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Manyi, M. M
Applied Entomology and Parasitology Unit, Department of Biological Sciences, Federal University of Agriculture, P M B 2373, Makurdi, Benue State, Nigeria.

Vajime, C.G
Department of Biological Sciences, Benue State University Makurdi, Benue State, Nigeria.

Imandeh, G. N.
Applied Entomology and Parasitology Unit, Department of Biological Sciences, Federal University of Agriculture, P M B 2373, Makurdi, Benue State, Nigeria.

For Correspondence:
Manyi, M. M
Applied Entomology and Parasitology Unit, Department of Biological Sciences, Federal University of Agriculture, P M B 2373, Makurdi, Benue State, Nigeria.

Seasonal changes of microfilarial infection and infectivity rates in mosquito populations within Makurdi, Benue State, Nigeria

Manyi, M. M, Vajime, C.G and Imandeh, G. N.

ABSTRACT

Studies on the infection and infectivity rates of *Wuchereria bancrofti* in mosquito populations in Makurdi, Nigeria were carried out over a 12 month period in four localities. Adult female mosquitoes (4,320) were morphologically identified and dissected following standard keys and procedures. 1,040 (24.1%) were *Anopheles gambiae* s.l.; 641 (14.8%) were *Anopheles funestus* Giles and 2,418 (56.0%) were *Culex quinquefasciatus* Say while 221 (5.1%) were tagged 'unidentified' *Anopheles* species. The overall microfilarial infection and infectivity rates were 10.1% and 4.8% respectively. The microfilarial infection and infectivity rates differed significantly (ANOVA; χ^2 *test p<0.05*across vector species, study months and the localities surveyed. The findings indicate that Makurdi is endemic for lymphatic filariasis, and that *Anopheles gambiae* s.l. and *Anopheles funestus* were potential vectors of lymphatic filariasis in Makurdi while *Culex quinquefasciatus* was the major vector. This work may provide an entomological baseline data required for evaluation and implementation of vector control interventions in the study area.

Keywords: Seasonal changes, microfilarial infection rate, infectivity rate, mosquitoes, Makurdi, Nigeria.

1. Introduction

It has been reported that several mosquitoes belonging to the genera *Anopheles, Culex and Aedes* are vectors for pathogens of various diseases such as malaria, filariasis, yellow fever, dengue, Japanese Encephalitis (JE) and haemorrhagic fever [1]. According to the World Health Organization [2], even when mosquitoes do not transmit disease, they may cause great annoyance, making areas originally suitable for human and animal occupation quite uninhabitable. Vector borne diseases are worldwide and exert enormous burden on the continent of Africa [3]. Malaria and lymphatic filariasis are two of the most common mosquito-borne parasitic diseases worldwide which can occur as concomitant human infections while also sharing common mosquito vectors [4]. Filariasis is an infection of the human lymphatic system caused by filarial nematodes that are vectored by mosquitoes. According to [5], 1.3 billion people are at risk of the disease globally and the disease is classified into two groups, Bancroftian (Wuchereria bancrofti) and Malayan (*Brugia malayi* and *B. timori).*

These three filarial parasites affect over 120 million people in 83 endemic countries worldwide, located primarily throughout tropical and subtropical regions of South America, Asia, the Pacific Islands and Africa [5]. Although designated by the WHO as the world's second leading cause of permanent and long-term disability, this mosquito-borne disease is "potentially eradicable" through drug therapy and vector control [5].

According to [6], Lymphatic filariasis (LF) has been recognised since medieval times and that depictions of the disfiguring disease have been found in medieval art, painting and maps of Greek and Roman medical writers.

The parasite *Wuchereria bancrofti,* which is responsible for the disease in Africa is transmitted by *Culex quinquefasciatus* in urban and semi-urban areas where increased pollution of freshwater bodies and the introduction of pit latrines favour the breeding of the mosquito [6, 7]. In West Africa, *Anopheles gambiae* complex and *Anopheles funestus* are the major transmitters of *Wuchereria bancrofti* infections [8].

