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Temporal Distribution of and Habitat Diversification by Some Mosquitoes (Diptera: Culicidae) Species in Benin City, Nigeria

[1]Felix I. Aigbodion and [1,2]Osariyekemwen O. Uyi
[1]Department of Animal and Environmental Biology, University of Benin, P.M.B. 1154, Benin City, Nigeria
[2]Department of Zoology and Entomology, Rhodes University, P.O. Box 94, Grahamstown, South Africa

Corresponding Author: Osariyekemwen O. Uyi, Department of Animal and Environmental Biology, University of Benin, P.M.B. 1154, Benin City, Nigeria

ABSTRACT

The distribution of various mosquito genera, abundance and their associated breeding habitats was studied between March 2008 and February 2009 in an increasingly urbanizing town (Benin City) in Nigeria. The habitats sampled, using dippers and pipettes, were broadly categorized into five viz., containers; stagnant pools, domestic run-offs, gutters and tree-holes/leaf axils. Seventeen species of mosquitoes (including 2 *Anopheles* species, 7 *Culex* species and 8 *Aedes* species) belonging to 3 genera were recorded. The abundance of the 3 mosquito genera varied significantly ($p<0.05$), with the *Culex* genera recording the highest abundance while *Anopheles* genera recorded the least. The most commonly encountered species were *Anopheles gambiae* complex, *Culex quinquefasciatus* and *Aedes aegypti* accounting for 18.08, 13.84 and 12.44%, respectively of the total collections. Mosquito species occurred in all five habitats sampled and populations were relatively abundant throughout the season with peak populations observed between July and September probably because of the high rainfall. The combination of factors such as seasonality, climate, environmental modification, urbanization and other anthropogenic related factors contributes to the increasing abundance of mosquito species in Benin City as most mosquito species bred in diverse habitats. The persistent occurrence of *Aedes*, *Culex* and *Anopheles* species and breeding habitat diversification by these mosquitoes, pose a serious epidemiological concern to the inhabitants of Benin City. Therefore, larviciding of breeding sites before the onset of the rainy season and public enlightenment on the environmental factors and/or human activities that encourage mosquito breeding are recommended.

Key words: Mosquitoes, temporal distribution, breeding habitats, disease vector, Benin city, seasonality, anthropogenic, factors

INTRODUCTION

Mosquitoes are nuisance species as well as potential transmitters of zoonotic and human diseases such as dengue fever, yellow fever and malaria. Several outbreaks of yellow fever have been reported in southern and central parts of Nigeria (Ezike *et al*., 2001). Malaria is a deadly disease that causes more than a million human deaths every year, mostly in the tropical areas of Africa, Americas and Asia (WHO, 2010) and remains a major tropical disease of serious public health importance in Nigeria. In Africa, the prevalence of lymphatic filariasis is especially striking, affecting over 40 million people in the sub-Saharan region alone (Dunyo *et al*., 1996). The abundance, behavior, spatiotemporal distribution and population dynamics of mosquito species is

