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EVALUATION OF RESTING SITES OF *CULEX QUINQUEFASCIATUS* AND *ANOPHELES GAMBIAE* S.L IN AN URBAN-RURAL TRANSECT IN JOS, NIGERIA
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EVALUATION OF RESTING SITES OF *CULEX QUINQUEFASCIATUS* AND *ANOPHELES GAMBIAE* S.L IN AN URBAN-RURAL TRANSECT IN JOS, NIGERIA

K. J. NJUNWA and R. J. IRVING-BELL

ABSTRACT

***Background*: The city of Jos, Nigeria, has been expanding with a consequent increase in the contact between humans and wild monkeys inhabiting the surrounding hills. Such a situation could increase the danger of the spread of zoonoses as well as arboviruses.**
***Objective*: To determine the relative monthly abundance of *Culex quinquefasciatus* and *Anopheles gambiae* s.l in three different habitats.**
***Design*: A longitudinal study.**
***Setting*: Urban-rural transect in Jos, Nigeria.**
***Results*: A total of 853 mosquitoes were collected, comprising of 98.5% *Culex quinquefasciatus* from all the three habitats and 1.5% *Anopheles gambiae* s.l only from the house habitat. The house habitat, C, yielded the most numbers of both species of mosquitoes, while the handcatch method significantly exceeded the box shelters in the yield of *Culex quinquefasciatus* and *Anopheles gambiae* s.l**
***Conclusion*: The indoor resting habit observed by *Cx. quinquefasciatus* and *An. gambiae* s.l. makes indoor residual spraying and use of insecticide treated nets suitable for their control.**

INTRODUCTION

Mosquitoes serve as vectors of many serious animal diseases to humans. Mosquito borne disease include malaria, filariasis, dengue and other arboviruses, that cause human suffering, loss of lives and considerably impaired economic development (1, 2). Globally, in 2013, mosquito borne diseases included malaria which caused a total of 584,000 deaths and 198 million cases (3), and dengue causes over 50-100 million new cases per year (4). Various mosquito species including *Culex, Aedes* and *Anopheles* spp are known to transmit arboviruses (2). The distribution of the mosquito species is influenced, among other factors, by the physical environment for breeding and resting (4-6) each of which can be altered by human activities and modify the disease transmission dynamics (5,7).

Jos, a city in Nigeria, like most African urban centres, has been gradually expanding with growing population. This expansion could bring forth the rise in contact between humans and wild monkeys that inhabit the surrounding hills. Such situation obviously increases the danger of the spread of zoonoses as well as arboviruses (9). Studies conducted in Jos Plateau showed that there was a significant difference in the abundance of mosquitoes in breeding sites in between the urban, semi-urban and rural areas, with *Culex quinquefasciatus* and *Aedes aegypti* being predominant in the larval samples from the containers (10).

Adult mosquitoes are most of the time resting in places of their preference than being in flight (7). Most species rest totally outdoors in natural resting places and only a few species like artificial shelters (7). The only few mosquito species found to rest indoors are known to be the vectors of malaria, filariasis and arboviruses (7). Outdoor resting mosquitoes tend to be dispersed in available habitats (6) and a number of methods have been used to collect them (6, 10, 11) sensitive and accurate sampling of *Anopheles* mosquitoes is a prerequisite for effective management of malaria vector control programmes. The most reliable existing means to measure mosquito density is the human landing catch (HLC, 12 sensitive and accurate sampling of *Anopheles* mosquitoes is a prerequisite for effective management of malaria vector control programmes. The most reliable existing means to measure mosquito density is the human landing catch (HLC] including among others box-shelters and powered aspirators and sweep nets.

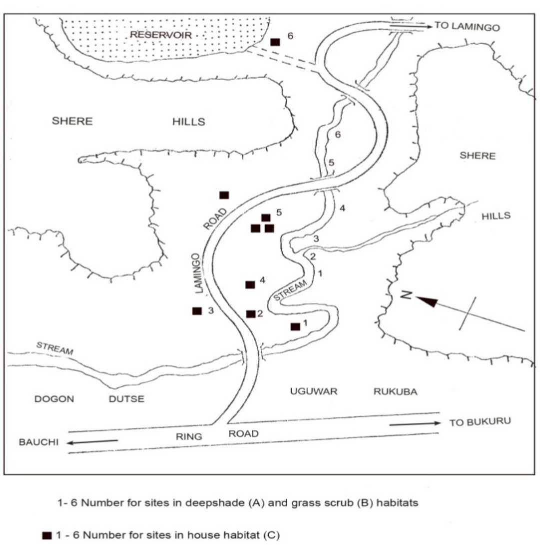
The present study was therefore carried out from the month of February to August to determine the resting habitat preferences for adult *Cx quinquefasciatus* and *An. gambiae* s.l along an urban-rural transect in Jos city using box shelters, powered aspirator and sweepnet. The results obtained aims to add to the information available for use in vector and disease control planning and implementation

