

## FOREST TYPES AND ARBOVIRUS VECTORS IN THE MAMU RIVER FOREST RESERVE OF SOUTHEASTERN NIGERIA

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**ABSTRACT.** In the forest reserves of southeastern Nigeria, the indigenous woodland is being progressively cleared and replaced by teak and gmelina plantations. The present study has investigated the risk of transmission of yellow fever in one such reserve by assessing the abundance of *Aedes* (*Stegomyia*) and other potential vector mosquitoes, using ovitraps and crepuscular human-bait collections. *Ae. africanus* was found abundant at ground level throughout the reserve and in the camp at its center. In the

cleared areas, the resulting slash and debris provided breeding places such as tree holes for high populations of *Ae. aegypti* and *Ae. africanus*. Since at the time of tree-planting the local population cultivate crops in these cleared areas for 2–3 years, this makes for a high degree of man-vector contact. On the other hand, once the plantations have grown they are very poor sources of these mosquitoes, and thus they may prove a means of environmental abatement of such disease vectors.

### INTRODUCTION

Following the epidemics of yellow fever (YF) on the Jos plateau in 1969 (Lee & Moore, 1972) and in the Okwoga district in 1970 (Monath, 1972), the role of forest monkeys in maintaining and amplifying YF virus in Nigeria has been elucidated by Monath et al. (1974), who found the incidence of YF neutralizing antibodies to be significantly higher in monkeys than in humans sampled from the same area. They postulated that wooded areas such as riverine forest could maintain the virus in an enzootic cycle of transmission among simians. Although monkey populations in many parts of Nigeria are too small and sporadic a reservoir of YF virus during inter-epidemic periods, *Ae. africanus* persisting in the dry season (Bang et al. 1979a) may also constitute a reservoir in the derived savanna forest zone of southeastern Nigeria lying between the

lowland rain forest and the southern guinea savanna. It is such ecotones that Germain et al. (1976) have detected of a zone of emergence of the yellow fever virus, where there is a greater frequency of man-vector contact by *Ae. africanus* not only outdoors but also indoors.

The Mamu River Forest Reserve of Anambra State is located in such an ecotone between the lowland rain forest and southern guinea savanna, being one of the 47 forest reserves in the four states of southeastern Nigeria, with 12 more planned for Anambra. In these reserves, the policy of the Federal and State Forest Services of Nigeria is the replacement of existing forests by monospecific plantations of fast growing trees. As implemented in the Mamu River reserve, the order of succession is the cutting and clearing of high forest, swamp forest, and parts of the savanna, resulting in a clear-fell area; this is followed by the planting of gmelina or teak seedlings. At this time, the local farmers and forestry workers are allowed to raise crops such as yam and cassava during the 2–3 years before the seedlings have grown too large. This practice, known as taungya farming, ensures a high degree of man-vector contact.

In view of the increasing need for such

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plantations to provide construction material and firewood, the present study was undertaken in the Mamu River reserve in 1976. The procedure was to compare the prevalence of mosquito species suspected of being yellow fever vectors in the original high forest, swamp forest and derived savanna with that in the clear-fell area and in two types of monospecific plantations. The objective was to evaluate the effect of these ecological changes on the risk of transmission of arbovirus infections, especially yellow fever. To this end, assessments of mosquito prevalence were also made in the forest camp in the centre of the reserve.

### DESCRIPTION OF AREA

Mamu River Forest Reserve, comprising an area of approximately 46 km<sup>2</sup> (6°20'N – 7°40'E) and located about 67 km west of Enugu, has a climatic pattern marked by a generally defined wet season (April to November) with 165–203 cm rainfall, and a dry season (December to March) with 25–50 cm of annual rainfall. It contained high forest, derived guinea savanna and broken swamp forest along with slashed areas left after clear-felling of the high forest. The reserve was instituted in 1930 by the then Federal Bureau of Forestry with the primary objective of clearing the remaining high forest and swamp forest in order to replace them by plantations of gmelina (*Gmelina arborea*) and teak (*Tectona grandis*). Now the reserve consists mainly of these plantations; there is also a forest camp in the center of the reserve. Along the perimeter of the reserve there are scattered villages among a mixture of oil-palm bush and southern guinea savanna. A north-south secondary road dissects the reserve, allowing access via numerous narrow tributary roads and paths to the primary parts of the forest.