known to be influenced by factors such as climate, seasonality, availability of micro-habitats for breeding, physicochemical parameters of breeding sites and anthropogenic related factors (Igbinosa, 1989; Blank, 1992; Aigbodion and Odiachi, 2003; Koenraadt *et al.*, 2004; Stoops *et al.*, 2007; Akram *et al.*, 2009; Impoinvil *et al.*, 2008; Midega *et al.*, 2010; Muturi *et al.*, 2008; Kim *et al.*, 2010). Exploring on mosquito population dynamics present a challenge for ecologists partly because, seasonal mechanism as influenced by climate can be difficult to predict and understand and thus can generate complex population fluctuation in some insects including mosquitoes (Wallner, 1987; Southwood and Henderson, 2000; Nunn and Altizer, 2006). The breeding sites preference and physicochemical parameters of mosquito breeding sites of different mosquito species have been extensively studied and are relatively well understood (Almiron and Brewer, 1996; Kant *et al.*, 1998; Stoops *et al.*, 2007; Muturi *et al.*, 2008). It is a general consensus among several researchers (Hanson, 1995; Bradshaw *et al.*, 2000; Koenraadt *et al.*, 2004; Okogun *et al.*, 2005; Stoops *et al.*, 2007; Akram *et al.*, 2009) that abiotic factors of temperature, relative humidity, altitude and rainfall play a vital role in mosquito development which in turn influences their population density. Environmental changes due to human activities greatly influence the distribution and survival of many mosquito species (Dossou-Yovo *et al.*, 1995; Adeleke *et al.*, 2008). Amusan *et al.* (2005) opined that the recent increase in agricultural activities and urbanization contributed to the breeding of different mosquito species in southwestern Nigeria. Over population in cities and indiscriminate disposal of wastes materials (including cans and discarded household materials) due to improper town planning and lack of adequate sanitary education increases the potential for breeding disease vector mosquito species. Benin City (6°19'N and 5°37'E), a town located in the Niger Delta region of Nigeria characterized with, rapid urbanization, increased population growth, indiscriminate building of residential houses and inadequate amenities to cope with the increasing population represent a good area to investigate. In the light of these growing environmental concerns in the city and the changes in temperatures worldwide, we focused our studies on the temporal distribution of some mosquito species from various larvae habitats. Constant studies on biology and larval ecology of mosquitoes have been observed as important tools in mosquito control (Kim *et al.*, 2010) and such studies will help to determine the existing and disappearing mosquito species, relative population densities and the extent of their distribution, seasonal trends and disease infection rates. This study was therefore designed to investigate the larval habitats and distribution of existing mosquito fauna in Benin City, Nigeria. The paper also discusses the possible public health implications of mosquito's species abundance on the inhabitants of the city.

MATERIALS AND METHODS

Study area: Seasonal distribution and species composition studies were conducted from March 2008 to February 2009 at selected sites across parts of and different habitat types in Benin City, Nigeria (Fig. 1). Benin City is an ancient city and the capital of Edo State in southern Nigeria with a population of over 1.4 million people. The city is located in the rainforest zone and is currently experiencing rapid urbanization and new developments with lack of appropriate city planning infrastructural measures. In this study, the city was partitioned into two zones viz., northern (Ikpoba Hill and Ugbowo axis) and southern zones (Sapele and Airport road axis). Two sample sites within each zone were selected for the long term investigations. All 4 sample sites are residential areas with some home gardens and a few scattered industrial sites. Road construction activities were also very conspicuous in all four sample sites. The study sites are characterized by man-made polluting sources such as plastic bags, cans, pots, fast-food wrappers, shallow ground pools, gutters,

