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Impact of urbanisation on bionomics and distribution of malaria vectors in Lagos, southwestern Nigeria

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Abstract

Background & objectives: The patterns of annual rainfall as well as average daily temperature have not changed drastically in the study area since 1960 when detailed baseline entomological surveys were carried out. However, the increase in human population from 1.2 to 10 million has resulted in both expansion of land and tremendous ecological and environmental change. This has led to drastic changes in vectors' densities as well as species' composition while the preferred larval habitat of malaria vectors has shifted to water reservoirs. A longitudinal study was carried out to investigate the impact of urbanisation on bionomics and distribution of malaria vectors in Lagos, a mega city in Nigeria.

Methods: Mosquitoes were collected indoors and outdoors using WHO standard techniques in the selected areas between January and December 2000. Specimens were identified using the morphological keys and PCR assays. ELISA tests were used for *Plasmodium falciparum* sporozoite infection.

Results: The *Anopheles gambiae* species-specific PCR identified 56% (435/777) of the *An. gambiae* s.l. as *An. gambiae* s.s. and 44% (342/777) as *An. arabiensis*. The molecular M and S forms represented 35.3 and 64.7% of the *An. gambiae* s.s. population, respectively. The *An. funestus* species-specific PCR identified 60% (239/401) of the *An. funestus* group as *An. funestus* s.s. and 40% (162/401) as *An. rivulorum*. The biting activity of *An. funestus* s.s. both indoors and outdoors attained a peak at 0200 and 2200 hrs, respectively, with a significant increase in the "pre-bed time" collections indoors (χ^2 = 6.15, df = 1, $p < 0.05$) and outdoors (χ^2 = 6.28, df = 1, $p < 0.05$). The overall outdoor collection was significantly higher (χ^2 = 28.23, df =3, $p < 0.05$) than that recorded indoors. The overall sporozoite rates for *An. gambiae* s.s., *An. arabiensis* and *An. funestus* were significantly different in both localities (χ^2 = 0.58, df = 2, $p < 0.01$). Infection rates in both indoor and outdoor collections were also different statistically (χ^2 = 0.67, df = 2, $p < 0.01$).

Interpretation & conclusion: Large number and species of anopheline mosquitoes collected in the study area may be associated with the availability of aquatic breeding sites. A phenomenon leading to an increase in man-vector contact and a high level of risk to the crowded urban population is observed.

Key words *Anopheles* mosquitoes – Nigeria – urbanisation

Introduction

About 50% of the world population lives in areas with malaria[1]. In sub-Saharan Africa, which accounts for > 90% of the global prevalence, risk of malaria infection and morbidity are often difficult to estimate accurately due to the interplay of several epidemiological parameters. Even within a single country,

there are considerable variations in malaria epidemiology due to differences in climatic, ecological and human activities.

As in most parts of West Africa, malaria transmission in rural areas of Nigeria is generally intense, perennial and well-documented[2–4]. This is not the same in urban areas where exploitation of natural resources and development activities are common phenomena. The consequences of urbanisation, deforestation and demographic growth suggest that unplanned urban growth is liable to alter the ecosystem and behaviour of vectors affecting malaria transmission.

In 1960, the first population census in Nigeria estimated the population living in Lagos to be 800,000, which surpassed 10 million in 1991. This increase in urbanisation encroached over surrounding greenland meant for agriculture. Today, most of the natural breeding sites of malaria vectors reported before have disappeared[5], though malaria still persists mesoendemically in Lagos. The main purpose of this study was to assess malaria infectivity in Lagos city under the impact of climatic change and urbanisation.

Material & Methods

Study area: This study was carried out in Lagos (03º54'E, 07º26'N), which lies in the forest area of Nigeria. The climate is tropical with a well-marked dry season during November to March. The rainy season extends from April to October with a short break in July.

Mosquito collection and processing: Mosquitoes were collected indoors using WHO standard techniques and supplemented with outdoor collections in the selected areas between January and December 2000. In the laboratory, anopheline mosquitoes were identified as far as possible using the morphological keys of Gillies and Coetzee[6] and stored dry on silica gel for PCR species identification of the *Anopheles gambiae* complex. The involvement of each species in malaria transmission was assessed using ELISA tests for *Plasmodium falciparum* sporozoite infection.

PCR identification of Anopheles gambiae s.l. and Anopheles funestus group: The *An. gambiae* species-specific PCR was carried out using the method of Scott *et al*[7] with minor modifications as detailed in van Rensburg *et al*[8], while *An. funestus* Giles was identified to species level using the multiplex PCR technique of Koekemoer *et al*[9].

Identification of the molecular forms in An. gambiae s.s.: The molecular M and S forms in *An. gambiae* s.s. were identified using the method described by Favia *et al*[10].

