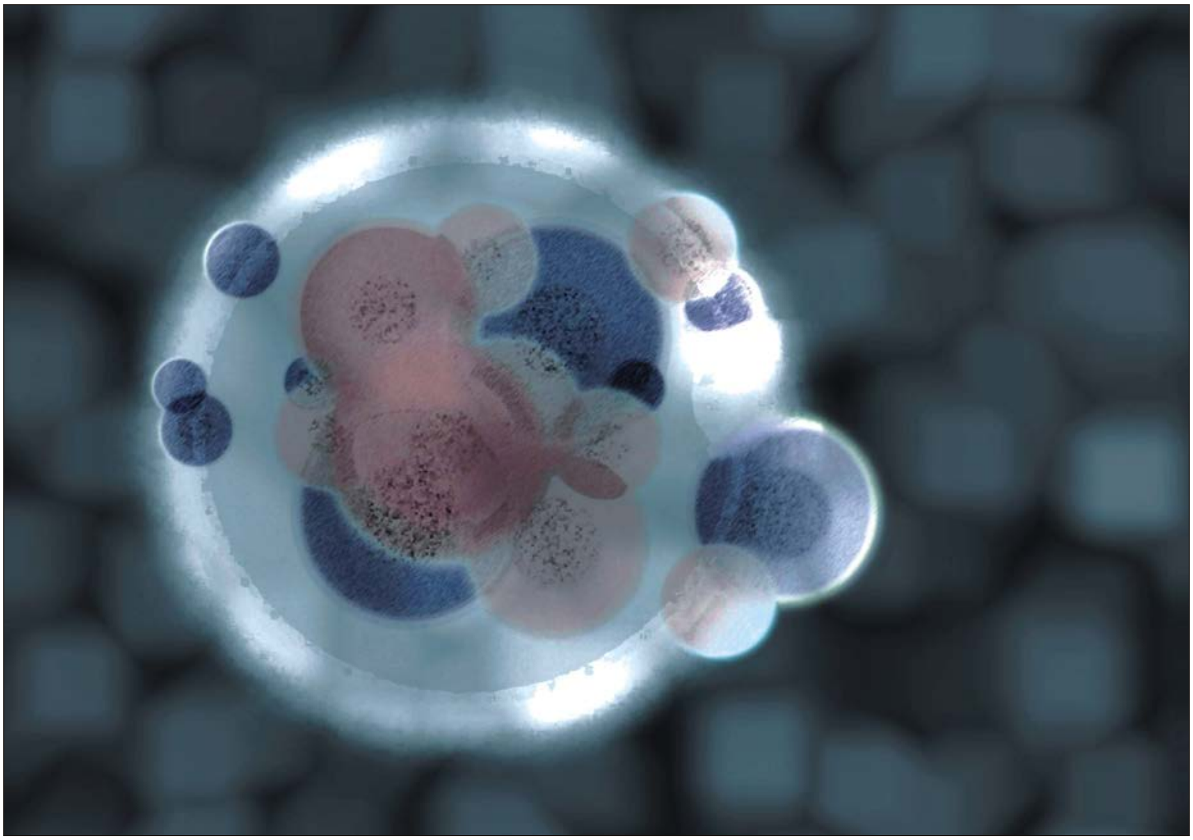

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Dry Season Refugia Breeding Ecology of Mosquitoes (Diptera: Culicidae) in Minna, North Central Nigeria