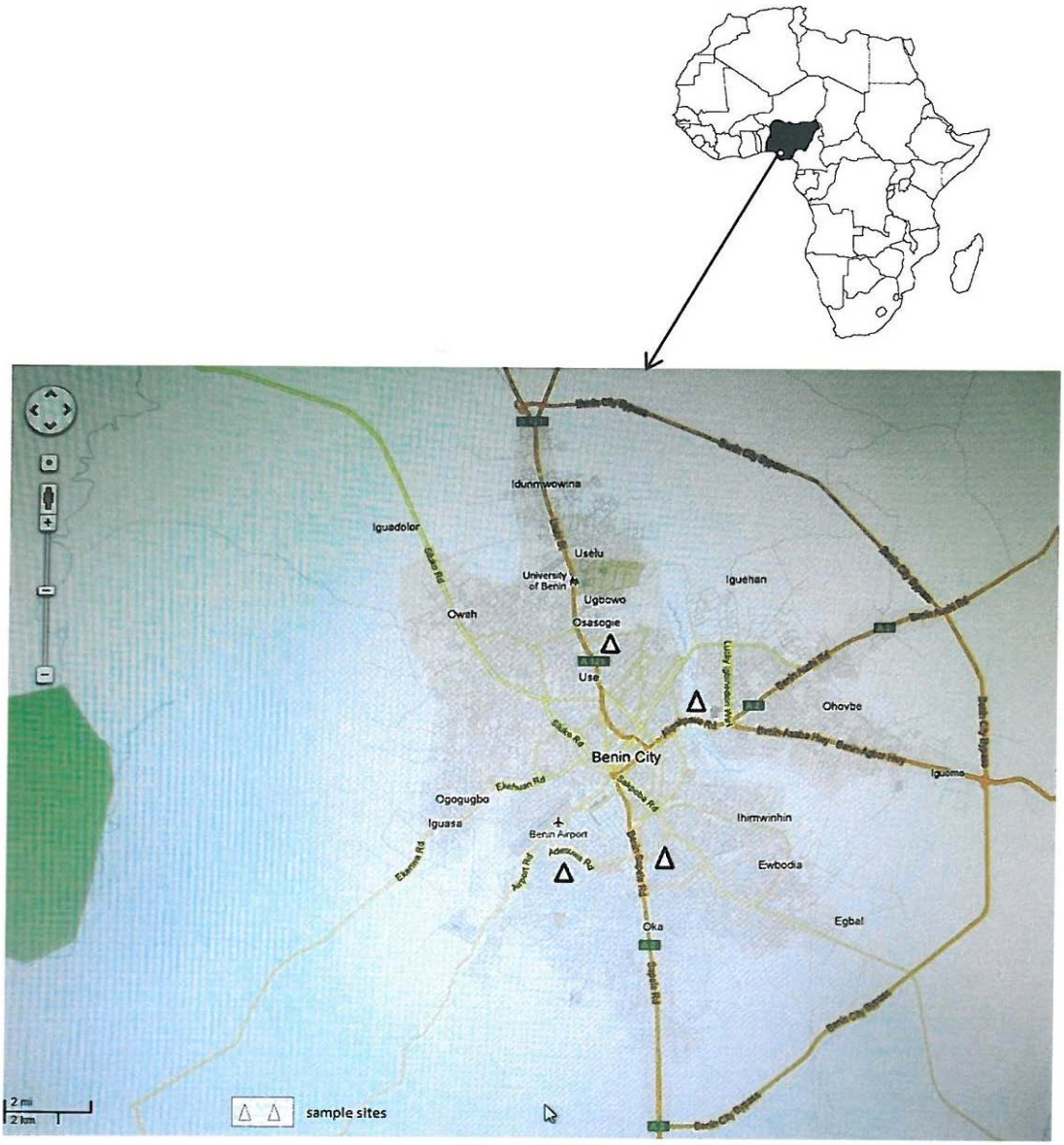

Fig. 1: Study area and location of sample sites

discarded household materials and domestic runoffs. In each sample site, five potential mosquitoes breeding microhabitats viz. containers (pots, cans and other related plastic items), ground pools (construction sites, pools around public taps and other ground pools with stagnant water), domestic run-offs (used water from cafeteria and households), gutters and tree holes/leaf axils (of plantain, cocoyam and pineapple plants) were sampled.

Sampling technique: Larvae of mosquito species were collected using a standard mosquito larval dipper (Clarke, USA) and pipette at all sampling sites on a monthly basis. At each sample site, mosquito larvae were sampled from gutters (n =10 per month), domestic runoffs (n =10 per month) and pools (n = 10 per month) using a standard number of dips. Twenty-five artificial containers

(e.g., cans, pots and discarded plastic containers) were placed and sampled at specific sites on a monthly basis. For tree holes/leaf axils, the number of dips was based on the area of the sample site, the number of tree holes/leaf axils present at each sites and amount of water present. In this latter case, where few mosquitoes were collected, additional samples were made to ensure uniform coverage of the sample site (Akram *et al.*, 2009). The data collected in this manner were corrected by dividing number of larvae obtained by number of dips. The larvae and pupae were removed from each scoop with an eye dropper (Kent *et al.*, 1987) and were placed into 250 mL plastic bottles with water from the sampling sites/habitats except for tree holes/leaf axils collections (which were placed in clear water from other sources). The fourth instar larvae were preserved in vials containing 35% isopropyl alcohol and a drop of glycerin (Akram *et al.*, 2009) and they were identified following Hopkins (1952) and Gillet (1972), while those that could not be identified were allowed to emerge into adults before identification. The numbers of mosquitoes species recorded from the two zones was not significantly different ($p>0.05$; Man-Whitney U test), hence the data was pooled. The abundance and distribution of mosquito larvae in various habitats were subjected to statistical analysis using Man-Whitney U test. This test is useful when comparing independent random samples from different locations and makes no assumption regarding the frequency distribution of the data (Bhattacharyya and Johnson, 1977; Sanders and Smidt, 2000).

