

## EPIDEMIOLOGY OF TREE-HOLE BREEDING MOSQUITOES IN THE TROPICAL RAINFOREST OF IMO STATE, SOUTH-EAST NIGERIA

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Anosike JC, Nwoke BEB, Okere AN, Oku EE, Asor JE, Emmy-Egbe IO, Adimike DA: Epidemiology of tree-hole breeding mosquitoes in the tropical rainforest of Imo State, south-east Nigeria. *Ann Agric Environ Med* 2007, **14**, 31-38.

**Abstract:** The study of tree-hole breeding mosquitoes was carried out in the tropical rainforest of Imo State Nigeria (two rural areas and two forest reserves in some parts of Orlu Senatorial Zone) between May – October 2002. Using standard entomological procedures, two macrohabitats (natural tree-holes and bamboo traps) and two microhabitats (leaf axils of cocoyams/pineapples and leaf axils of plantain/banana) were sampled for various mosquito species. Mosquitoes were recovered from all the various biotypes sampled. Types of mosquitoes species encountered, their relative abundance, as well as genera varied significantly during the study ( $p < 0.05$ ). Four genera of mosquitoes: *Aedes*, *Culex*, *Anopheles* and *Toxorhynchites* were recovered while 16 species of mosquitoes encountered include: *Aedes aegypti*, *Ae. africanus*, *Ae. simpsoni*, *Ae. albopictus*, *Ae. stokesi*, *Ae. taylori*, *Ae. apicoargenteus*, *Culex quinquefasciatus*, *Cx. nebulosus*, *Cx. trigrupes*, *Cx. decens*, *Anopheles gambiae*, *An. funiestus*, *An. coustani* and *Toxorhynchites viridibasis*. Most of the mosquitoes showed oviposition preferences for one or more habitats. The presence of *Ae. africanus*, *Ae. simpsoni* and *Ae. aegypti* indicate that the study areas were at risk of yellow fever epidemic. The presence of *Anopheles* and *Culex* species ensured endemicity of malaria and filariasis, while the recovery of *Ae. albopictus* in this region suggests a possible outbreak of dengue fever in future if not properly controlled.

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**Key words:** ecology, epidemiology, tree-hole, mosquitoes, tropical rainforest, yellow fever, disease vector, Imo State, Nigeria.

### INTRODUCTION

Mosquitoes inhabit various habitats of the environment in both the polar/temperate and tropical regions. With the exception of the early works of Dunn [6], and Philip [28], and the brief surveys of studies by Service [30], little is known of the ecology of the mosquitoes that breed in tree-holes in Nigeria or elsewhere in the West African sub-region of Africa. Early researches recorded and attempted

to control the vectors or suspected vectors of yellow fever in these habitats, but paid little attention to the bionomics. During the past few decades, most of the research on mosquitoes has been concerned with malaria vectors, that in the Nigerian zoogeographical region do not breed in tree-holes, and consequently this fauna has been largely neglected. Although Bang [1] studied on the prevalence of potential vectors of yellow fever in the vicinity of Enugu, Nigeria and Brown and Bang [3] made their ecological

studies on the *Aedes simpsoni* in southeastern Nigeria, further studies are currently needed [21] to clarify the present status of the tree-hole breeding mosquitoes in this part of Nigeria.

Mosquitoes have been more thoroughly studied and better known taxonomically than any other insect order, with the possible exceptions of a few Lepidoptera. The disparity of knowledge between the Culicidae and other entomofauna is especially apparent in the tropics where mosquitoes are the primary vectors of human malaria parasite, filariasis, and many other arboviruses.

In their aquatic stages, different species of mosquitoes may occupy the same habitat and form part of a single guild. Among larvae which inhabit small containers, intra- and interspecific competition has been inferred and demonstrated, albeit primarily from laboratory studies [12, 16, 19]. Field investigations at the community level have been relatively neglected, in spite of recommendations suggesting their potential fruitfulness [2]. Tropical mosquitoes in which aquatic stages occupy water-filled tree-holes include some of the most important transmitters of arboviruses, such as yellow fever [17] and certain tree-hole mosquitoes such as *Aedes aegypti* have been the subjects of numerous and detailed investigations [4]. This study was undertaken to examine a tree-hole mosquito community because the tree-hole represents a small, discrete and patchy microhabitat where the limonitic fauna may be censured relatively completely. In this system, immigration can occur only by natality, migration by adult eclosion, and aquatic fauna which share the same trophic level may be competing for resources such as food and space.