The three types of forest and savanna, the clear-fell area and the two types of forest plantations, and in addition the forest camp, have the following characteristics as described in detail.

1. The high forest, which can be denoted as a disturbed secondary forest, is subject to the selection system of silviculture, since large trees gradually are removed by local timber contractors. The largest species (*Chlorophora excelsa*) and (*Brachystegia eurycoma*) attain canopy levels of 23 meters, affording considerable shade. A lower canopy consists of medium-sized trees 9–12 m such as *Chrysophyllum albidum*, Benin mahogany (*Khaya grandifoliola*) and oil palms (*Elais guineensis*). Vines or creepers such as *Landolphia owaeriensis* climb the tree trunks and contribute to both canopy levels. Mosquito breeding sites range from ground pools that are especially common during the wettest months, to tree holes occurring at both ground and canopy levels.

2. The broken swamp forest, which contains streams flowing continuously throughout the year, is flooded in the wet season. As in the high forest, two canopy levels can be distinguished, the upper level (22–25 meters) consisting mainly of *Uapaca staudtii* and *Pycnanthus angolensis*, and the lower level (9–12 meters) formed primarily by *Piptadeniastrum africanum* and *Musanga cecropioides*. Overall, *Mitragyna ciliata* was found to be the most common swamp species, while oil palms were frequent and contributed to both canopy levels. The swamp forest is surrounded by farms in which oil palm, yam and cassava are cultivated. As sources of mosquito larvae, most of the tree holes have developed from rotting branches in living trees. The majority of the tree holes examined appeared to have been indirectly caused by man either by cutting of branches for firewood or the felling of trees.

3. The clear-fell area, located along the southeast section of the reserve, is characterized mainly by widely scattered Benin mahogany and *Pterygota macrocarpa*. Fallen trees and stumps, the remnants of what originally was a high secondary forest, are sources of numerous tree holes and tree cavities. The forestry employees plant unshaded crops

of yams (*Dioscorea* sp.), coco-yam (*Colocasia esculentum*) and cassava (*Manihot utilissima*). Prior to the final clearing of these slash areas, and while planting of the plantation seedlings is in progress, the farming procedure known as taungya is continued at least two years before the plantation areas are abandoned as the planted trees increase in size.

4. The derived savanna in the reserve is fairly open and surrounded principally by a gmelina plantation. Coarse grass is present, waist-high during the wet season, with scattered clusters of gmelina 8–10 meters high. Remnants of *Daniellia oliveri* and *Lophira lanceolata* are present, occasionally encircled by dense stands of bush. Tree holes in this zone are often formed as a result of dead and decaying branches.

5. The teak forest, planted after the original forest has been cleared, often during taungya farming, has a spacing between trees ranging up to four meters. Within 6 years these seedlings have attained a continuous canopy at about 8 meters in height. Characteristic of this type of plantation is the heavy shade given by the broad leaves, and a dense layer of decaying leaves on the ground resulting in a high humidity. Catchments of rainwater in leaf cups are readily found, tree holes and cavities are common, and ground pools are present in the teak plantations.

6. The gmelina forest planted and spaced similarly has physical characteristics not unlike those of the teak forest. Plantations of this species have reached a height of 9–12 meters after 13 years of growth. Ground pools and leaf cups are common, while tree holes and cavities occur in about the same density as in the teak plantation.

7. The forest camp, situated near the center of the Mamu River Forest Reserve, is completely surrounded by a gmelina plantation. A secondary road, along which are two schools and an open market, dissects the camp and connects it with villages to the north and south. The human population within the camp continually fluctuates between 5000 and

7000 according to the seasonal employment. Housing consists of mud huts in compact lineal tracts, with numerous clay pots used for water storage indoors. The water is obtained from a stream flowing along the western edge of the camp. Along the sides of the tracts, cassava and coco-yam are cultivated, with scattered banana, plantain and pineapple.