RESULTS

Data collection from March 2008 and February 2009 on the species composition and abundance of mosquitoes revealed the presence of seventeen (17) species (Fig. 2) viz., *Anopheles gambiae* complex (18.08%), *A. funestus* complex (4.36%), *Aedes aegypti* (12.44%), *A. simpsoni* (3.34%), *A. albopictus* (4.36%), *A. palpalis* (2.24%), *A. vittatus* (4.77%), *A. unilineatus* (2.86%), *A. luteocephalus* (4.40%), *A. africanus* (3.0%), *Culex quinquefasciatus* (13.84%), *C. nebulosus* (3.30%), *C. tigripes* (3.88%), *C. decens* (4.33%), *C. pipiens* (5.02%), *C. moucheti* (6.94%) and *C. cinereus* (2.98%) belonging to 3 genera (*Anopheles* = 2 species; *Aedes* = 8 species and *Culex* = 7 species). *Anopheles gambiae* complex, *C. quinquefasciatus* and *A. aegypti* were the most abundant species encountered in this study.

Overall, abundance of mosquito genera varied significantly ($p<0.05$) during the study, with *Culex* and *Aedes* having high abundance compared to *Anopheles* mosquitoes which recorded a

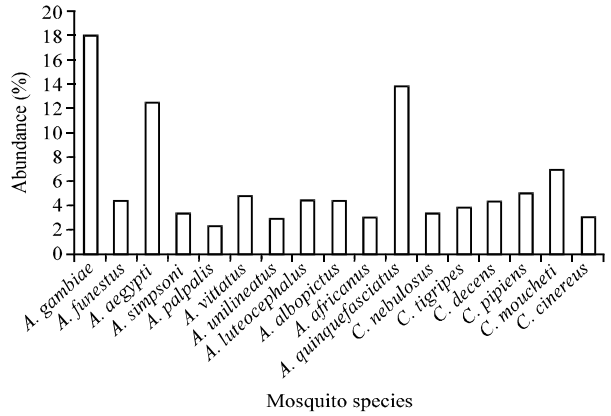

Fig. 2: Percentage mosquito species abundance in Benin City, Nigeria between March 2008 and February 2009

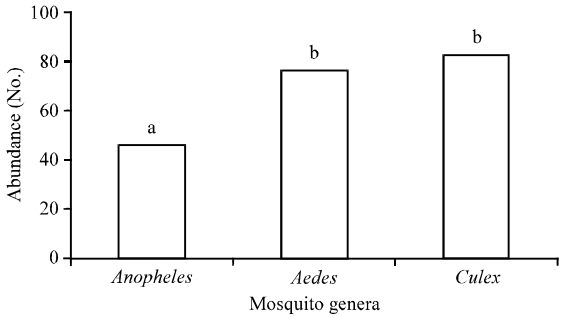

Fig. 3: Mean number of mosquito genera recorded in Benin City, Nigeria between March 2008 and February 2009, Bars followed by same letters are not significantly different at p>0.05 by Mann Whitney U test

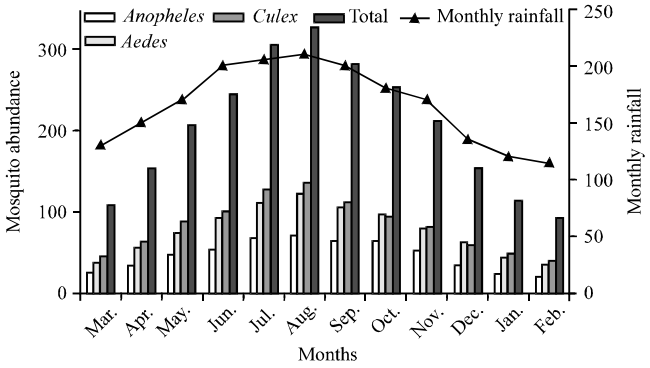

Fig. 4: Temporal distribution of three mosquito genera in relation to rainfall between March 2008 and February 2009 in Benin City, Nigeria

significantly lower numbers (Fig. 3). All three mosquito genera were recorded monthly throughout the year and their population was high from May to November with peaks between July and September followed by a decline that persisted through to February of the next year (Fig. 4). *Culex* mosquitoes were consistently more abundant on monthly basis compared to *Aedes* and *Anopheles*. The peak population period of all three mosquito genera coincided with high rainfall that is usually experienced between June and September annually in Nigeria. This was further demonstrated by the strong positive relationship between rainfall (total monthly rainfall for 12 months) and the abundance (mosquito abundance data for 12 months) of *Aedes* ($R^2 = 0.933$), *Anopheles* ($R^2 = 0.935$) and *Culex* ($R^2 = 0.950$) mosquitoes (Fig. 5a-c).