Prior to this study, the number of species of tree-hole breeding mosquitoes in any part of the rainforest region of Nigeria has not been fully elucidated. One of the purposes of this study, therefore, was to properly identify types of mosquitoes that breed in the tree-holes and evaluate the status of these tree-hole breeding mosquitoes in the rainforest area of Orlu senatorial zone of Imo State, Nigeria.

Unless the feeding habits of these mosquitoes have been altered by the prevalence of a readily available human food source, circumstantial evidence indicated that additional tree-hole yellow fever vectors had become established in Orlu area. A second major objective of this study was to ascertain if the mosquitoes of the tree-holes and leaf axils of plants are those that can transmit the arboviruses of yellow fever. Ozurumba *et al.* [25] have documented the chronology of yellow fever outbreaks in pre-independent Nigeria. For instance, in Nigeria, the first recorded major epidemic involving Lagos, Abeokuta, Onitsha Forcados, Warri as well as Calabar occurred in 1913.

Between 1914-1924, there was a minor outbreak in Jebba, Kaduna, Lagos, Southern Provinces, River Benue villages, Benin, Warri and Forcados. Later, in 1925, another outbreak along the railway line from southern province to the north, occurred with *Aedes* species being incriminated as a potential vector. Between 1927 and 1928, an epidemic of yellow fever occurred at Ile-Ife with many cases and

deaths. There were no documented outbreaks of yellow fever in Nigeria from 1937-1944. However, 30 cases, mostly Europeans, were diagnosed by liver examination, mainly from the southern provinces [25].

In 1946, serological results revealed endemic yellow fever in Ogbomosho and *Aedes acgypti* was incriminated. From 1950-1953, there was an epidemic involving Onitsha province, Umulokpa, Iwollo and Ngwo areas [26].

Consequently, as a result of serology [1928-1966] confirmed endemicity of yellow fever in many parts of southern and central Nigeria [3, 7, 9, 25, 26]. The results of several yellow fever outbreaks in Nigeria indicate the breeding of different mosquito vectors. Their introduction does suggest that the mosquito fauna of Imo State especially in the Orlu area, is being altered. The third main objective of this study was to determine the status of these and any additional recent introduction in the tropical rainforest region of Imo State. Considering the fact that little is known about the ecology of tree-hole breeding mosquitoes in Nigeria, or of its host preference in general, the present study has become necessary.

## MATERIALS AND METHODS

**The study area.** This investigation on Tree-hole mosquitoes was carried out in four areas of Orlu Zone [Awo-Idemili Orsu L.G.A., forest reserve in Amazu-Ebenator also Orsu L.G.A., Forest reserve in Ubulu Oru West L.G.A. and Orlu area] between May – October 2002. During this period, the ecological distribution of various species of mosquitoes inhabiting water filled tree-holes and their allies in the area were sampled. Altogether, two major macrohabitats were examined, namely:

- i. Natural tree-holes and
- ii. Bamboo traps, while microhabitats such as leaf axils of cocoyams, pineapples as well as plantain/ bananas were also examined.

Orsu, Orlu and Oru West are among the 27 local Government Areas of Imo State Nigeria. Imo State is located in the south-eastern part of Nigeria. It lies approximately between latitudes 5°-6° North of the Equator and longitude 7° East of the Greenwich Meridian.

**Climate and vegetation.** Orsu, Orlu and Oru West Local Government Areas are in the tropical rainforest geoclimatic zone. The vegetation is typical of the southeastern rainforest, thick, deciduous/evergreen forest. The seasons in the study area are, well defined: namely dry season (from mid-October to March) and wet season (which spans through April to early October); this study, however, was made during the wet season. The total average rainfall of the wet season during the study was 196.6 mm. The rainforest cover of the area is the tree canopy.