MATERIALS AND METHODS

Study Area: The study area was a transect from the Jos urban area of Dogon Dutse / Uguwar Rukuba beyond the Ring Road to the old water reservoir in the rural bush area of Lamingo in Shere Hills 9^0 55′ N 8^0 55′ E Fig. 1. There were three types of habitats along the urban-rural transect in this study namely deep shade riverbed habitat (A), grass scrub habitat (B) and house habitat (C). Habitat A consisted of a seasonal stream running from the reservoir along the transect, with pools of water in the river bed which seemed to dry up later in the dry season. The vegetation of dense shrubs provided deep shade along the stream. Habitat B was dominated by grass with low scrub extending in the rest of the area. Habitat C were the houses at Dogon Dutse, water treatment station and a reservoir guard house. In each habitat, six sites were chosen for sampling purposes.

The annual mean temperature ranged from 21^o C to 24^o C, and annual rainfall over the area was between 101.6cm and 152.4 cm most of which fell during April to October. In the remaining five months it was mainly dry with less than 2.5cm per month and the humidity fell to a low level owing to a warm dry wind or "Harmattan" blowing from the north.

Figure 1
Sketch map of study area in Jos



Study Design: There were supposed to be two sampling occasions per week from February to August, but due to an acute transport problem particularly during the first three months, the weekly distribution of sampling occasions could no longer be maintained. Sampling was later on performed as often as transport was available with the maximum of two sampling occasions per week making a total of 25 sampling occasions. All the outdoor sites were approximately equal in area, and the indoor ones were also about equal. The sampling started in the morning at around 8.00am and would go on up to 1.00pm when all the sites were covered.

In the outdoor sites all available micro-habitats to the maximum of six were searched for mosquitoes for example, rock holes, crevices, vegetation, tree trunks, culverts under bridges, and rodent burrows. In the house, the walls and objects hanging on them, tables and chairs and other items from within the room were searched. It was not possible to enter bedrooms because of the reluctance expressed by most of the occupants. So in some cases outdoor kitchens, stores and other rooms that they could offer were used for the work. Each house constituted a site and the areas searched in it were regarded as microhabitats.

Sampling Methods

Artificial Resting Sites: Box Shelters: The modified standard box shelter devised by Morris was used. The cardboard box was brown and measuring 30cm high 40cm wide and 20cm deep with the opening reduced to 30cm by 24cm to provide the interior with more shade. The modification of the box shelter by reducing the size of the opening was the result of the very few numbers caught in the boxes with full size opening possibly because the box interior was too exposed. A small porous pot containing water with the mouth covered with polythene sheeting secured in position with a rubber band was introduced into the box shelters in order to raise the humidity conditions so as to attract more mosquitoes. A wooden slab was placed in the bottom of the box shelters to support the weight of the pot. Boxes were wrapped in polythene sheeting to prevent rain from soaking them.

Two box shelters with their pots were set at each site in each habitat. In deep shade and grass scrub habitats, boxes were always positioned facing south to reduce the effect of the Harmattan winds from the north. In the houses, box shelters were put below the window facing inside the room in order to intercept outgoing mosquitoes negotiating their way towards the window. A mosquito mesh cage measuring 35cm high, 45cm wide and 25cm deep with 1/5 cm galvanised steel wire frame, open on one of the wider sides and with a small opening with mosquito netting sleeve in the opposite face was used for removing mosquitoes. The cage would be secured into position around the mouth of the box using two strings which formed part of the cage. The whole process was performed as fast as possible in order to prevent the escape of mosquitoes. Then by using an oral aspirator, and a torch, mosquitoes were collected from all the corners of the box, and the cage itself through the opening of the net sleeve. The mosquitoes were then transferred into labelled Perspex cups covered with mosquito netting with a cotton plug in a hole through which the mosquitoes were introduced and they were kept alive with 5-10% sucrose solution in cotton wool placed on the net cover.