The breeding habitats of mosquitoes considered in this present studies were stagnant pools, containers, gutters, domestic run-offs and tree holes/leaf axils and all the three mosquitoes genera showed their capacities to breed in all habitat types investigated with slight preference for containers, stagnant pools and gutters (Fig. 6). Overall observation on the abundance of mosquitoes encountered in pools, containers, domestic run-offs and gutters revealed that *Culex* mosquitoes were more abundant followed by *Aedes*, while *Aedes* were more abundant in tree holes/leaf axils followed by *Culex* and *Anopheles*. Also the abundance of *Culex* compared to *Aedes* in all 5 habitats were not significantly different ($p<0.05$), whereas the abundance of *Anopheles* differs significantly ($p<0.001$) from *Aedes* and *Culex* (Fig. 6). Figure 7a, b and c shows various mosquito species and

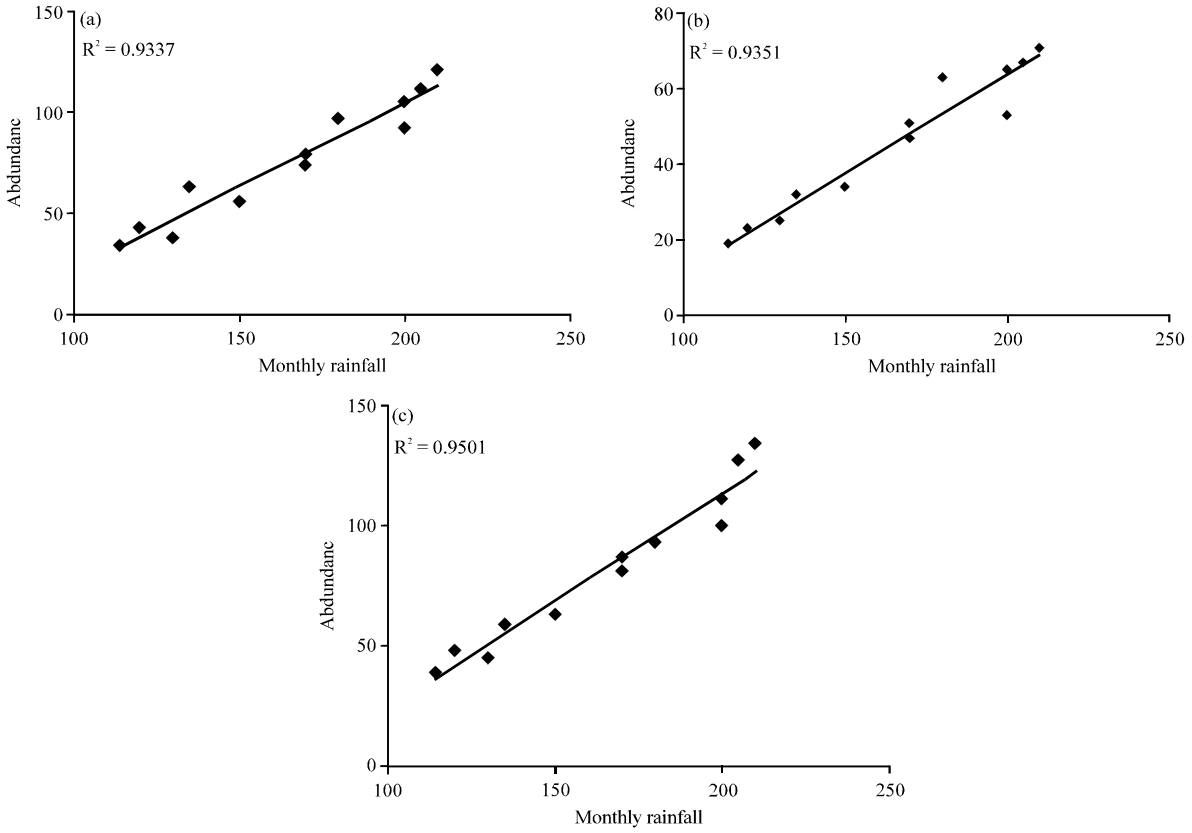

Fig. 5(a-c): Relationship between (a) *Aedes*, (b) *Anopheles* and (c) *Culex* sp. abundance and monthly rainfall in Benin City, Nigeria (from March 2008 to February 2009)