## METHODS AND PROCEDURES

**OVIPOSITION ASSESSMENTS.** Twenty bamboo cups (weathered for at least 4 weeks and boiled) were placed in each of the 6 vegetation types at the base of 20 trees located 20 m apart. The cups were filled with water to the original water level each week. Larval surveys were conducted every 2 weeks, the larval identifications being recorded for each habitat. Frequencies of cups positive for different species, and the numbers of larvae in the cups, were assessed from March until November. In addition a CDC ovitrap (Fay and Eliason, 1966) was placed near each bamboo cup, amounting to 20 ovitraps in each of the six vegetation types. The paddles were set up bi-weekly and collected after a 2-day exposure, wrapped in paper and dried for 5 days. The egg-positive paddles were soaked in pre-sedimented water for 2 days to obtain a hatch of larvae and were submitted to 2 more cycles of 5-day drying and 2-day soaking.

In the forest camp 20 compounds were selected, and in each compound 1 ovitrap was placed inside one of the rooms (indoor) and 1 ovitrap was placed outside but within the compound (outdoor). In the camp area itself, 20 ovitraps were placed near 20 trees at ground level (camp). Along a lineal transect extending 800 meters from camp westwards into a gmelina plantation, 20 ovitraps were placed in a similar manner at each of 5 sites located at distances of 50, 100, 200, 400 and 800 meters from the edge of the forest camp. Thus for indoors, outdoors, camp area and the 5 gmelina sites, assessments of the proximity of oviposi-

tion to the forest camp inhabitants were based on a total of 160 ovitraps.

In each of the 6 vegetation types 20 tree holes were selected at ground level, having the capacity of holding water for at least 10 days. Larval surveys were conducted every 2 weeks from July until November when many of the holes became dry. Using a ladle and pipettes in an attempt to collect all the water in the tree hole, the larvae and debris were removed from it and placed in a vial, and then the holes were re-filled with water to their original level. Identifications were made from 4th-instar larvae, but in addition the pupae were reared to adults for final identification.

**ADULT ASSESSMENTS.** Human-bait collections for 4 hours centering on sunset were performed at approximately 2-week intervals at ground level between January and December, and at canopy levels between July and December, 1976. Ground level catches were made by three teams of two scouts per team, three sites (about 150 m apart) being used in each habitat. Canopy catches were carried out by one team of two scouts during the same time

period as the ground catches. The platforms had been constructed at the following canopy heights in meters: high forest (21), swamp (18.0), clear-fell area (8.7), savanna (11.5) teak (7.7 meters) and gmelina (8.9).

## RESULTS

Judging by oviposition frequency in bamboo cups and ovitraps *Ae. aegypti* was by far the most abundant vector species in the clear-fell forest, the derived savanna and the forest camp. Many non-vector species were also found, but are not tabulated; these include *Ae. apicoargenteus* which was abundant at all sites, and *Culex albiventris* and *Cx. nebulosus* which were predominant in collections from bamboo cups and tree holes in the high forest, swamp forest and the two plantation types. The prevalence of *Ae. aegypti* oviposition was considerably lower in the swamp forest, the high forest, and the 2 plantation types. (Table 1).

Of the other arbovirus vectors, *Ae. luteocephalus* was not found in tree holes; in bamboo cups and ovitraps it was very

Table 1. Percent positive bamboo cups, CDC ovitraps and tree holes for arbovirus vectors in six vegetation types (and the forest camp).