**Criteria for selection.** In 1994, a yellow fever epidemic was reported in Awo-Idemili, the headquarters of Orsu

**Table 1.** Sample characteristics.

Locations	Number
Macrohabitat	
Eggs, larvae, pupae collected from tree holes (Natural tree-holes)	20
Bamboo cut sections (bamboo traps)	30
Microhabitat	
Axils of plantains/banana	20
Axils of pineapples/cocoyams	100
Total samples	170

**Table 2.** Monthly rainfall recorded during the study.

Month	mm
1. May	180.8
2. June	188.8
3. July	205.0
4. August	200.0
5. September	215.0
6. October	190.0
Total	1,179.6
Average monthly rainfall	196.6

local Government Area; there is therefore a need to investigate the types of mosquitoes in this area. Many lives were claimed by the said epidemic. The WHO came into action when notified through the LGA's primary Health department in Orsu, and the whole population at risk were vaccinated.

The reason for including Ubulu in Oru west local Government Area is because it is a community neighbouring Awo Idemili, and moreover, in Ubulu there is a thick rainforest which serves as a forest reserve. In that forest, there are monkeys. Again adjacent to Awo Idemili there is another community, Amazu-Ebenator, also in Orsu Local Government Area, where another forest reserve is inhabited by monkeys. It is also a taboo to touch the monkeys. In these two forests, the tree-holes were sampled.

**Table 3.** Monthly abundance of mosquitoes in natural treeholes encountered during the study.

Mosquito species	May	June	July	Aug.	Sept.	Oct.	Total	Percentage
<i>Aedes aegypti</i>	06	06	04	04	10	03	33	15.71
<i>Aedes africanus</i>	10	12	04	06	10	06	48	22.85
<i>Aedes simpsoni</i>	00	01	02	02	01	00	06	2.85
<i>Aedes albopictus</i>	02	00	01	00	02	00	05	2.38
<i>Aedes stokesi</i>	00	00	01	02	00	00	03	1.43
<i>Aedes taylori</i>	01	04	02	00	03	01	11	5.24
<i>Aedes luteocephalus</i>	04	08	03	03	06	03	30	14.28
<i>Aedes apicoargenteus</i>	00	00	04	00	00	00	04	1.90
<i>Culex quinquefasciatus</i>	04	02	01	03	08	10	28	13.33
<i>Culex nebulosus</i>	10	06	00	00	04	00	20	9.52
<i>Culex tigripes</i>	00	06	00	02	01	00	09	4.28
<i>Culex decens</i>	00	01	02	00	02	01	06	2.85
<i>Toxorhynchites viridibasis</i>	02	00	00	02	02	01	07	3.33
Total for the month	39	46	24	27	49	25	210	100

Furthermore, the study was extended to the Orlu Local Government Area, a neighbouring area to Orsu. This was in order to obtain enough samples from tree-holes. Even though the chosen areas lack sufficient natural tree-holes (macrohabitats), there are abundant microhabitats which include the leaf axils of cocoyams/pineapples, or plantains/banana. Bamboo traps were added to make up the natural tree-holes.

**Methods of collection.** Natural tree-hole collection: collected by the use of a large-bore glass pipette (0.5-1.0 cm) attached to a squeeze bulb rubber. Twine was used to tie the bamboo traps. Collection is by first untying and then emptying into the beaker.

**Identification of mosquitoes of microhabitats – Axils of plantains/banana, cocoyams/pineapples.** The mosquitoes were identified into genera and species according to the keys adopted by Edward [8] and Gillett [11].

The process for identification was as follows: each labelled Petri dish containing several collected mosquitoes were photographed in a magnified form and then identified. Again, the microscope is used for further identification with particular reference to the head, thorax wings and hind legs [32].

## RESULTS

Mosquitoes were recovered from all the various biotypes sampled. However, their relative abundance as well as the type of genera vis-à-vis the species varied. An average monthly rainfall of 196.6mm was observed (Tab. 2). Overall results are presented in Tables 3-7. Sixteen species of mosquitoes encountered include: *Aedes aegypti*, *Ae. africanus*, *Ae. simpsoni*, *Ae. stokesi*, *Ae. taylori-furcifer*, *Ae. luteocephalus*, *Ae. albopictus*, *Ae. apicoargenteus*, *Culex quinquefasciatus*, *Cx. nebulosus*, *Cx. tigripes*, *Cx. decens*, *Toxorhynchites viridibasis*, *Anopheles coustani*, *An. gambiae*, and *An. funestus*.