ELISA tests: ELISA tests for *P. falciparum* sporozoite infection was carried out on 792 *Anopheles* mosquitoes, comprising of 202 specimens of *An. rivulorum* and *An. funestus* and 75% of the respective populations of *An. gambiae* s.s. and *An. arabiensis* (selected using a random number table). Head and thorax of each mosquito was placed in PBS (pH 7.4) and tested by direct ELISA[11].

Results

Species composition of Anopheles mosquitoes: A total of 1178 female *Anopheles* mosquitoes collected consist of four species of that 554 (47%) were caught indoors and 624 (53%) outdoors. Indoor and outdoor data were pooled for analysis since there was no significant difference in the species composition or abundance of the total number of mosquitoes collected. The relative abundance of the species was expressed as the corresponding percentage of the total number of *Anopheles* collected (Table 1). The *An. gambiae* species-specific PCR identified 56% (435/777) as *An. gambiae* s.s. and 44% (342/777) as *An. arabiensis*. The molecular M and S forms of the *An. gambiae* s.s. represented 35.3 and 64.7% respectively. The *An. funestus* species-specific PCR identified

Table 1. Species composition of female *Anopheles* mosquitoes collected in the study area

Species	Indoors	Outdoors	Total
An. gambiae	225 (51.7)	210 (48.3)	435 (36.9)
An. arabiensis	128 (37.4)	214 (62.6)	342 (29.0)
An. funestus	133 (55.6)	106 (44.4)	239 (20.3)
An. rivulorum	68 (42.0)	94 (58.0)	162 (13.8)
Total	554 (47.0)	624 (53.0)	1178 (100)

Figures in parentheses indicate percentage.

60% (239/401) of the *An. funestus* group as *An. funestus* s.s. and 40% (162/401) as *An. rivulorum*.

Biting activities of Anopheles mosquitoes: The biting activities of four species found most abundant in the overall collection were not different in two localities. Indoor and outdoor biting activities of *An. gambiae* s.s. observed throughout the night reached a peak at 0300 and 2200 hrs, respectively (Fig. 1). The biting activity of *An. funestus* s.s. both indoors and outdoors attained a peak at 0200 and 2200 hrs respectively (Fig. 2), with a significant increase in the "pre-bed time" collections (indoors: $\chi^2 = 6.15$, df = 1, $p < 0.05$); (outdoors: $\chi^2 = 6.28$, df = 1, $p < 0.05$). *Anopheles arabiensis* and *An. rivulorum* were more exophagic with more than 68 and 71% of their respective biting populations occurring outdoors respectively (Table 1). The overall outdoor collection was significantly higher ($\chi^2 = 28.23$, df = 3, $p < 0.05$) than that recorded indoors.

P. falciparum sporozoite rates: Overall, 32 (4%) of the 792 *Anopheles* mosquitoes tested were found positive for *P. falciparum* infection. The circumsporozoite antigen (CSA) rate was 6.6% for *An. gambiae* s.s., 1.8% for *An. funestus* s.s. and 3.1% for *An. arabiensis*, and none of *An. rivulorum* specimen was found positive (Table 2). The overall sporozoite rates for *An. gambiae* s.s., *An. arabiensis* and *An. funestus* were significantly different in both localities ($\chi^2 = 0.58$, df = 2, $p < 0.01$). Infection rates in both indoor and outdoor collections also showed statistical significance ($\chi^2 = 0.67$, df = 2, $p < 0.01$).

Discussion

Increase in urban population has major implications for malaria epidemiology both in terms of vector population and host-vector contact leading to high frequency and dynamics of malaria transmission.

Rapid urbanisation with its consequent population explosion and increase in the number of slums in Lagos metropolis has brought about considerable changes in environmental conditions thereby creat-