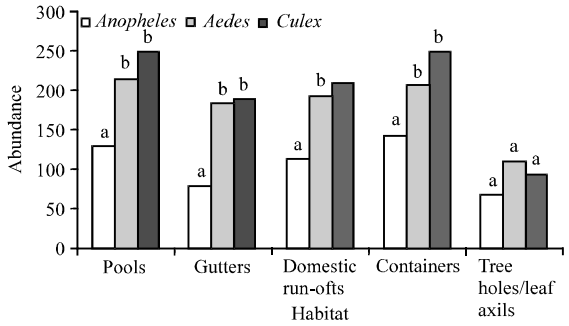

Fig. 6: Different mosquito genera associated with particular habitat, types in Benin City between March 2008 and February 2009, Bars followed by same letters are not significantly different at p>0.05 by Mann Whitney U test

their associated habitats. Although all species of *Culex*, *Aedes* and *Anopheles* mosquitoes bred at all sites, it was observed that *C. quinquefasciatus*, *C. moucheti*, *C. nebulosus*, *C. tigripes* and *C. decens* showed slight preference for breeding in pools, domestic run-offs, gutters and containers (Fig. 7a) while *A. gambiae* and *A. funestus* complexes demonstrated similar breeding site preference pattern with high population levels recorded from stagnant pools and containers

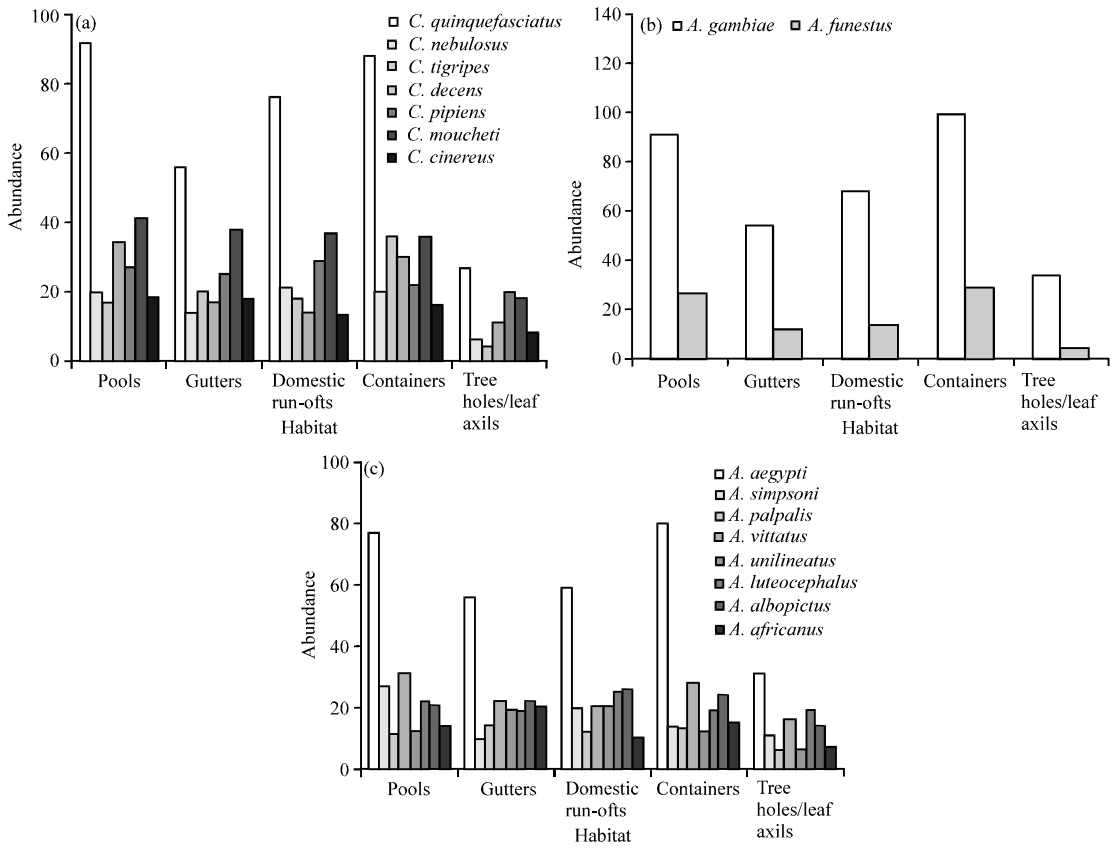

Fig. 7(a-c): (a) *Culex*, (b) *Anopheles* and (c) *Aedes* species abundance and associated habitats in Benin City, Nigeria between March 2008 and February 2009

(Fig. 7b). Figure 7c showed that *A aegypti*, *A. vittatus*, *A. albopictus* and *A. simpsoni* are able to breed very well in pools, gutters, domestic run-offs and containers as well as tree holes/leaf axils.