**Table 4.** Monthly relative abundance of mosquitoes in bamboo traps encountered during the study.

Mosquitoe species	May	June	July	Aug.	Sept.	Oct.	Total	Percentage
<i>Aedes aegypti</i>	06	12	10	06	12	06	52	24.65
<i>Aedes africanus</i>	04	06	10	08	08	04	40	18.96
<i>Aedes simpsoni</i>	00	06	06	03	05	10	30	14.22
<i>Aedes albopictus</i>	01	00	02	01	00	01	05	2.37
<i>Aedes stokesi</i>	00	00	00	02	01	00	03	1.42
<i>Aedes taylori</i>	04	06	02	06	02	01	21	9.95
<i>Aedes luteocephalus</i>	01	04	01	00	00	02	08	3.79
<i>Aedes apicoargenteus</i>	00	00	02	00	00	01	03	1.42
<i>Culex quinquefasciatus</i>	03	01	01	02	03	06	16	7.58
<i>Culex nebulosus</i>	10	02	00	00	01	04	17	8.06
<i>Culex tigripes</i>	00	01	02	01	00	02	06	2.84
<i>Culex decens</i>	00	01	02	00	00	01	04	1.90
<i>Toxorhynchites viridibasis</i>	01	00	00	01	02	02	06	2.85
Total for the month	30	39	38	30	34	40	211	100

**Table 5.** Monthly relative abundance of mosquito species encountered in the leaf axils of plantain/banana during the study.

Mosquitoe species	May	June	July	Aug.	Sept.	Oct.	Total	Percentage
<i>Anopheles coustani</i>	00	04	00	00	04	00	08	4.30
<i>Anopheles gambiae</i>	00	00	05	03	03	06	17	9.14
<i>Anopheles funestus</i>	00	02	00	03	00	01	06	3.23
<i>Aedes aegypti</i>	06	12	08	02	14	08	50	26.88
<i>Aedes simpsoni</i>	02	04	02	00	00	04	12	6.45
<i>Aedes africanus</i>	00	00	02	00	00	01	03	1.61
<i>Culex quinquefasciatus</i>	10	08	14	06	09	08	55	29.57
<i>Culex tigripes</i>	03	02	00	00	04	00	09	4.84
<i>Culex nebulosus</i>	00	02	00	01	01	04	08	4.30
<i>Culex decens</i>	01	00	02	02	00	00	05	2.69
<i>Toxorhynchites viridibasis</i>	01	00	00	02	02	08	13	6.99
Total for the month	23	34	33	19	37	40	186	100

**Table 6.** Monthly relative abundance of mosquito species encountered in the leaf axils of cocoyam/pineapples during the study.

Mosquitoe species	June	July	Aug.	Sept.	Oct.	Total	Percentage
<i>Anopheles coustani</i>	03	06	08	10	05	32	13.40
<i>Anopheles gambiae</i>	00	10	08	15	16	55	23.01
<i>Anopheles funestus</i>	03	04	01	04	01	13	5.44
<i>Aedes aegypti</i>	07	14	10	15	10	56	23.43
<i>Aedes simpsoni</i>	03	10	04	07	05	29	12.13
<i>Culex quinquefasciatus</i>	06	08	10	05	10	39	16.32
<i>Culex tigripes</i>	00	02	02	00	01	05	2.09
<i>Culex nebulosus</i>	00	00	01	00	01	02	0.84
<i>Culex decens</i>	00	01	02	00	01	04	1.67
<i>Toxorhynchites viridibasis</i>	00	02	00	00	02	04	1.67
Totals	23	34	33	19	37	40	100

**Table 7.** Monthly relative abundance of culex species encountered in the leaf axils of plantain/banana during the study.