It has been reported that transmission of bancroftian infection occurs mainly during rainy season when mosquitoes are most abundant, thus demarcating well-defined seasons when

transmission is high and low [6]. The epidemiology of the disease in Nigeria is complicated because of the diversity of the environmental conditions of the different regions [9]. In Nigeria, only Bancroftian filariasis is endemic, as reported for rural communities in the lower Cross River Basin [10, 11]; for Ezza in Ebonyi State [12]; for Igwu basin of Rivers State and parts of the Niger Delta [13, 14] as well as parts of Central Nigeria particularly rural communities in Plateau, Nassarawa and Benue States [15].

Bancroftian filariasis, caused by *Wuchereria bancrofti* is widespread in Nigeria and constitutes a major public health problem as well as a major cause of acute and chronic morbidity [16]. *Anopheles gambiae* and *Anopheles funestus* are the major vectors in rural Nigeria while *Culex quinquefasciatus* is the major vector in urban and semi-urban areas [17]. These mosquito vectors which breed and transmit bancroftian filariasis in Nigeria are aided by human activities, brought about by urbanization and overcrowding as well as industrialization which together create abundant breeding sites [16].

The availability and proximity of human settlements to these numerous breeding sites of the vectors play an important role in the disease transmission and intensity in both rural and urban areas [9, 16].

Globally, Nigeria is ranked second highest with lymphatic filariasis [18]. The National Lymphatic Filariasis Elimination programme (NLFEP) was established in 1997 with the mandate to eliminate Lymphatic Filariasis (LF) as a Public Health problem. In 2007, the NLFEP was merged with the National Onchocerciasis Control Programme (NOCP) in order to integrate implementation of mass drug administration (MDA) in areas that are co-endemic for both LF and Onchocerciasis [18, 6]. However, the NLFEP has not yet completed the mapping of the disease, and as a result, MDA is yet to commence in most of the States likely to be endemic [6]. Records from the Federal Ministry of Health [18] have shown that MDA has been implemented in only five States (Plateau, Nassarawa, Ekiti, Ondo and Osun). Therefore, the need to ascertain the infection and endemicity rates in other parts of the country like Benue State is very paramount for the commencement of MDA. Thus, the present investigation was carried out to study the seasonal changes of microfilarial infection and infectivity rates in mosquito populations within Makurdi, Benue State, Nigeria.

2. Materials and Methods
2.1 Study Area
The present investigation was carried out between July, 2011 and June, 2012 in Makurdi to cover wet and dry season periods. Makurdi is the capital of Benue State located in the middle belt region, North Central Nigeria [19]. It is intersected by the river Benue which is a major source of water with other networks of streams, standing pools, over filled and blocked drainages [20]. Over-grown bushes and fields, even around residential homes and offices are easily noticeable in Makurdi. These provide suitable breeding sites for mosquitoes throughout the wet and dry seasons. There is also characteristic high temperature in Makurdi, (30-39 ºC), which

helps in the speedy development and hatching of mosquito eggs. It is suspected that temperature may have an impact on transmission of vector diseases in the selected localities throughout the year. Makurdi is located between longitude 8º35'E and 8º41'E and latitude 7º45'N and 9º52'N. Other detailed geographical and regional indices of the study area have been provided by [21, 22, 23], some of which have been depicted in Fig. 1.

2.2 Ethical Consideration and Collection of Mosquito Samples
Verbal informed consent was obtained from the head of each of the randomly selected households before their houses were accessed for mosquito collection in all the study localities. All mosquito samples were collected using standard procedures as provided by [24]. Sampling units were randomly selected from four localities and due to the present security challenges in Nigeria, the mosquito samples were collected with the help of "fly boys" who were recruited from the various study localities where they were well known by the residents of the localities sampled.

Mosquito samples were collected between the hours of dawn and dusk. Specifically, the mosquitoes were collected from 0600-0900 hours at dawn and 1800-2100 hours at dusk from living rooms in the study localities, either alive or dead, most of which were engorged (blood fed).