It is however, important to note that the box shelters suffered frequent damage by trampling from livestock, and by the deliberate stealing of pots and wooden slabs meant to support the pots in the boxes. This seriously affected the catches. In total 36 box shelters were used two at each site for all habitats.

Sweep Net and Power Operated Aspirator: As a form of comparison with the box shelters, a sweep net and power operated aspirator were used. A sweep net 35cm in diameter was used to catch mosquitoes resting in houses, vegetation where possible, crevices and cracks by first agitating them with a stick and then catching them in flight. Because of the paucity of mosquitoes, especially in the outside resting sites, no limit was attached to the number of sweeps.

A car battery operated aspirator was used in dense vegetation, rock holes and other places where the sweep net could not do. This aspirator was a converted Nissan car vacuum cleaner K504 30100 12 Volt 80 Watts run by direct current by connecting it to a car cigarette lighter. A Perspex cup with an open bottom was glued over the cleaner intake by its lid where a slit had been cut. A small mosquito netting bag was introduced into the Perspex cup catching mosquitoes as they were blown in when the machine was operating. The oral suction tube was used for transferring mosquitoes from both the sweep net and the small net bag in the powered aspirator into labelled cups where they were kept alive as in the case of the box shelter samples.

Identification of Mosquitoes: For identification under a Bausch and Lomb (0.7 x 3x) dissecting microscope, mosquitoes were first killed using ethyl acetate vapour, and then each mosquito was categorised to its generic and specific level using keys modified from Edwards (14), Gillies and DeMeillon (15) for culicines and anophelines respectively.

Meteorological Recordings: The temperature and relative humidity were recorded by using a whirling hygrometer on the day of sampling. The data for rainfall were taken from the Geography Department of the University of Jos located nearby.

RESULTS

Sampling Occasions and Number of Mosquitoes Caught: There was a total of 19 and 25 sampling occasions for box shelter and sweepnet/battery operated aspirator (handcatch) methods respectively over a period of seven months from February to August Table 1.

Table 1

Number of mosquito sampling occasions achieved

Collection method	Feb	Mar	April	May	June	July	Aug	Total
Box shelters	2	5	3	7	2	-	-	19
Handchatch (Sweepnet/Aspirator	2	5	3	7	4	1	3	25

Table 2

Number of Cx quinquefasciatus and An. gambiae s.l. caught in deep shade habitat (A), grass scrub habitat (B) and house habitat (C)

Mosquito species	Habitats				
	A	B	C	Total	%
Cx quinquefasciatus	39	5	796	840	98.5
An gambiae s.l.			13	13	1.5
Total	39	5	809		
% of N=853	4.6	0.6	94.8	853	100

A total of 853 mosquitoes were collected of which the most 809 (94.8%) came from house habitat (C), 39 (4.6%) deep shade habitat (A), and 5 (0.6%) grass scrub habitat (B), (Table 2). *Cx. quinquefasciatus* was the most abundant species at 840 (98.5%) collected from all the three habitats, while 13 (1.5%) were *An gambiae* s.l. collected only from the house habitat, C.

Relative Abundance of Cx quinquefasciatus and An gambiae s.l. Caught by the Handcatch and Box Shelter Methods: A combined total of 534 (62.6%) and 319 (37.4%) of both species of *Cx quinquefasciatus* and *An. gambiae* s.l were caught by the handcatch and box shelter methods respectively (Table 3). The handcatch method yielded much higher numbers of *Cx quinquefasciatus* and *An. gambiae* s.l than the box-shelters (p = 0.0257).

Table 3

Relative abundance of Cx. quinquefasciatus and An. gambiae s.l. Collected by the handcatch and box-shelter methods

Mosquito species	Handcatch		Box-shelter		Total			
	No.	%	No	%	No	%	$\chi^{2(1)}$	p-value
Cx quinquefasciatus	522	97.8	318	99.7	840	98.5	4.976	0.0257
An gambiae s.l.	12	2.2	1	0.3	13	1.5		
Total (%)	534 (62.6)	100	319 (37.4)	100	853	100		

Comparison of Cx quinquefasciatus and An gambiae s.l. Abundance between Sites for Hand Catcher and Box shelter Collection Method: Since sampling sites 1 to 6 were chosen to give a short transect sampling line from an urban to a rural local environment, the collections were examined for (a) any differences along the line within each habitat type, then (b) a comparison of all habitats along the line. The data used were combined numbers for each species for the months, March to June. The boxshelters placed indoors that is house habitat (C) yielded a total of 306 mosquitoes of which *Cx. quinquefasciatus* numbered 305 (99.7%) and *An. gambiae* s.l. 1 (0.3%) (Table 4). The results show that there was considerable variation between sites 1-5 with no clear trend but site 6 consistently yielded no mosquitoes.