Month	<i>An. coustani</i>		<i>An. gambiae</i>		<i>An. funestus</i>	
	n	%	n	%	n	%
June	03	8.8	6	10.9	03	23.1
July	08	23.5	10	18.2	04	30.8
August	08	23.5	08	14.5	01	7.7
September	10	29.4	15	27.3	04	30.8
October	05	14.7	16	29.9	01	7.7
Total	34	100	55	100	13	100

Three genera – *Aedes*, *Culex* and *Toxorhynchites* – were recorded in the natural tree-holes (macrohabitat). There were more *Aedes* than *Culex* with *Toxorhynchites* as the least.

13 species of mosquitoes were observed. Of epidemiological significance is the highest relative abundance of *Ae. africanus* (2.5%), followed by *Ae. aegypti* (15.71%) and *Ae. luteocephalus* (14.28%) (Tab. 3).

Observations on the monthly relative abundance of mosquitoes in the bamboo traps revealed the presence of 8 species of *Aedes*, 4 species of *Culex* as well as *Toxorhynchites* (Tab. 4). *Aedes aegypti* had the highest relative abundance (24.7%) followed by *Ae. africanus* (19.0%) and *Ae. simpsoni* (14.2%).

Also observation of the leaf axils of plantain/banana showed that 11 species of mosquitoes were encountered. *Culex quinquefasciatus* showed the highest relative abundance of 29.6% followed by *Aedes aegypti* (26.9%). The presence of these two mosquito species is worrying. The monthly abundance of mosquitoes species encountered in the leaf axils of plantain/banana is shown in Table 5. In another microhabitat – the leaf axils of cocoyams/pineapples, a total of 11 species of mosquitoes were recorded. The highest relative abundance is *Aedes aegypti* (23.43%) followed by *An. gambiae* (23.01%) and *Culex quinquefasciatus* (16.32%) (Tab. 6). Oviposition in leaf axils of cocoyams/pineapples is shown in Table 7. Altogether, a total of 16 species of mosquitoes were revealed in the macrohabitats and microhabitats, respectively. Different mosquito species showed oviposition preferences for one or more habitats. Also, most mosquito species co-exist both in macro- and microhabitats.

## DISCUSSION

Both the rural areas and forest reserves revealed the presence of several mosquito species inhabiting both macro- and microhabitats. Of the mosquitoes encountered, virtually all have been reported in different ecological environments in Nigeria.

As noted, many tree-holes did not hold water for any length of time [7]. Because of these difficulties, cut bamboo sections (bamboo pots) were introduced for the study

of the tree-hole mosquitoes adopting the methods of Dunn [6]. The natural tree-holes used herein were those of *Azadirachta indica*, *Mangifera indica* and *Gmelina* trees. The species of bamboos used were those of *Bambusa vulgaris* and were available in the rainforest during the wet season; they were therefore used with confidence in studying the ecology of the tree-hole breeding mosquitoes.

However, a few of the tree-holes became contaminated with dead leaves, and some other insects besides mosquitoes were found in them e.g. Chironomid larvae. Vertical and heavily shaded tree-holes provided a distinct habitat from the more exposed horizontal ones, and consequently it was better to regard bamboo cups, which were placed amongst the vegetation and shaded from direct sunlight, as comparable to vertical, rather than the horizontal tree-holes [17].

In this study, no horizontal tree-holes were encountered as they are comparably rare in Nigeria. Lowrie [16], who found six in villages and 21 away from villages, detected no substantial difference between the mosquito species breeding in these two habitats.

Preference for different macrohabitats, seasons, and microhabitat provide means by which these mosquito species collected from tree-hole, bamboo traps and axils of plants may be segregated in space and time during their oviposition. It is the oviposition behaviour of adults that is responsible for the spatial and, to some extent, temporal occurrence of larvae.

Food type, an additional dimension for segregating species, must be inferred from the limited literature, mainly on the functional morphology of larval mouthparts, and among members of tree-hole community can be applied only to gross trophic difference at the generic level [16, 34].

Tree hole inhabitants of the genus *Culex* are generally regarded as plankton feeders. *Aedes* larvae are capable of both browsing and filter feeding, and in the latter mode may overlap in diet with *Culex*. Larvae of the genus *Eretmopodites* have grasping mouthparts adapted for facultative predation and browsing [29]. All members of the genus *Toxorhynchites* are obligate predators. *Ae. africanus*, which is principally a forest/jungle species tops the collection and is gradually replaced by *Ae. luteocephalus*, mostly in the village areas. *Ae. africanus* make up 22.85% of collections from natural tree-holes which is in agreement with Corbet [5].