These periods of sample collection were chosen because previous studies have shown that most mosquitoes enter houses to feed at early hours of the night and struggle to go out in the early hours of the day to rest outdoors [25, 7].

The mosquitoes were collected from dark corners, walls, ceilings, clothing and other objects inside living rooms with the aid of mouth-aspirators, mosquito sweep nets, pyrethrum spray sheets and window trap method where applicable.

The mosquito specimens were kept in holding tubes, inside cooling boxes, and carried to the laboratory on the same day or the following day for characterization, identification, dissection and examination as adopted by [26, 24, 27, 28, 29]. Those mosquito samples that could not be processed on the same day were refrigerated against the next day according to the methods of [26].

Even though, the mosquito population for this study was only drawn from indoor-resting mosquitoes, which were expected to be only females, some male mosquitoes were also caught along with the females. Male mosquitoes were therefore, distinguished from the females using key morphological features as described by [7].

2.3 Identification of Mosquito Samples
Dissecting microscope was used for detailed observation and identification of the mosquitoes with particular reference to the head, thorax, wings and hind-legs according to [30]. Morphological characteristics such as length of maxillary palps, wing spots, leg shape, mouthparts and abdominal end model as presented by [31] and [7] were used to identify the *Anopheles* species that co-exist in Makurdi. Observations of the morphological features were made at x 40 magnification of the microscope.
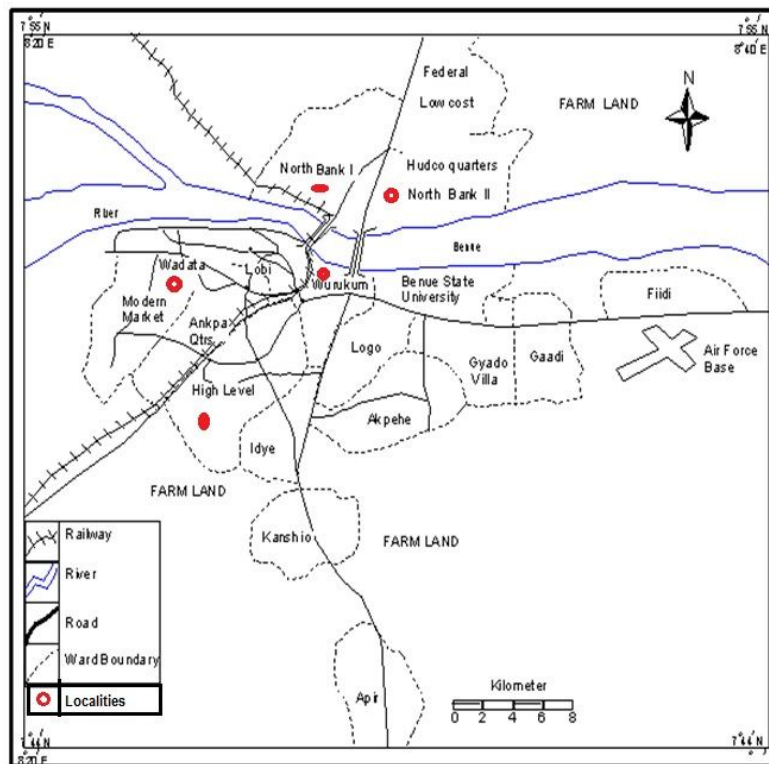
Fig.1 Map of Makurdi Showing the Study Localities (Ministry of Lands and Survey Makurdi, 2011)**.**

2.4 Preparation of Mosquitoes for Dissection

Live blood fed mosquitoes were killed with chloroform, ether or carbon (IV) oxide while unfed mosquitoes were collected in a test tube and while at the bottom, the end of the tube was raped sharply against the palm of the hand to stun the mosquitoes according to the WHO standard [4]. After immobilization, each mosquito was placed on a slide and held by one wing while the legs were being removed one at a time and after wards, the other wing was pulled off. The mosquito was then placed on a fresh dry slide and arranged in a more suitable position for dissection of the stomach/abdominal region and salivary glands as described by [24] and as adopted by [29].