Table 4

Total collections of Cx quinquefasciatus and An gambiae s.l. from different sites by box shelter in house habitat (C) and outdoor deep shade habitat (A)

Species		House habitat C transect sites (Urban to rural)						Total	%
		1	2	3	4	5	6		
Cx quinquefasciatus	No.	64	99	33	42	67		305	99.7
	%	21.0	32.5	10.9	13.8	22.0			
An. gambiae s.l.	No.					1		1	0.3
Total								306	100
		Deepshade habitat A transect sites (Urban to rural)							
		1	2	3	4	5	6		
Cx quinquefasciatus	No.	5	1				7	13	
	%	38.5	7.7				53.8		100

The outdoor deep shade habitat (A) box shelters yielded a total of 13 *Cx. quinquefasciatus*, (Table 4). There was no trend of abundance along the transect line and sites 3-5 yielded no mosquitoes. When the catches for *Cx. quinquefasciatus* from the indoor and outdoor habitats were compared, it showed clearly that the box shelters placed indoors yielded far more mosquitoes than those placed outside, $t_{(5)} = 3.505$, p = 0.0171, (Table 4). For the grass scrub habitat (B) not a single mosquito was collected using the box-shelters.

Monthly Abundance of Cx quinquefasciatus and An gambiae s.l. for Box Shelter Catches: The collection from box shelters was analysed to see if there were differences in monthly abundance. For this purpose the data is presented as mean monthly figures (Table 5) to allow for differences in the number of sampling occasions between months (Table 1). Box shelter collections were discontinued from July owing to the onset of heavy rains which further reduced the attractiveness of the traps and also because of theft and damage to them. Note that *Cx. quinquefasciatus* is the only species to be considered and that grass scrub habitat, B, is excluded owing to zero yield. It is clear from the monthly totals of Table 5, that box shelters yielded most *Cx. quinquefasciatus* in April and May at 35.8% and 36.6% of the total catch respectively.

Table 5

Mean monthly abundance for Cx quinquefasciatus by site and habitat (Outdoor deep shade A and indoor house C) for box shelter catches

Site	Months and Habitats										Total
	February		March		April		May		June		Catches
	A	C	A	C	A	C	A	C	A	C	
1				4.6		5.7	0.7	3.1		1.0	
	2					9.0	0.1	9.7		1.0	
	3					1.0		4.1		0.5	
	4					5.3		3.7		1.5	
	5				9.4	2.3		1.4			
6							1.0			4.0	
Habitat totals				14.0		23.3	1.8	22.0		4.0	65.1
Monthly totals				14.0		23.3	23.8			4.0	65.1
% Monthly totals				21.5		35.8	36.6			6.1	

A two way analysis of variance for habitat C, using the data transformation showed that there was a significant difference in abundance between months ($F_{(4)} = 3.089$, $p = 0.0339$), but not between sites ($F_{(5)} = 0.8598$, $p = 0.5220$).

Comparison of Cx. quinquefasciatus and An. gambiae s.l. Abundance between Sites for the Handcatch Collections: Collections by hand catching are considered in the same sequence as that of box shelter collections already explained. However, in this case the sampling period was longer, February to August, and extending well into the rainy season. A total of 503 mosquitoes were collected from the house habitat, C, comprised of *Cx quinquefasciatus* at 97.6% (491) and *An gambiae* s.l. at 2.4% (12) (Table 6). As with the box shelter data, there was no trend in abundance with site, and the site 6 house remained barren of mosquitoes. Inadequate number (5) of *Cx quinquefasciatus* were caught from the grass scrub habitat (B) than the 26 *Cx quinquefasciatus* yielded from the deep shade habitat sites (A) (Table 6).