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Abstract: This study was carried out in Minna, Nigeria, to elucidate the dry season breeding ecology of mosquitoes in the area thus, providing a basis for all-year-round effective implementation of informed larviciding interventions. Mosquito larvae were sampled bi-weekly between the hours of 0800 and 1100 from randomly selected larval breeding habitats in the city, using a 350 mL capacity Dipper. The physical characteristics of the selected habitats were evaluated and related to larval productivity. The results indicated that *Anopheles* mosquitoes constituted 55.00% of all larvae collected, followed by *Culex* (36.29%) and *Aedes* (17.49%). The patterns of mean monthly density distribution of the three mosquito Genera were similar, i.e., decreasing significantly ($p<0.05$) from the beginning to the end of the dry season. The mosquito types showed significant ($p<0.05$) preferences for certain habitats, with *Anopheles* and *Aedes* preferring the Drains (24.40±5.13 and 14.20±5.12 larvae/sampling day, respectively) and *Culex* mosquitoes encountered more frequently in the Swamps (16.80±6.22 larvae/sampling day). The Drains were the most productive habitats, accounting for over 50% larval production during the period, distantly followed by the Swamp (31.60±16.38 larvae/sampling day) while, the densities of larvae in the Wells and Rivers were significantly low (7.40±7.79 and 3.40±5.24 larvae/sampling day, respectively). Again, in terms of physical attributes, the Drains were the most ideal habitat for larval development, been relatively small (diameter = 2.30±0.00 m); most shallow (depth = 0.14±0.01 m); warmest (27.52±0.48°C) and nearest to human habitations (2.80±0.00 m). The epidemiological implications of these results were discussed and concluded that targeting dry season larviciding interventions at the productive larval breeding habitats will go a long way in reducing the menace of mosquito-borne diseases in Minna.

Key words: *Aedes*, *Anopheles*, *Culex*, genus, habitat characteristics, larvae

INTRODUCTION

Mosquitoes are dipteran flies solely responsible for the transmission of important human diseases including malaria, filariasis, yellow fever, dengue fever, etc. (Belding, 1942; El-Badry and Al-Ali, 2010; Balakrishnan *et al*., 2011; Chakkaravarthy *et al*., 2011; Paulraj *et al*., 2011). These diseases have had serious negative impacts on the economic development, as well as, medical and social well-being of people living in their areas of prevalence (Amiruddin *et al*., 2012). For example, while dengue fever puts two-fifths of the world's population at risk of infection, malaria accounts for 10% of Africa's overall disease burden (Okenu, 1999; World Health Organization, 2003; Njan-Nloga *et al*., 2007) and kills about 300,000 Nigerians each year, especially pregnant women and young children below the age of five (Salako, 1997; Odaibo, 2006). The vectorial capacity of mosquitoes for the diseases they transmit is largely influenced by the intensity of larval production from breeding habitats (Depinay *et al*., 2004). Thus, the subject has received serious attention from mosquito (Anyanwu and Iwuala, 1999; Sogoba *et al*., 2007; Chaki *et al*., 2009) but such studies have focused mainly on the breeding of mosquitoes in the rainy season, due to the creation of abundant breeding habitats by rainfall; even though mosquitoes have adapted to breeding in large numbers in habitats that receive their moisture from sources other than rainfall.

To this end, though the level of mosquito breeding activities is significantly higher in the rainy than dry season (Olayemi and Ande, 2008), malaria prevalence rates remains relatively high in Minna during the dry season (Olayemi *et al*., 2009, 2012), indicating that the

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limited mosquito breeding activities in the dry season is above the threshold required for significant transmission of mosquito-borne diseases. Yet, mosquito larval control measures in Minna, as in other parts of Nigeria, are concentrated more in the rainy season against the back-drop that mosquito breeding in the dry season is inconsequential and may not promote the transmission of mosquito-borne diseases during this period thus, not deserving to be targeted for serious anti-larval mosquito control interventions. Thus, there is need for a systematic investigation of the breeding activities of mosquitoes during the dry season, so as to elucidate the active larval breeding sites during the period, a pre-requisite to the development of appropriate seasonally-sensitive mosquito anti-larval strategies. This study was, therefore, carried out to determine the relative densities and distribution of mosquito types in Minna during the dry season, assess the relative contributions of the larval breeding habitats to mosquito production in the area during this period, as well as, characterize such habitats.

MATERIALS AND METHODS

Study area: Minna, the capital city of Niger state, Nigeria, is located within longitude 6°33'E and latitude 9°37'N, covering an estimated land area of 88 km^2, with an estimated human population of 1.2 million. The area has a tropical climate with mean annual temperature, relative humidity and rainfall of 30.20°C, 61.00% and 1334.00 mm, respectively. The climate presents two distinct seasons: a rainy season between May and October and a dry season (November-April). The vegetation in the area is typically grass dominated savannah with scattered tress.