2.5 Dissection of the Salivary Glands for Determination of Infection Rates

This was intended to incriminate the mosquito vectors and establish the microfilarial infection rates for both *Anopheles and Culex* species, using the procedure described by [29]. The salivary glands of the nulliparous mosquitoes were not dissected since they are not infected.

The anterior part of the mosquito to be dissected was placed on a slide with the head pointing to the right hand side and a drop of saline was added to keep the specimen fresh. Meanwhile, the left dissecting needle was placed gently on the thorax, just below the region where the glands lie. The right needle was also placed at the same point but pulled towards the right direction to bring out the head with the salivary glands attached. Some salivary glands however, did

not come out with the head of the mosquito but these were located by carefully teasing the lower part of the thorax and examining carefully.

The glands were detached from the head and then placed on another microscope slide with a little drop of saline and covered with a cover slip and a gentle pressure was exerted on the cover slip to rupture the gland cells.

Afterwards, the thoracic muscles were teased carefully in a saline solution to look for microfilariae. If the salivary glands contained microfilariae, the microfilariae were seen to emerge from the glands.

All the microfilariae identified in the mosquitoes for this study had nuclei which did not reach their tails, the tails tapered evenly and they also had sheaths. These features were convincing enough to classify them as those of *Wuchereria bancrofti* as described by [32]. *Wuchereria bancrofti* larval stages (L_1, L_2 and L_3) were also sought for during dissection from the three parts of the female mosquitoes (abdomen, thorax and head respectively) using their morphological features after they were stained with Giemsa's stain as described by [32, 33].

Infection and Infectivity rates were therefore, calculated using the formulae adopted by [33] as follows:

$$Infection\ Rate = \frac{Number\ of\ Mosquitoes\ carrying\ L_1 + L_2 + L_3}{Number\ of\ Mosquitoes\ dissected}\ X\ 100$$

$$Infectivity\ Rate = \frac{Number\ of\ Mosquitoes\ carrying\ L_3}{Number\ of\ Mosquitoes\ dissected}\ X\ 100$$

2.6 Statistical Analysis of Data

The Predictive Analytical Software (PASW) Version 18 was used in running Chi-square (χ^2) statistic and one-way Analysis of Variance (ANOVA) on the data collected.

Significant levels were measured at 95% confidence level with significant differences considered at $p<0.05$.

In addition, Chi-square (χ^2) statistic was considered the best statistic for test of homogeneity across sample localities so as to determine whether or not the nature of the sample localities affected the distribution of data across them. The fact that part of the data obtained in this study was continuous, and it was also required to compare means across more than two (2) samples, ANOVA was therefore used.

3. Results

The results of the present investigation have been depicted in Tables 1, 2, 3 and Fig. 2 respectively. Infection rates were recorded as 4.3%, 31.8% and 1.8% in the wet season 1, dry season and the wet season 2 respectively while Infectivity rates were obtained as 2.2%, 14.7% and 0.9% in the same order. Statistical analysis (ANOVA) showed significant differences $(P<0.05)$ between the infection rates and infectivity rates across the seasons and also among the vector species.

Infection and infectivity means between the seasons also showed significant difference at 5% level. The microfilarial infection rates were significantly higher $(P<0.05)$ than

infectivity rates across the seasons, with the highest microfilarial infection and infectivity rates of 31.8% and 14.7% in the dry season, even though the mosquito vector population was lower during this period (Table 1).

Considering the microfilarial infectivity rates of the vector species independently, the order of vector importance of the identified vectors in Makurdi was *Culex quinquefasciatus >Anopheles funestus > Anopheles gambiae.* The same trend was observed in both the wet and dry seasons of the study period: there were more L_3 larvae found in the mosquito vectors with majority occurring during the dry season than the other larval stages. Even though, the mosquitoes were carrying microfilarial infection, their actual infectivity rates were lower than the infections they carried. Though, the population of mosquitoes was more in the two wet seasons under consideration, potential risk of transmission of *Wuchereria bancrofti* larvae was more pronounced in the dry season.