Table 6

Cx quinquefasciatus and An gambiae s.l. abundance between sites by handcatch collection method for house habitat (C), grass-scrub habitat B, and deep shade habitat A

Species		House habitat C transect sites (Urban to rural)						Total	%
		1	2	3	4	5	6		
Cx quinquefasciatus	No.	117	107	57	97	113		491	97.6
	%	23.8	21.8	11.6	19.8	23			
An. gambiae s.l.	No.				4	8		12	2.4
Total								503	100
		Grass-scrub Habitat B transect sites (Urban to rural)							
		1	2	3	4	5	6		
Cx quinquefasciatus					1		4	5	
		Deepshade Habitat A transect sites (Urban to rural)							
		1	2	3	4	5	6		
Cx quinquefasciatus			13	2	3	1	7	26	

Collections of *Cx. quinquefasciatus*, being the only species caught in all habitats were analysed to see if there were differences between the habitats and between the sites. By using a two way analysis of variance with data transformation it was shown that there was a significant difference in abundance between the habitats ($F_{(2)} = 17.3528$, $p = 0.0001$) but not between the sites ($F_{(5)} = 0.1768$, $p = 0.9662$).

Monthly Abundance of Cx quinquefasciatus and An gambiae s.l. from Handcatches: The collection from handcatching were also analysed to see if there were differences in monthly abundance. The data are presented as mean monthly figures for each habitat (Table 7).

Table 7

Mean monthly species abundance by handcatch collection method for deep shade habitat (A), grass-scrub habitat B and house habitat (C)

Deepshade habitat A	Months							Total
Species	Feb	Mar	Apr	May	June	Jul	Aug	
Cx quinquefasciatus				2.9	1.3			4.2
Grass-scrub habitat B	Months							Total
Species	Feb	Mar	Apr	May	June	Jul	Aug	
Cx quinquefasciatus				0.5	0.3			0.8
House habitat C	Months							Total
Species	Feb	Mar	Apr	May	June	Jul	Aug	
Cx quinquefasciatus		5.6	28	38.3	15.3		16.7	103.9
An gambiae s.l.		0.2		0.1			3.3	3.6

Cx. quinquefaciatus and *An. gambiae* s.l., caught from the indoor house habitat (C) had a rather unique monthly distribution as opposed to the first two mentioned habitat collections (Table 7). Firstly, *Cx. quinquefasciatus* was caught almost every month save for February and July, with a higher yield in April to June and August, and a peak in May. On the other hand *An. gambiae* s.l. was caught in greater numbers in August, while in March there was a low yield and in May, the lowest.

Due to the relatively consistent mean monthly yield of *Cx. quinquefasciatus* caught indoors (Table 8), the data was further analysed using a two way analysis of variance with transformation of the mean monthly totals to see if there was much variation in monthly abundance. The results showed that there was no significant difference in abundance between the sites ($F_{(5)} = 2.559$, $p = 0.0481$) but a highly significant difference between the months ($F_{(6)} = 5.988$, $p = 0.0003$), as was shown for box shelter collection method.

Table 8

Mean monthly abundance of Cx quinquefasciatus from the house habitat C hand catches

Months								
Sites	Feb	Mar	Apr	May	June	Jul	Aug	Total
1		0.2	12.7	5.1	2.0		11.3	31.3
2		0.2	2.3	11.4	4.8			18.7
3			6.3	3.9	1.5		1.7	13.4
4			3.7	8.9	4.5		2.0	19.1
5		5.2	3.0	9.0	2.5		1.7	21.4
6								
Total		5.6	28.0	38.3	15.3		16.7	103.9

Relationship of Species Abundance to Meteorological Conditions: The yields for *Cx quinquefasciatus*, and *An. gambiae* s.l., from the three habitats for at least three months were combined and compared with monthly rainfall, and mean relative humidity and temperature for the three habitats (Fig. 2) using percentages of individual species totals for any relationship (Fig. 3).

The temperatures did not vary much over the sampling period, whereas there was a considerable increase in relative humidity from April with a drop in July after which it went up again in August. The rainfall was on the increase from March to August. *Cx. quinquefasciatus* had a peak in May then a decline, and *An. gambiae* s.l. had a peak in August (Fig. 3). The low yield shown by the July data is partly due to the fact that there was only one sampling occasion for that month.

Figure 2

Monthly Rainfall (cm), Combined mean Temperature(^{0}C) and Relative Humidity (%) for habitats A, B, and C.