Mosquito larval sampling, processing and identification: The city of Minna was searched for accessible dry season mosquito larval habitats (Fig. 1). Mosquito larvae were sampled bi-weekly from the habitats using a 350 mL capacity Dipper (Azari-Hamidian *et al*., 2011), between 0800 and 1100 h, from November 2008 to March 2009. Five samples were taken from each breeding site per sampling day. Collected specimens were immediately preserved in 40% formaldehyde solution and transported to the laboratory for further analysis. The larvae were identified to Genus level using aids provided by Hopkins (1952) and Gillies and Coetzee (1987).

Physical characterization of larval habitats: The distance between the larval habitats and the nearest human-

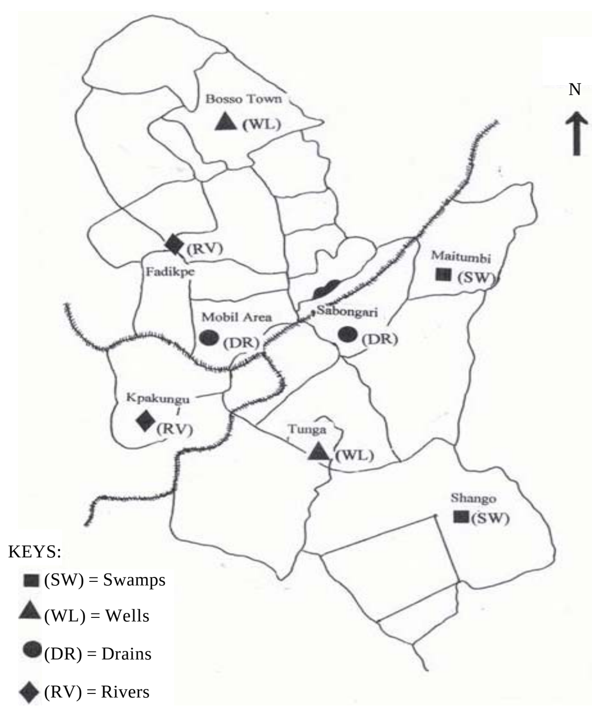

Fig. 1: Map of Minna showing the sampling sites and habitat types 2 0 2 4 6 8 km, Source: Ministry of land and Survey, Minna, Niger State

inhabited house was measured in meters using a graduated tape. The degree of exposure of larval habitats to sunlight was determined by estimating shade cover in percentages. The depth of water medium was measured using a meter rule while, the size of the surface area was determined by measuring the diameter along the widest plane. Water temperature was determined using an ordinary mercury thermometer, by dipping the bulb just below the water surface. Water turbidity was analysed electronically at the Quality Control Laboratory of Niger River Basin Development Authority, Minna.

Data analysis: Mosquito density was determined as mean number of larvae collected per sampling day and relative abundance of the Genera was expressed as simple percentages. Differences in larval densities of mosquito Genera in the various habitats, as well as, variations in the physical characteristics among the sites were compared using ANOVA. On the other hand, monthly variations in the densities of the mosquito Genera were compared using Chi-square test. All statistical differences were established at $p = 0.05$ level of significance.

RESULTS

Table 1 shows the mean relative abundance and monthly distribution of the mosquito Genera in Minna during the study period. The abundance of the mosquito types differed significantly ($p < 0.05$) with the anophelines constituting almost half of all larvae collected, distantly followed by *Culex* (36.29%) and *Aedes* (17.49%) mosquitoes. Aggregate mosquito density varied significantly ($p<0.05$) during the period, decreasing drastically from the beginning of the dry season (i.e., November = 28.20±9.80 larvae/sampling day) till March (11.00±4.00 larvae/sampling day). The mean monthly distribution of the individual mosquito Genus followed the same patterns as the aggregate population although, *Aedes* had its least density in February. During the five months study period, *Anopheles* had consistently significant ($p<0.05$) higher densities except during the month of December, when the genus was at par with *Culex*.