In terms of months during which the study was carried out, microfilarial infection rates were higher in October, 2011 through February, 2012 (dry season), with January, 2012 having the highest infection rate of 60.3%, and no microfilaral infection was recorded in July, 2011 (Table 2). Microfilarial infection rates differed significantly across the study months $(\chi^2\text{-} test, p<0.05)$.

Table 1: Seasonal Changes of Microfilarial Infection and Infectivity Rates in Mosquito Vectors within Makurdi.

Mosquito species and seasons	Number of mosquitoes Dissected	No. with L_1	No. with L_2	No. with L_3	Infection Rate (%)	Infectivity Rate (%)
Wet Season 1: (July-Oct. 2011)						
Culex quinquefasciatus	985	11	24	28	6.39	2.84
Anophelesgam biae s.l.	545	1	3	6	1.83	1.10
Anopheles funestus	362	0	1	5	1.66	1.38
Anopheles (unidentified)	59	1	1	3	8.47	5.08
Wet Season 1 Total	**1,951**	**13**	**29**	**42**	**4.3**	**2.2**
Dry Season: (Nov. 2011-March, 2012)						
Culex quinquefasciatus	760	16	97	126	31.45	16.57
Anopheles gambiae s.l.	148	14	21	12	31.76	8.11
Anopheles funestus	69	16	5	10	44.93	14.49
Anopheles (unidentified)	60	4	5	4	21.66	6.67
Dry SeasonTotal	**1,037**	**50**	**128**	**152**	**31.8**	**14.7**
Wet Season 2: (April-June, 2012)						
Culex quinquefasciatus	673	5	7	9	3.12	1.34
Anopheles gambiae s.l.	347	0	0	3	0.86	0.86
Anopheles funestus	210	0	0	0	0.00	0.00
Anopheles (unidentified)	102	0	0	0	0.00	0.00
Wet Season 2 Total	**1,332**	**5**	**7**	**12**	**1.80**	**0.90**
Total	**4,320**	**68**	**164**	**206**	**10.1**	**4.8**

(a) Infection rate (ANOVA: F-ratio=29.574, p=0.001)

(b) Infectivity rate (ANOVA: F-ratio=14.981, p=0.001)

In terms of study localities, North-bank had the highest microfilarial infection rate of 16.1%, followed by High-level (11.2%) while Wadata and Wurukum localities had similar microfilarial infection rates of 7.8% and 7.3% respectively

(Table 3). These differences in microfilarial infection rates across the localities were significantly different $(\chi^2\text{-} test, p<0.05)$.

Also, comparing the microfilarial infection rates with respect to species of mosquitoes encountered in the study area, *Culex quinquefasciatus* had the highest infection rate of 7.5%, followed by *Anopheles gambiae* (1.4%) and *Anopheles funestus* (0.9%) while the 'unidentified' species of *Anopheles* mosquitoes had the lowest microfilarial infection rate of 0.4% respectively (Table 3). Statistically, there was a significant difference in the microfilarial infection rates between the mosquito species (χ^2- *test*, *p*<0.05).

Table 2: Monthly Microfilarial Infection Rates in *Anopheles* and *Culex* Mosquitoes Dissected from Makurdi

Month of Study	No of Mosquitoes dissected	Species of Mosquitoes/Infection Rates (%)				
		Culex quinquefasciatus	*An. gambiae*	*An. funestus*	Unidentified *An. species*	TOTAL Infection
July, 2011	503	-	-	-	-	-
August, 2011	558	10 (1.8)	1 (0.2)	-	-	11 (2.2)
September, 2011	569	12 (2.1)	-	1 (0.2)	-	13 (2.3)
October, 2011	321	41 (12.8)	9 (2.8)	5 (1.6)	5 (1.6)	60 (18.7)
November, 2011	202	67 (33.2)	11 (5.4)	8 (3.9)	5 (2.5)	91 (45.0)
December, 2011	186	59 (31.7)	17 (9.1)	11 (5.9)	3 (1.6)	90 (48.4)
January, 2012	174	78 (44.8)	14 (8.0)	10 (5.7)	3 (1.7)	105 (60.3)
February, 2012	178	29 (16.3)	5 (2.8)	2 (1.1)	2 (1.1)	38 (21.3)
Match, 2012	297	6 (2.0)	-	-	-	6 (2.0)
April, 2012	309	9 (2.9)	1 (0.3)	-	-	10 (3.2)
May, 2012	510	6 (1.2)	1 (0.2)	-	-	7 (1.4)
June, 2012	513	6 (1.2)	1 (0.2)	-	-	7 (1.4)
TOTAL	4,320	323 (7.5)	60 (1.4)	37 (0.9)	18 (0.4)	458 (10.1)