	Bamboo Cups <sup>1</sup>						
	Camp	High	Swamp	Clear-fell	Savanna	Gmelina	Teak
<i>Aedes aegypti</i>	38.3	0.6	3.3	29.4	30.3	0.3	0.8
<i>Ae. luteocephalus</i>	3.1	0.1	2.2	1.1	2.2	0.0	0.3
<i>Ae. africanus</i>	5.0	0.0	5.8	0.6	2.2	0.0	0.6
<i>E. chrysogaster</i> <sup>3</sup>	9.5	11.7	5.8	0.0	12.5	1.5	3.9
				CDC Ovitrap <sup>1</sup>			
<i>Aedes aegypti</i>	33.8	9.2	5.3	23.8	19.5	7.8	8.6
<i>Ae. luteocephalus</i>	3.1	0.3	0.6	0.0	0.8	0.0	0.3
<i>Ae. africanus</i>	2.5	0.6	2.2	2.3	0.3	0.3	2.2
<i>E. chrysogaster</i> <sup>3</sup>	3.4	5.6	5.8	5.8	3.6	5.3	10.3
				Tree Holes <sup>2</sup>			
<i>Aedes aegypti</i>	—	0.0	0.8	18.0	6.0	0.5	0.0
<i>Ae. luteocephalus</i>	—	0.0	0.0	0.0	0.0	0.0	0.0
<i>Ae. africanus</i>	—	0.8	10.7	0.8	13.0	0.8	2.5
<i>Ae. vittatus</i>	—	0.0	0.0	7.5	0.0	0.0	0.0
<i>E. chrysogaster</i> <sup>3</sup>	—	0.0	2.9	0.8	1.5	0.0	0.0

<sup>1</sup> Sampled from March to November, 1976.

<sup>2</sup> Sampled from July to November, 1976.

<sup>3</sup> *Eretmapodites*, group *chrysogaster*.

Table 2. Average biting densities of the six most common mosquito species taken in crepuscular human-bait collections in six vegetation types (and the forest camp): number per 10 man-evenings, March to November.

Species	Camp	Gmelina	Teak	Savanna	Clear-fell	High Forest	Swamp
<i>Aedes aegypti</i>	4.2	2.1	2.9	6.0	56.4	9.0	1.2
<i>Ae. luteocephalus</i>	4.7	0.1	0.0	0.3	0.9	0.4	0.5
<i>Ae. africanus</i> (ground)	18.9	4.3	3.5	12.3	19.2	6.5	25.3
(canopy)	—	(9.1)	(7.3)	(5.0)	(27.1)	(23.2)	(92.1)
<i>Ae. circumalutentis</i>	0.1	0.5	0.6	0.3	1.7	0.7	0.2
<i>Ae. vittatus</i>	0.0	0.0	0.1	0.1	6.0	0.4	0.0
<i>Mansonia africana</i>	1.3	3.2	1.9	3.8	3.0	1.5	1.1
Total for 6 species (ground)	29.2	10.2	8.9	22.8	87.2	18.5	28.3

rare in the 2 plantation types, in contrast to its regular appearance in the 3 man-modified vegetation types and the swamp forest. *Ae. africanus*, which preferred tree holes to the artificial oviposition traps, was prevalent in the swamp forest and savanna vegetation types, where it outnumbered the other vector species; its oviposition was rare in gmelina plantations but not infrequent in teak plantations. Whereas *Ae. vittatus* was collected only from tree holes in the clear-fell types, *Eretmapodites* of the group *chrysogaster* were collected from bamboo cups and ovitraps at all sites except the camp.

The biting densities encountered in the crepuscular hours during the wet season (Table 2) reveal that the most generally prevalent species was *Ae. africanus*. It was the only one to be taken on the canopy platforms, except for the occasional *Ae. aegypti* and *Ae. luteocephalus* (average less than 1 per 10 man-evenings) encountered on the comparatively low platform in the clear-fell area. In the swamp forest and the derived savanna, the numbers of *Ae. africanus* greatly exceeded the total of the other 5 species. It comprised more of the captures on human bait than any other single species in the camp area and in all the forest types except the clear-fell.

Total mosquito densities of the six species taken together were considerably lower in the gmelina and teak plantations than in any of the other vegetation types; This also holds good for *Ae. africanus* considered alone. *Ae. luteocephalus* was almost completely absent from the plantations, but was quite abundant in the camp area. In the high forest where the ovitrap index had shown it to be abundant, *Ae. aegypti* exceeded *Ae. africanus* at ground level, the main activity of the latter species being in the canopy.