The larval habitat preferences of the mosquito Genera and relative productivity levels of the habitat types are shown in Table 2. Though, the three mosquito Genera were encountered in all the breeding sites investigated, they occurred at very low densities in some habitats. *Anopheles* and *Culex* showed significant preference for breeding in Drains and Swamps, respectively and were the dominant mosquitoes in these habitats. The *Aedes* mosquitoes bred preferentially in the Drains also (14.20±5.12 larvae/sampling day). The three Genera were more or less least encountered in the Rivers and Wells. The Drain was the most productive larval habitat during the study period, as more than 50% of the larvae were collected from this site, distantly followed by the Swamp (33.47%). Unlike the other two Genera, *Anopheles* was well represented in all four habitat types.

Table 3 shows the physical characteristics of the mosquito breeding habitats. The Wells and Drains were the nearest to human habitations while, the Swamp was the farthest (26.50±0.00 m). The breeding sites were mostly exposed to sunlight, ranging from 63.40±15.02% exposure in the Drains to almost 100% in the Wells. The depth of water in the breeding sites ranged from 0.14±0.01 m in Drains to 0.84±0.09 m in the Rivers. The River was the most turbid habitat (0.81±0.10 m) while the Well was the least (0.02±0.00 m). The surface area of the breeding sites were relatively large; while the Wells and Drains were the smallest, the Swamp had a mean diameter of 13.42±2.15 m and the River was the largest with mean

Table 1: Mean monthly density of mosquito larvae in Minna, Nigeria, during the dry season of 2008/2009

Mosquito genus	November (2008)	December (2008)	January (2009)	February (2009)	March (2009)	Mean±SD (%)
Anopheles	12.00±4.50^{c*}	9.60±4.00^{b}	8.00±1.50^{a}	7.20±3.10^{a}	6.00±2.40^{a}	8.56±2.33 (46.22)^{c**}
Aedes	6.00±1.50^{c}	4.20±1.30^{b}	3.20±0.50^{b}	0.80±0.50^{a}	2.00±0.90^{a}	3.24±2.00 (17.49)^{a}
Culex	10.20±3.80^{d}	9.60±4.20^{c}	6.40±2.70^{b}	4.40±1.50^{a}	3.00±0.70^{a}	6.72±3.15 (36.29)^{b}
Aggregate	28.20±9.80 (34.32)^{c}	23.40±9.50 (28.47)^{b}	17.60±4.70 (21.41)^{b}	12.40±5.10 (15.09)^{a}	11.00±4.00 (13.38)^{a}	18.52±7.48 (100.00)

*Values followed by same superscript alphabets in a row are not significantly different at p = 0.05, **Values in parenthesis are percentage distribution and such values followed by same superscript alphabets in the column are not significantly different at p= 0.05

Table 2: Mean density of mosquito larvae in different breeding habitats in Minna, Nigeria, during the dry season of 2008/2009

Habitat	*Anopheles*	*Aedes*	*Culex*	Aggregate
Swamps	11.80±6.10^{b*}	3.00±4.06^{a}	16.80±6.22^{c}	31.60±16.38(33.47)^{b**}
Wells	3.80±3.96^{b}	0.40±0.56^{a}	3.20±3.27^{b}	7.40±7.79 (7.84)^{a}
Drains	24.40±5.13^{b}	14.20±5.12^{a}	13.40±6.99^{a}	52.00±17.24 (55.08)^{c}
Rivers	2.80±3.90^{b}	0.40±0.89^{a}	0.20±0.45^{a}	3.40±5.24 (3.60)^{a}
Aggregate (%)	42.80±19.09^{c}	18.00±10.63^{a}	33.60±16.93^{b}	94.40±46.65 (100.00)

*Values followed by same superscript alphabets in a row are not significantly different at p = 0.05, **Values in parenthesis are percentage distribution, values followed by same superscript alphabets in the column are not significantly different at p = 0.05

Table 3: Mean physical parameters of different mosquito larval habitats in Minna, Nigeria, during the dry season of 2008/2009

Habitat	Distance (m)	Exposure (%)	Depth (m)	Turbidity (m)	Size (m)	Temperature (°C)
Swamps	26.50±0.00[b*]	86.00±30.70[b]	0.17±0.02[a]	0.21±0.03[b]	13.42±2.15[b]	26.60±0.51[a]
Wells	4.30±0.00[a]	99.99±0.01[c]	0.60±0.12[b]	0.02±0.00[a]	1.20±0.00[a]	25.50±0.77[a]
Drains	2.80±0.00[a]	63.40±15.02[a]	0.14±0.01[a]	0.16±0.01[b]	2.30±0.00[a]	27.52±0.48[b]
Rivers	7.34±0.00[a]	92.40±15.56[b]	0.84±0.09[b]	0.81±0.10[c]	52.54±4.91[c]	27.34±0.41[b]

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

52.54±4.91 m surface area diameter. Water temperature varied within narrow limits (range = 25.50±0.77 to 27.52±0.48°C). However, while the Well was the coolest, the Drain was the warmest.