DISCUSSION

The composition of mosquitoes species belonging to three genera *Anopheles* (2 species), *Culex* (7 species) and *Aedes* (8 species) as observed in this study has not been previously reported in Benin City, Nigeria. Although several workers (Igbinosa, 1989; Mafiana *et al*., 1998; Aigbodion and Odiachi, 2003; Okogun *et al*., 2005; Anosike *et al*., 2007) in Nigeria have reported the presence of all species encountered in this study, but no singular paper/publication has reported the presence and composition of mosquito species in one ecological zone (rainforest zone) as reported in this paper. Mosquito species occurred in all five habitats sampled in Benin City and populations were relatively abundant throughout the season with peak populations observed between July and September probably because of the high rainfall. The month of April to October is usually the rainy (wet) season in Nigeria and it's characterized with high humidity, high rainfall and average temperature of 26.5°C. A combination of these factors may be responsible for the higher larval abundances recorded during the rainy season. The strong positive correlation between rainfall and the abundance of the three mosquito genera justifies the explanations given above. The increases in mosquito populations during the wet seasons have been previously reported in Nigeria

(Igbinosa, 1989; Anosike *et al.*, 2007; Adeleke *et al.*, 2008) and elsewhere (Dossou-Yovo *et al.*, 1995; Koenraadt *et al.*, 2004). Environmental factors such as temperature, relative humidity, seasonality and water quality have been found to be promising predicator of mosquitoes distribution (Pemola and Jauhari, 2005; Stoops *et al.*, 2007; Impoinvil *et al.*, 2008; Muturi *et al.*, 2008). Availability of water collections with suitable fauna, flora and physicochemical composition is a major limiting factor to oviposition and breeding of mosquitoes species. The persistence monthly occurrence of all three mosquito genera (Fig. 4) in Benin City may in parts be due to the increased and varied human activities, urbanization and other related anthropogenic factors that create different natural and artificial habitats as sources of water for oviposition and breeding sites for several mosquitoes species. Mosquitoes breeding sites were frequently observed in the designated study sites during this study. Also poor economic condition, low literacy levels, poor sanitation levels, indiscriminate disposal of wastes (including discarded household materials, cans, plastic and metal containers), abundant numbers of abandoned construction sites, uncontrolled domestic run-offs and poor maintenance of gutters and drainages may in parts, be responsible for the increase in mosquitoes breeding sites in Benin City. The consequence of one or a combination of these factors is the increase in mosquitoes vector abundance and vectorial capacity (Dossou-Yovo *et al.*, 1995; Ezike *et al.*, 2001; Aigbodion and Odiachi, 2003; Okogun *et al.*, 2005; Adeleke *et al.*, 2008; Impoinvil *et al.*, 2008; Akram *et al.*, 2009). In this study, *Culex* genera was the most abundant while *Anopheles* was the least. The lack of significant difference ($p>0.05$) between *Culex* and *Aedes* genera showed that Benin City is a good breeding ground for both mosquitoes genera.