In the clear-fell area, where the greatest variety of mosquito species was encountered (namely 20), the total for the 6 commonest species was by far the highest. This vegetation type was the only one in which the vector *Ae. vittatus* was taken in appreciable numbers. Moreover, *Ae.*

*aegypti* was so prevalent here that its average biting density was 3 times that of *Ae. africanus*. The relative abundance of these two principal species in the six vegetation types (Fig. 1) demonstrates the extent to which they exceed *Mansonia africana*, which was consistently present at all the sites. This figure also illustrates graphically how the lowest densities occurred in the gmelina and teak plantations.

**IN AND NEAR THE FOREST CAMP.** The results obtained with CDC ovitraps exposed in bedrooms, compounds, the camp area, and the transect into the gmelina plantation, are shown graphically (Fig. 2) for the three principal vector species. *Ae. aegypti* was the most active within the camp including the indoor rooms, and a marked decrease was apparent within the gmelina

plantation. *Ae. africanus* was most frequent in that part of the plantation which was within 50–100 m of the edge of camp. The numbers of *Ae. luteocephalus* were low at all sampling sites.

When the biting densities at the sites in the camp and gmelina transect are plotted for 5 abundant vector species (Fig. 3), it is seen that *Ae. africanus* was the most abundant species on human bait, indicating that the CDC ovitraps had favored *Ae. aegypti*. At all 4 sites in the gmelina plantation at distances between 50 and 800 meters from camp, *Ae. africanus* adults were taken on man at rates exceeding 5 per 10-man evenings (biting density 0.5 per man evening). In the camp area it reached its highest biting density (2 per man-evening). It was also

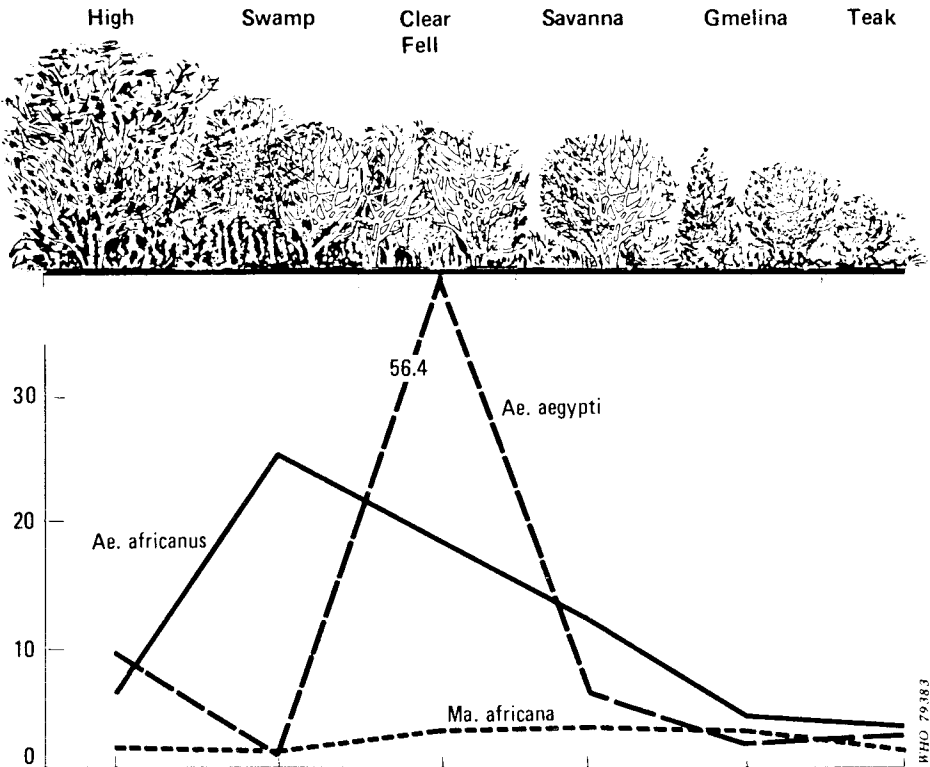


Fig. 1. Average biting densities of three vector species in six vegetation types: numbers per 10 man-evenings, March to November, 1976.