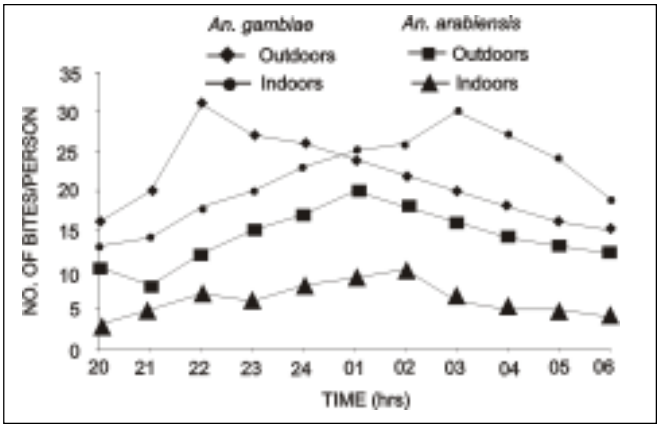

Fig. 1: Indoor and outdoor biting cycle of *An. gambiae* and *An. arabiensis*

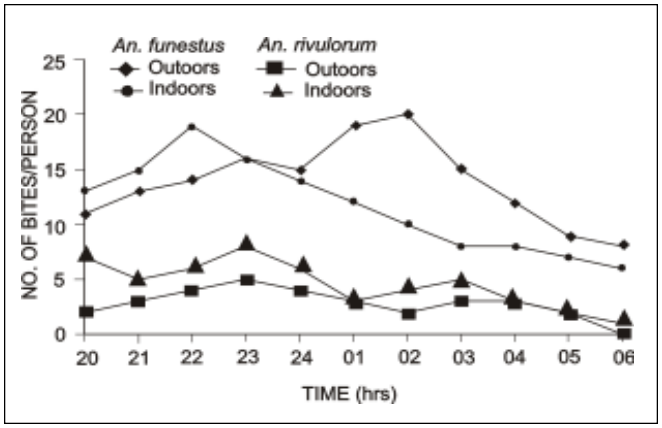

Fig. 2: Indoor and outdoor biting cycle of *An. funestus* and *An. rivulorum*

Table 2. Number of mosquitoes tested and percentage found carrying *Plasmodium falciparum* circumsporozoite antigens in both indoor and outdoor collections

Species	Indoors		Outdoors		Total	
	No. tested	No. (% +ve)	No. tested	No. (% +ve)	No. tested	No. (% +ve)
An. gambiae	173	14 (8.1)	159	8 (5.0)	332	22 (6.6)
An. arabiensis	122	2 (1.6)	136	6 (4.4)	258	8 (3.1)
An. funestus	75	2 (2.7)	37	0 (0)	112	2 (1.8)
An. rivulorum	24	0 (0)	66	0 (0)	90	0 (0)
Total	394	18 (4.5)	398	14 (3.5)	792	32 (4.0)

ing more vector breeding sites. These changes had exerted its tolls on human health most especially on the incidence of malaria over the years. However, there is no documentation to show the effects of these ecological modifications on human health and to what extent these affect anopheline fauna in the study area.

Nevertheless, previous studies carried out in the Lagos area have documented the presence of *An. gambiae*, *An. melas* and *An. arabiensis* as major malaria vectors[12–14]. Same species of anopheline mosquitoes were recorded in the recent study carried out in the coastal area of Lagos with *An. moucheti* as an additional species[5]. In the present study, we reported the presence of *An. funestus* and *An. rivulorum* in addition to the previously documented species in Lagos area. Although, the density of these species was relatively low compared to *An. gambiae* s.l. which remained the predominant species in the study area[5, 12–15]. Some of the species reported here were found to occur in sympatry, however, sympatry of two or more sibling species is a common phenomenon and well-documented among members of the *An. gambiae* complex[6]. The occurrence of *An. rivulorum* in sympatry with *An. funestus* s.s. in the study area supports the previous observations on the possibility of incipient species in *An. funestus* in west Africa[16].

Hourly variation in biting activities of the reported species showed that indoor and outdoor biting activities extend throughout the night. However, differences in biting cycle between *An. gambiae* s.s. and *An. funestus* s.s. could be due to a difference of about an hour in the times of occurrence of their biting peak periods and a corresponding change in the vertical distributions with which these were associated[13]. Meanwhile, the peak biting period observed for *An. gambiae* s.s. and *An. arabiensis* agrees with previous records for *An. gambiae* s.l. in northern Nigeria[17].

Record on the distribution of the M and S molecular forms of *An. gambiae* s.s. is scanty in Nigeria, however, the difference in the proportion of the M and S molecular forms of the *An. gambiae* s.s. in the study area was significant and similar to the previous reports[10,18–20]. *P. falciparum* circumsporozoite antigen rate recorded for *An. gambiae* s.s., *An. arabiensis* and *An. funestus* s.s., contrasts with our findings in the coastal area of Lagos[4] where *An. gambiae* s.s. was responsible for most of malaria transmission in the wet season. Although *An. rivulorum* has been reported as a secondary malaria vector in Africa[17, 21–24], but it appears not to be of major importance in malaria transmission in the study area.

The contribution of the three most important afrotropical malaria vectors in the study site may account for the perennial malaria transmission, compared to other parts of Nigeria where one vector species predominates and transmission is seasonal[25,26].

Conclusion

This study has a number of epidemiological implications: first, the effect of ecological changes on vector species abundance or composition may lead to high level of malaria transmission and infection. Secondly, the presence of *An. funestus* s.s. may indicate shift in species composition in the study area. This may have implications on control measures targeting a single species, such as genetic manipulation of *An. gambiae* s.s. which will have little impact on malaria infection associated with either *An. funestus* s.s. or *An. arabiensis*. Furthermore, the exophagic behaviour of *An. arabiensis* will make it less susceptible to residual insecticide and impregnated nets. Lastly, the peak biting periods recorded for *An. funestus* and *An. gambiae* imply that a considerable human exposure to malaria infection would have occurred before people go to bed. The results from this study further suggest the need for an integrated vector control programme that will be effective against all malaria vector species existing in the urban centres.

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