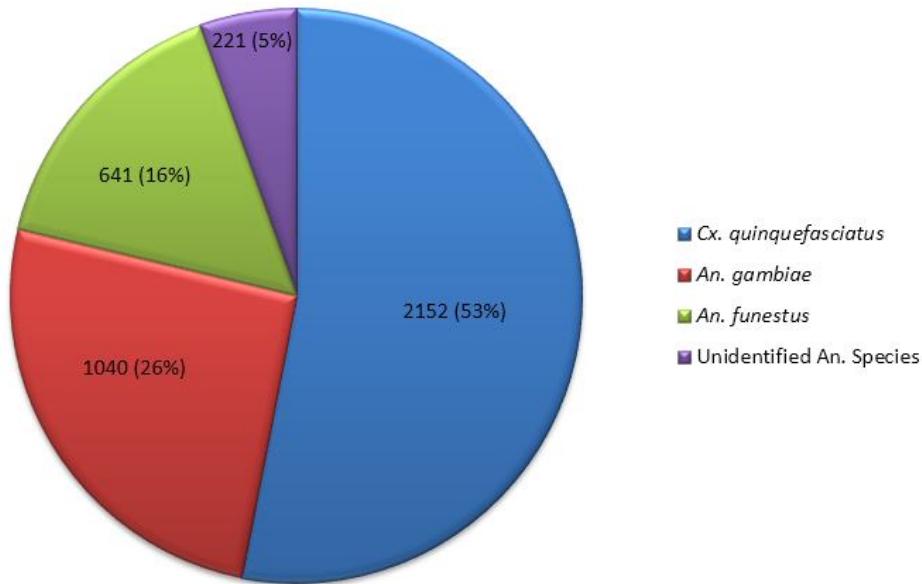Months vs infection rate: χ^2 *test, p*<0.05

Fig 1: Proportion of the Mosquito Species found in Makurdi during the Study Period.

Table 3: Microfilarial Infection Rates in *Anopheles* and *Culex* Mosquitoes Dissected from four Localities in Makurdi

Study Locality	No of Mosquitoes dissected	Species of Mosquitoes/Infection Rates (%)				
		Culex quinquefasciatus	*An. gambiae*	*An. funestus*	Unidentified *An. species*	TOTAL Infection (%)
High Level	1,128	105(9.3)	2(0.2)	12(1.1)	7(0.6)	126(11.2)
Wurukum	1,193	61(5.1)	12(1.0)	9(0.4)	5(0.4)	87(7.3)
North-bank	834	93(11.2)	32(3.8)	9(1.1)	-	134(16.1)
Wadata	1,165	64(5.5)	14(1.2)	7(0.6)	6(0.5)	91(7.8)
TOTAL	**4,320**	**323(7.5)**	**60(1.4)**	**37(0.9)**	**18(0.4)**	**438(10.1)**

(a) Anopheles group: $\chi^2 = 7.143$, $d.f = 2$, $P = 5.99$ (b) *Culex* vs *Anopheles*: $\chi^2 = 56.000$, $d.f = 1$, $P = 3.84$