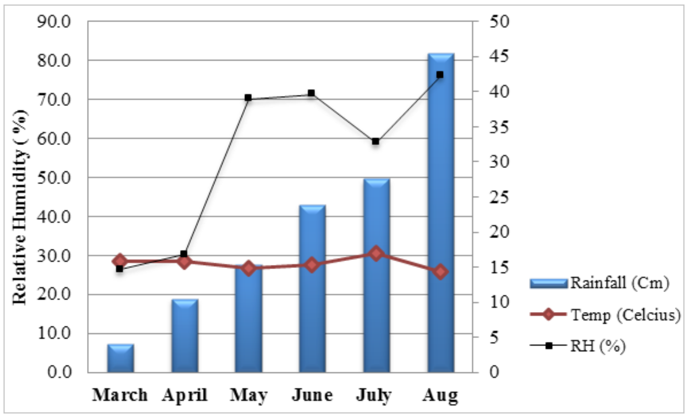
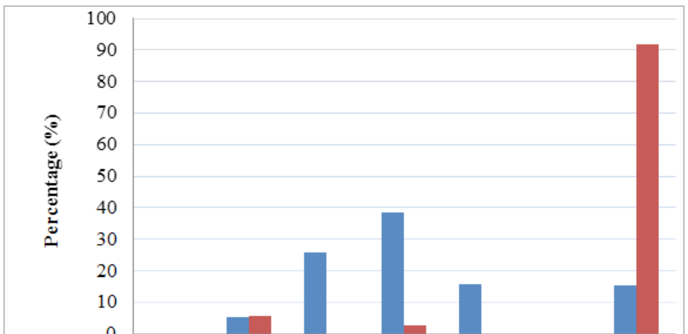


Figure 3

Combined mean monthly mosquito species abundance for habitats A, B, and C for Cx quinquefasciatus and An. gambiae s.l from hand catches.



	Feb	March	April	May	June	July	August
Cx quinq	0	5.1	25.7	38.3	15.5	0	15.3
An gambiae	0	5.6	0	2.8	0	0	91.7

DISCUSSION

Size of Mosquito Catches: The purpose of this study was to investigate the relative monthly abundance of *Cx. quinquefasciatus* and *An. gambiae* s.l in three different habitats in an urban-rural transect in Jos city, Nigeria. The total number of mosquitoes caught (853) is small considering the magnitude of sampling effort: 19 occasions for box shelters and 25 for hand catches, (Table 1 and Table 2). This is mainly due to the fact that, unlike indoor house habitat, C, outdoor deep shade habitat, A, and grass scrub habitat, B, always yielded small numbers of mosquitoes most probably owing to their dispersed tendency in outdoor resting sites as remarked by Service (16). *Cx. quinquefasciatus* was the most abundant species constituting 98.5% (840) due to its habit of breeding in foul water in septic tanks with unscreened vents, pit latrines as well as blocked open sewers and gutters (17).

The number of *An. gambiae* s.l mosquitoes caught before the rains started was quite small, and this could possibly be due to lack of permanent clear water bodies in the project area except for the water reservoir which is unlikely to support mosquito breeding because of the fish population.

Relative Abundance of Cx quinquefasciatus and An gambiae s.l. Mosquito Species Caught by Handcatch and Box Shelter Methods: The numbers of mosquitoes caught by hand catches 534 (62.6%) and the box shelters 319 (37.4%) were small, probably, as explained by Menon and Rajagopalan (18), due to the fact that the number of mosquitoes resting in artificial boxes placed inside huts and also outdoors depend on the availability of alternative resting sites and this may vary according to area and may change seasonally. This accounts for the higher number of mosquitoes caught by hand catching ($p = 0.0257$) as they could be collected from a variety of indoor microhabitats such as walls, under tables, hanging clothing, ceiling and some empty containers which are more suitable resting places than box shelters. Regarding the outside resting mosquitoes, the crevices and holes were possibly more preferred to grass or box-shelters as the former are likely to have fewer variations in temperature and relative humidity, although this depends on the species.