Again, *Ae. taylori*, recorded by Dunn [6], was also recorded in this study. *Aedes aegypti*, *Culex quinquefasciatus* and *Culex nebulosus* are also peridomestic breeders and are found in the tree-holes located in the villages and also where domestic containers provide additional habitats for larvae.

*Cx. nebulosus* was very common in the polluted water of village pot, and is undoubtedly part of the reasons why it is more abundant in the village than in the forest reserve. The breeding pattern of *Ae. aegypti* varies according to locality

[30]. In the Kaduna area of Nigeria, it was not common in domestic utensils, but Lowrie [16] found that it represented 25% of the larvae collected from village pots and elsewhere. Surtees [33] found it breeding in clay pots both inside and outside village huts, with the exceptions of *Ae. aegypti* and *Cx. quinquefasciatus* none of the mosquitoes found breeding in the tree-holes are regarded as anthropophilous in their biting habits. There was, therefore, no specific attraction in villages and the differences between the mosquito species found in the village and in the forest reserve were relatively minor.

Several other species which were recorded include *Ae. simpsoni*, *Ae. albopictus*, *Ae. stokesi*, *Ae. apicoargenteus*, *Cx. tigripes*, *Cx. decens* and *T. viriaibais*. They are recorded as minor species of the natural tree-holes. The monthly distribution shows that *Aedes (Stegomyia)* tops the collection. *Aedes aegypti* has the highest percentage. This is because of habitat preferences exhibited by most *S. tegomyia* species. As most of the bamboo traps were located in the open, *Ae. aegypti* tops the collection because it usually predominates in open habitats more closely associated with man [31].

Vertical separation of *Stegomyia* mosquitoes in African forests has been observed previously [5, 10, 31, 33]. Where some co-exist, some common in both open woodland and forest, whereas some are restricted to the closed-canopied rainforest. Most species of mosquitoes in tropical Africa are found breeding in the rainwater retained in the leaf axils of a variety of numerous wild and cultivated plants, as well as tree-holes [13, 15]. In addition to the macrohabitats [i.e. natural tree-holes and bamboo traps], the study was extended to the microhabitats of the plant leaf axils. The ovipositions in the axils of cocoyams of the species *Concorus soritorus* and pineapples, plantain and banana were studied. Cocoyam leaf axils proved to be the most favourable larval habitat in terms of the percentage positive for all larvae.

Again, cocoyams are extensively cultivated in Eastern Nigeria. The banana/plantain group was the next most favoured habitat; banana axils were less efficient in holding water than the plantain axils, which were often found dry even immediately after rain. It was noted [28] that those banana varieties in which the petioles are juxtaposed to form a sheath constitute the most efficient larval breeding sites. Pineapple and Dracana axils, besides being the most difficult to sample, had a moderate water – retaining capacity and were clearly less favourable as a habitat for mosquito breeding; nonetheless, most mosquito species appeared to prefer them to the artificial habitats such as bamboo traps.

Cocoyams were poor producers in May or June, since being an annual crop they are not planted until April or May. The percentage of larval collection is higher during September, a month in which there were more rainy days. It is likely that larval densities would increase as the cocoyam plants mature and axil size increases.

The relationship between some of these mosquito species and diseases are of epidemiological significance. The

involvement of *Ae. aegypti*; *Ae. africanus* and *Ae. simpsoni* in the sylvatic, rural and urban cycles of transmission of yellow fever in different parts of Africa is widely reported [20, 21, 25]. The existence of these species of *Aedes* in both rural areas and urban areas of the Orlu senatorial zone is worrying. The various local Government areas involved, as well as the Imo State Health Department, should launch a joint Health Campaign against these vectors in these areas before a suspected outbreak of the disease. It is interesting to note that a sylvatic yellow fever epidemic occurred in many rural communities in Nigeria as far back as 1913 when the first major epidemic involving Lagos, Abeokuta, Warri, Onitsha, and Calabar was recorded. In 1991, another outbreak was recorded in Delta State [21, 26, 27].