This study showed that *Culex* species generally ranked as the leading genus followed by *Aedes* and *Anopheles* species in stagnant pools, gutters, domestic run-offs and containers, while in tree holes/leaf axils, *Aedes* ranked as the highest. The presence of all three mosquitoes genera at all sampled habitats demonstrate the abilities of mosquitoes to breed at all habitat types throughout the year in Benin City and this indicates a high potential for malaria, yellow fever and bancroftian filariasis in the city. Of all species encountered in this study, *A. gambiae* complex was the most abundant constituting 14.4% of the total species recorded and it was observed alongside *A. funestus* complex to breed in all 5 habitat types. The recording of high numbers of *A. gambiae* and *A. funestus* complexes are of epidemiological significance because they are proven and established vectors of malaria and lymphatic filariasis in Nigeria. Malaria is the most endemic parasitic disease in the study area. Although, *Anopheles* species has been shown to have preference for breeding in ground pools (Igbinosa, 1989), the high occurrence of *Anopheles* species in gutters and domestic run-offs and containers is however remarkable and shows that these species can utilize other habitats apart from ground pools. Our observation supports the findings of Adeleke *et al.* (2008) and Okogun *et al.* (2005) who reported the breeding of *Anopheles* species in gutters and tree holes in southern Nigeria. This breeding habitat shift and/or diversification of breeding habitats may be a result of urbanization and other challenges associated with it. The implication of this gradual micro-ecological habitat shift will be high vectorial potential and transmission threshold of malaria in the Benin City. Several workers (Okogun *et al.*, 2005) have reported the incidence of malaria rate to be as high as 100% in Nigeria. *Culex quinquefasciatus* was the second most abundant species and was recorded at all the micro-ecological habitats investigated including tree holes and leaf axils. Although its population was higher in containers and pools, it showed no distinct preference for a particular habitat as breeding sites. A similar trend was also observed among the other *Culex* species. Most *Culex* species have been reported to prefer pools and containers as breeding sites (Igbinosa, 1989; Adeleke *et al.*, 2008; Mafiana, 1989). The

occurrence of *Culex* species recorded in this study is similar to the findings of Anosike *et al.* (2007) and Hopkins (1952). *Culex nebulosus*, *C. moucheti* and *C. cinereus* has been noted to be very common in polluted waters and sites which have foul smell (Service, 1965; Anosike *et al.*, 2007). *Culex* disease vectors encountered in this study include *C. quinquefasciatus*, *C. pipiens* which are known vectors of bancroftian filariasis and *C. decens* a potential vector of arboviruses in general. Incidentally, these species were encountered in substantial numbers thus giving rise to epidemiological concerns. The numbers of *Aedes aegypti* recorded accounted for 12.44% of the total mosquitoes collected. *Aedes* was the second most abundant genera (37.28%) but the richest in terms of number of species (8 species, in total). This study indicates that *Aedes* bred in all micro-habitat types. This indiscriminate breeding habit has been reported by Okorie (1978), Mafiana *et al.* (1998) and Okogun *et al.* (2005). *Aedes aegypti* and *A. albopictus* have been implicated in the transmission of yellow fever and arboviruses. The latter species is thought to have been introduced into Nigeria from Southeast Asia where it has been known as an efficient vector of yellow fever and dengue fever (Ezike *et al.*, 2001). Its route into Nigeria is not clear. Though, yellow fever epidemics have not been recently reported in Benin City, an outbreak of this disease has been reported in the neighboring states (Mbanugo and Okpalononuju, 2003). The persistent occurrence of *Aedes*, *Culex* and *Anopheles* species and breeding habitat diversification by these mosquitoes as recorded in this study, pose a serious epidemiological concern to the inhabitants of Benin City.

CONCLUSION

Some of the mosquitoes encountered are medically important as they are known vectors of lymphatic filariasis, malaria, yellow fever and dengue fever among others and these diseases are likely to be recorded at higher rates during the rainy (wet) season when most breeding habitats such as containers, domestic run-offs, gutters, stagnant pools and tree holes and plant axils are water-filled and thereby supporting the development of various mosquito species that transmit such diseases. Most mosquitoes species bred in all habitats (without showing clear preference), this maybe largely due to man's modification of the environment and changes in weather patterns. The contribution of human activities and increasing environmental modifications in the area to the breeding of mosquito vectors is therefore of particular importance to efforts at mosquito vector control. Selected measures including larviciding of breeding sites are among recommended measures to be implemented annually particularly months before the onset of the wet season in the area to reduce the menace of mosquito vector borne diseases. In conclusion, this study has provided information on temporal distribution and larval habitats of mosquitoes in Benin City. Since most of the species encountered are potential vectors of mosquito-borne diseases, we therefore recommend that the residents of Benin City be enlightened on the environmental factors that contribute to mosquito breeding. The State and Local Governments should also embrace proper environmental sanitation so as to reduce the breeding sites of mosquitoes. In order to maintain historical records of relative vector population densities and seasonal population trends, continuous monitoring of various mosquito species is highly recommended.

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