Comparison of Cx quinquefasciatus and An gambiae s.l. Abundance between Sites for Hand Catches and Box Shelters: The number of *Cx quinquefasciatus* collected by hand catching and box-shelters were considered together for any trend in their abundance along the transect; with *An. gambiae* s.l samples being treated the same way. The house habitat C yielded more *Cx. quinquefasciatus* and *An. gambiae* s.l than outdoor habitats (A and B). This can be explained by the fact that these two species are commonly endophagic and endophilic, that is, they mainly tend to feed and rest indoors, but they often shelter in outdoor resting places (7). There was a large difference in the yield of mosquitoes from the grass scrub habitat (B) and the deep shade habitat (A). The grass scrub had much fewer mosquitoes than the deep shade habitat perhaps due to the fact that the temperatures in the grass scrub habitat were a little higher and relative humidity lower than that for the deep shade habitat. Furthermore, the mosquitoes were likely to stay much closer to their breeding places, most of which were a few ponds remaining in the riverbed in the deep shade habitat. When the yields for *Cx. quinquefasciatus* from habitat A, and C were compared using a two way analysis of variance it was shown that there was a significant difference ($p < 0.01$) in the abundance of the species between the two habitats, but not between the sites ($p > 0.05$) (Table 4). Service had a similar observation, indicating that this species appears to be associated with urbanisation where it was the most common anthropophilic and endophilic Culicine in northern Nigeria (19). There was no clear trend in variation of the abundance of *Cx. quinquefasciatus* between site 1 to 5 in the house habitat C, and site 6 yielded no mosquitoes at all (Tables 4 and 8). It is to be noted, however, that sites 1, 2 and 5 always yielded higher numbers than sites 3 and 4. The presence of foul water in the partially blocked ditches or quite slowly flowing stream near the former three sites may have contributed to recorded numbers *Cx. quinquefasciatus* in those sites (17). *An. gambiae* s.l. were caught from site 4 and 5 only, where site 5 was the water treatment station and had water draining from pipes to a small pond which is likely to have supported the breeding of this species mainly because nobody slept in there and therefore there was not attraction to the mosquitoes (20). The guard-house at site six yielded no mosquitoes (21) and as already mentioned owing to the absence of suitable breeding grounds for mosquitoes.

The numbers of mosquitoes collected from habitat A and B also showed no clear trend in variation between sites, while in habitat B most mosquitoes were collected between sites 4 to 6 (Table 6). The probable explanation for the above observation is that at site 2 in the deep shade habitat A, there was a variety of microhabitats, such as piled water pipes, a lot of crevices in the banks of the gully of the river as well as in the riverbed itself and vegetation. Still more significant, however, is the fact that site 2 was most often sampled using the battery operated aspirator due to its nature that rendered the sweep net unsuitable for use in this site (22). This led to more microhabitats being reached and a good number of species recovered (18, 19). The high yield of mosquitoes from site 6 of habitat A was due to the availability of riverbed pools in the deep shade habitat from where adult mosquitoes moved to the crevices and vegetation of the grass-scrub habitat (23).

Relationship of Monthly Abundance of Cx quinquefasciatus and An gambiae s.l. to Meteorological Conditions: The monthly abundance of *Cx quinquefasciatus* and *An gambiae* s.l. (Table 7) showed a monthly variation. The May peak for *Cx quinquefasciatus* observed in this study is in line with that of study (19) that found that this species had a seasonal distribution different from that of the other species encountered, where it had a sudden increase in numbers April, and May, at the beginning of the wet season, followed by a downward trend probably due to prior build up in limited breeding sites before the rains started (19).

An.gambiae s.l. had its peak in August, as similarly reported by Service (19) followed by sharp decline in population from January to April and to rise again from may and peak in September (10). The more or less constant temperatures registered during the sampling period indicate that the effect of temperature on the monthly distribution of the mosquito species was quite minimal, and since relative humidity tended to increase with the onset or rainfall and then remained almost constant as the rains increased further, it can be stated that the major environmental factor influencing the monthly abundance of mosquitoes in Jos and similar tropical areas is rainfall (24). It is most likely that this conclusion holds for other mosquito species. The low yield for most of the species noted in July is because there was only one sampling occasion in that month.

In conclusion, the present study has revealed considerable information about *Cx quinquefasciatus* and *An gambiae* s.l. abundance in the three habitats studied. The greatest number of *Cx. quinquefasciatus* was caught indoors, and all *An. gambiae* s.l. were indoors. With regard to adulticide control measures, it appears that the use of long lasting insecticidal nets and indoor residual spraying against *An. gambiae* s.l. and *Cx. quinquefasciatus* would significantly reduce the populations of these species provided there is no change in their behaviours with time. The use of box shelters as an alternative method for mosquito sampling has been shown not to have a relative advantage over sampling using the sweepnet and/or aspirator. The role of meteorological conditions on the monthly abundance has been shown and rainfall seems to play the major role compared to temperature and relative humidity.

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