DISCUSSION

The three mosquito Genera namely, *Aedes*, *Anopheles* and *Culex*, that serve as vectors of serious human diseases including, yellow fever, malaria and filariasis, respectively, were encountered in Minna at fairly high densities though with drastic reductions in abundance as the dry season advanced. These results have important epidemiological implications for the transmission and control of mosquito-borne diseases in Minna. This may mean a high transmission rates of these diseases during the dry season, as earlier observed for malaria in the area (Olayemi *et al*., 2009), thus demanding a need for the intensification of anti-larval interventions during the dry season. Such efforts will yield encouraging results, as fewer sites will be targeted for larviciding measures, coupled with the fact that the population density of the mosquitoes is already undergoing drastic reductions, probably, due to the effects of inclement weather conditions characteristic of the dry season.

The mosquito types showed significant preferences for breeding in certain habitats, results similar to those reported from Ilorin, a neighbouring State Capital (Olayemi and Ande, 2008; Olayemi *et al*., 2011). Studies have shown that mosquitoes possess distinct oviposition attractants in the form of the presence of certain salts, conspecific organisms, aquatic vegetation and/or absence of certain predators in larval habitats thus, determining their density in such sites (Hwang *et al*., 1980; Bentley and Day, 1989). While, the breeding site preferences exhibited by the *Anopheles* and *Culex* mosquitoes, i.e., Drains and Swamps, respectively, agree with the results of similar studies elsewhere (Goma, 1960; Olayemi and Ande, 2008), that of *Aedes*, i.e. Drains, contradicted the known breeding habit of the Genus. *Ae. aegypti*, for example, breeds preferentially in domestic containers around homes (Adebote *et al*., 2006; Brown *et al*., 1992). Therefore, the preference of *Aedes* mosquitoes for breeding in the Drains during the dry season in Minna, may be due to the usual scarcity of water-holding domestic containers during such period and confirms the adaptability of *Ae. aegypti*, for example, to breeding in large numbers in unusual habitats when preferred conventional sites are not available.

The Drains were the most productive larval habitats during the dry season in Minna. The reasons for this finding may not be far-fetched as; incidentally, certain physical characteristics of this habitat type make it ideal for high mosquito larval production. To this end, the Drains were the smallest/most shallow and warmest habitats during the period. While, the former attributes will ensure the absence of large predators (Lundkvist *et al*., 2003), the latter promotes high metabolic rates and hence faster larval survival and developmental rates (Kirby and Lindsay, 2009). Thus, coupled with the fact that the Drains were the nearest mosquito breeding sites to homes, this habitat type pose serious threats to the health of the residents of Minna, as the high mosquito production from these sites will ensure intense human-vector contact and hence, transmission of mosquito-borne diseases. The Wells and Rivers in Minna were not active mosquito production sites during the dry season. This may be due to the presence of large predators and low temperature in the Rivers and small surface area exposed to atmospheric oxygen and constant disturbance caused by the dipping of water-fetching buckets into the Wells.

CONCLUSION

Mosquito vectors of diseases bred actively but preferentially in certain larval habitats during the dry season in Minna, confirming the relatively high prevalence rates of mosquito-borne diseases in the area during this season; thus, suggesting the need for the intensification of anti-larval measures even in the dry season. The Drains posed the greatest threat to the health of the residents of Minna, been the most productive mosquito breeding sites in the dry season, occasioned by their favourable environmental conditions for the survival and faster developmental rates of larvae. Therefore, targeting dry season larviciding measures at such preferred and productive breeding sites will go a long way in reducing the menace of mosquito-borne diseases.

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