4. Discussion

This is the second time, after the work of [34] that *Culex quinquefasciatus* was found to be the dominant vector of *Wuchereria bancrofti* in Makurdi with *Anopheles gambiae* and *Anopheles funestus* also featuring in the study area. Among these mosquitoes, *Culex quinquefasciatus* had the highest population in the dry season across the four localities. This also agrees with the findings of [16] and [17], who stated that *Anopheles gambiae* and *Anopheles funestus* are the main vectors in rural Nigeria while *Culex quinquefasciatus* remains the major vector in the urban and semi-urban areas. This is linked to the fact that the latter species is known to breed in poorly sanitized areas with filthy and fowl smelling water collections that are eminent in the study area [34]. This may explain why [35] reported *Wuchereria bancrofti* infection to be a major public health problem in Benue State and advocated for the inclusion of the state in the National Programme to Eliminate Lymphatic Filariasis (NPELF). Also working in Ebonyi State, in Nigeria, [36] reported *Culex quinquefasciatus* as the major vector with *Anopheles gambiae* and *Anopheles funestus* also playing significant roles in the transmission of lymphatic filariasis in the area.

The incrimination of *Culex quinquefasciatus* in this study is in line with the earlier observations by [37] on the possible involvement of *Culex* species in the transmission of lymphatic filariasis in Northern Nigeria. It is also in consonance with the findings of [38] that *Culex quinquefasciatus* is a potential vector of bancroftian filariasis in most West African cities. The overall microfilarial infection rate of 10.1% obtained in the present study is therefore, comparable to reports from filariasis endemic countries [39, 40]; but is much higher than that obtained [41], who reported an overall microfilarial infection rate of only 0.5% in the Kainji Lake area of Nigeria. This contrast may be attributed to the fact that the malaria vector control using pyrethroid treated nets carried out at the Kainji Lake area at that time may have controlled the vectors of bancroftian filariasis in communities where both diseases co-existed.

Earlier epidemiological study in India revealed concomitant infection of *Plasmodium falciparum* with *Wuchereria bancrofti* in human population [42]. Co-infection of *Wuchereria bancrofti* and *Onchocerca volvulus* has been reported in human populations in Tanzania [43]. In contrast, this study did not identify any co-infection of *Plasmodium* species and *Wuchereria bancrofti* in any mosquito specimen. This may be due to the behaviour of the vector species and duration of parasite cycles in the mosquito[7]. Moreover, several authors have advanced that the life cycle patterns, behaviour and ecology of microfilariae play significant roles in their appearance in the thoracic muscles and or salivary glands of infected mosquitoes [32, 16, 4, 7].

Some authors have also reported that multiple infections in mosquitoes are of no apparent advantage to parasite transmission [44, 4], consequently, the simultaneous transmission of *Wuchereria bancrofti* and *Plasmodium falciparum* is considered rare as has been documented in Tanzania [45].

A similar observation has been made along the Kenyan coast where less *Anopheles gambiae* (0.06% and 0.4%) were reported to be co-infected by the infective stages of *Wuchereria bancrofti* and *Plasmodium falciparum* [46, 47].

The generalisation by [48] that "although, potential vectors may be plentiful, the actual number of simultaneous infections in humans appear lower than expectations" apply to the findings in the present study. In spite of the high number of mosquito vectors dissected for infection rate of *Wuchereria bancrofti* in the study area, there was not a single record of co-infection of the two parasites in the present investigation.

There are other records on microfilarial infection rates from works done in Nigeria [49] that reported an experimental filarial infection rate of up to 74.6% in laboratory reared *Culex quinquefasciatus* in the Jos area (middle belt region) [50] reported an overall microfilarial infection rate of 5.5%, also in the Jos area; [34] similarly reported a total microfilarial infection rate of 2.26% in Makurdi. Explanations for the discrepancies compared to the 10.14% microfilarial infection rate obtained in the present study cannot be exactly ascertained. However, the explanations may be similar to those provided by [51] as: vector sample size, changes in environmental conditions and vulnerability of the human hosts in the respective areas.