Subsequent to this, post-epidemic entomological investigations conducted in that area yielded eggs of a mosquito unknown in Nigeria: *Aedes albopictus*, a native of South-East Asia; where it is an established vector of dengue haemorrhagic fever. It is also a laboratory-proven potential vector of yellow fever, Rift Valley fever, and others [9]. The route of importation into Nigeria is unclear. However, it was plausibly through imported used tyres from Asian countries, as has been reported in the USA [31]. Ezike *et al.* [9] working on *Ae. albopictus* in Nigeria, noted a steady increase in its population in field collection. This observation is in agreement with the present study. The epidemiological impact of this mosquito is very unhealthy. The mosquito is a fast colonizer, catholic in its feeding habit and is capable of breeding in both domestic and forest environments. Today, it is the predominant mosquito collected in certain areas and habitats in Nigeria [Anosike, in preparation].

Observations made in Enugu metropolis [22, 27] and Awka metropolis [18] showed that *Ae. albopictus* was mostly encountered in addition to *Ae. aegypti* and *C. quinquefasciatus*. This conforms with the findings of the present study. Indeed, this is worrying considering the fact that *Ae. albopictus* is fast becoming common throughout most of Nigeria, and would most likely be primarily responsible for the transmission of a dengue fever outbreak.

The recovery of both *An. gambiae* and *An. funestus* in this study is of epidemiological importance. These are proven and established vectors of malaria and lymphatic filariasis in Nigeria. These mosquitoes vary in their vector potential from one microhabitat to another. Our results support the observations made in midwestern Nigeria [23] where bamboo stump mosquito cutters yielded more growth of *An. gambiae* species. *An. gambiae* is the major malaria vector in the rainforest areas and *An. funestus* the major malaria vector in the savannah areas of Nigeria, as earlier documented [30]. Although Igbinsa [14] observed that the *Anopheles* species lack preference for breeding in containers, evidence abounds that they breed in ground pools [24]. Originally, *Anopheles* breeds in clear [highly oxygenated] water with a suitable PH, temperature and nutrients composition, as predominantly found in the area.

Of late, mosquitoes are being recovered in different micro-ecological habitats contrary to their known ecological habitats, similar to the isolation of *Anopheles* even in tree-holes. The indication of this report is that there is a high vector breeding potential and transmission threshold of malaria. Indeed, the breeding potential of the sub-family Anophelinae species support the holoendemicity of malaria, particularly in rural communities where parasite rates of up to 100% have been reported [23, 29]. The emergence and re-emergence of mosquito vectors in unusual breeding sites could plausibly be due to variation in environmental modifications in these areas over the years. Consequently, vector control remains the most feasible management method for vector-borne diseases. In this regard, the control of malaria requires proper environmental planning and environmental audit [23].

### CONCLUSIONS

Some of the mosquitoes encountered are medically important as they are known vectors of lymphatic filariasis, malaria, yellow fever and dengue fever among others. These mosquitoes also breed in unusual habitats due to changes in environmental factors. In this part of the world, regular vector surveillance to detect warning signs posed by vector activities, as well as regular immunizations of non-immune human populations, have remained the reliable methods of abating yellow fever outbreaks. The presence of the two forest reserves in the study area inhabited by monkeys up to the time of this study serve as reservoirs for the yellow fever arboviruses. The people of the study areas are therefore at risk of being infected by yellow fever arbovirus which could be born at any time if not aborted. Again, the presence of *Ae. aegypti*, which is more abundant near living houses in all the sampled areas during the rainy season, is a sign that if, eventually, any infected person is around the areas during such a season, there would be a sporadic man-to-man transmission, as all the inhabitants of the study areas are exposed to mosquito bites. Furthermore, other mosquito-borne diseases such as malaria, dengue fever, filariasis, encephalitis, are likely to be recorded at higher rates during the rainy season when most tree holes and plant axils are water-filled and thereby supporting the growth of various mosquito species that transmit such diseases.

### RECOMMENDATIONS

The first step for environmental management and control is to avoid the planting or cultivating of cocoyams near living houses. Again, pineapple orchards and plantain/banana plantations should be isolated from living quarters. This is because the axils of these plants when filled with rainwater support the breeding of various mosquito species.

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