None of those records are in agreement with the results of the present investigation, although the infection rate of *Wuchereria bancrofti* reported in the present study is similar to the findings of [52], who reported microfilarial infection rates of 9.2% and 11.1% in *Anopheles gambiae* s. s. and *Anopheles arabiensis* respectively in Central Nigeria. However, they did not identify *Culex quinquefasciatus* as a vector in their study area. With regard to infectivity rates, there have not been any documented records on comparison between vector infectivity rates in the wet and dry seasons in Makurdi except for the present study. The microfilarial infectivity rates obtained in the present study were at variance with those reported by [33] in a similar study on seasonal changes of infectivity rates of bancroftian filariasis vectors in coast province, Kenya. It is likely that these variations are due to differences in rainfall amount and human population density as well as availability of suitable breeding sites in the study localities.

The results of this study have shown that the microfilarial infection and infectivity rates were low during the wet season and high during the dry season in the study area. This implies that the potential risk of transmission of *Wuchereria bancrofti* larvae is more pronounced in the dry season in the Makurdi area. This is at variance with, and opposite to the findings of [33]. The present observation at Makurdi is also contrary to that by [53] who pointed out three discrete periods of *Wuchereria bancrofti* transmission in West Africa to be firstly from May to July (early wet season), secondly from August to September (end of wet season) and thirdly from October to November (early dry season) as periods of low, intense and moderate transmissions respectively. The sharp contrast between the result of the present study as compared to those of [53] and [33] may be attributed to factors such as those that control the movement of microfilariae. For instance according to [32], the microfilariae prefer warm, moist skin in warm weather to be able to leave the mosquito's salivary glands and penetrate the host; cold makes them inert and dryness destroys them. The higher occurence of L_3 (infective larvae) in the mosquitoes in this study may therefore, be one explanation for their inability to leave the salivary glands during the dry season.

According to [4], high ambient humidity and skin moisture favour successful transmission of lymphatic filarial microfilariae, since the vector's salivary glands play no role in the transmission process, unlike malaria. This may also be one reason why more mosquitoes were carrying microfilariae during the dry season than the wet season; biting activity and transmission were reduced during the dry season, making the vectors to harbour more microfilariae in their salivary glands than during the wet season in the study area.

Chandler AC *et al.* [32] reported that optimum conditions for microfilarial growth are $\leq 80°F$ (26.9 ^{0}C) and 90% humidity. This implies that only a small percentage of the ingested microfilariae would have developed to L_3 infective larvae. The high temperature usually experienced in the Makurdi area (≤ 100 ^{0}F) may also have contributed in reducing the activity of the microfilariae during mosquito bites, thus leaving them lodged in the salivary glands of the vectors.

The overall microfilarial infection rate in the present study (10.14%) was lower as compared to other records elsewhere. One reason for this comparatively low microfilarial infection rate may be the initial control effort of December, 2004 and March, 2005 by the Global Programme to Eliminate Lymphatic Filariasis (GPEWLF) in Benue State where mass chemotherapy using invermectin and Albendazole was done as part of efforts to eliminate the disease [35]. This may also be the reason why [35] working on the mapping of lymphatic filariasis in Benue State, Nigeria, did not record a single infection out of the 100 individuals (human) examined for the disease. Another follow-up explanation for the low microfilarial infection rate in the Makurdi area may be derived from [32] who have reported that in order for an infective human host to infect mosquitoes, there must be about 15 or more microfilariae per drop of blood (20cu.mm), and that a high concentration of 100 or more microfilariae per drop of blood is fatal to the mosquitoes. This implies that though, the human host might be a reservoir, the mosquitoes would not get infected if the recommended dosage is not met by the host.

5. Conclusion
Microfilarial infection and infectivity rates were significantly higher in *Culex quinquefasciatus* than in *Anopheles* species.

Wuchereria bancrofti was the only filarial parasite encountered during the study, while *Culex quinquefasciatus* was found to be the dominant vector of lymphatic filariasis in the study area.

The results obtained in the present study have shown that the microfilarial infection and infectivity rates were lower during the wet season and higher during the dry season in the study area. This implies that the potential risk of transmission of *Wuchereria bancrofti* larvae was more in the dry season. Hence, dry season breeding sites and adult populations of these vectors in the study area should be controlled.

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