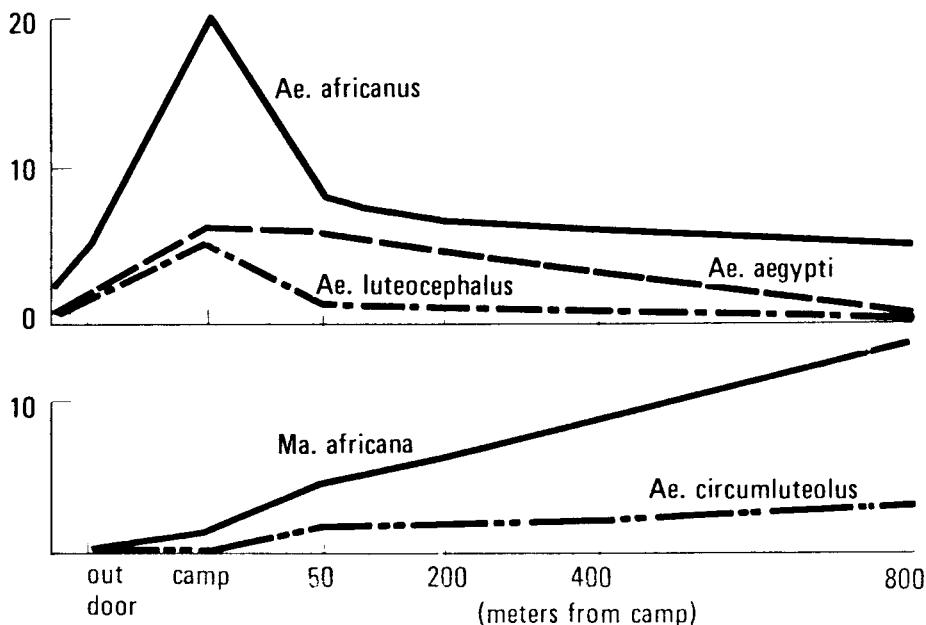


Fig. 3. Average biting densities of 5 vector species in the forest camp and the gmelina transect: numbers per 10 man-evenings, May to December.

breeding habitats (tree holes and cavities) created by the stumps and remnants of the felled and fallen trees. Moreover, these tree holes were much more frequently infested than those in the original forest, resulting in a greatly increased adult density of this species. *Ae. aegypti* is known to be bimodal in its biting activity in southeastern Nigeria (Bang et al. 1979b), the morning peak of activity being between 6 and 8 a.m., when the labourers would be engaged in taungya cultivation in the clear-fell areas. The evening peak would be important for virus transmission in the forest and the villages near the periphery of the reserve. Larval surveys of domestic water containers in the forest camp showed that a high percentage (35%) had become positive for *Ae. aegypti* near the end of the wet season, resulting in high adult densities in camp.

Preliminary serological studies performed on 92 forestry workers from the camp found a significant percentage

(55%) to have been positive for group B antibodies (unpublished data). Only 18 of the sera were negative to the 7 complement-fixation (CF) antigens used in the tests. This high percentage of positive sera could indicate that group-B virus activity had recently occurred among the camp population. Early virus isolation attempts from mosquito pools collected from the 6 vegetation types plus the camp have yielded 12 group-B viruses from mosquitoes caught between May and September 1976, 9 of which were from *Ae. africanus* caught in the swamp forest, and 3 (all Dengue 1) were from *Ae. aegypti* in the clear-fell area.

It was in the swamp forest that *Ae. africanus* was most prevalent during both the wet and the dry season, the average biting density being 2.5 per man-serving; it was also prevalent in the clear-fell area and forest camp (average 2 per man-evening). This species was found to breed most commonly in tree holes in the broken swamp forest, and in the savanna

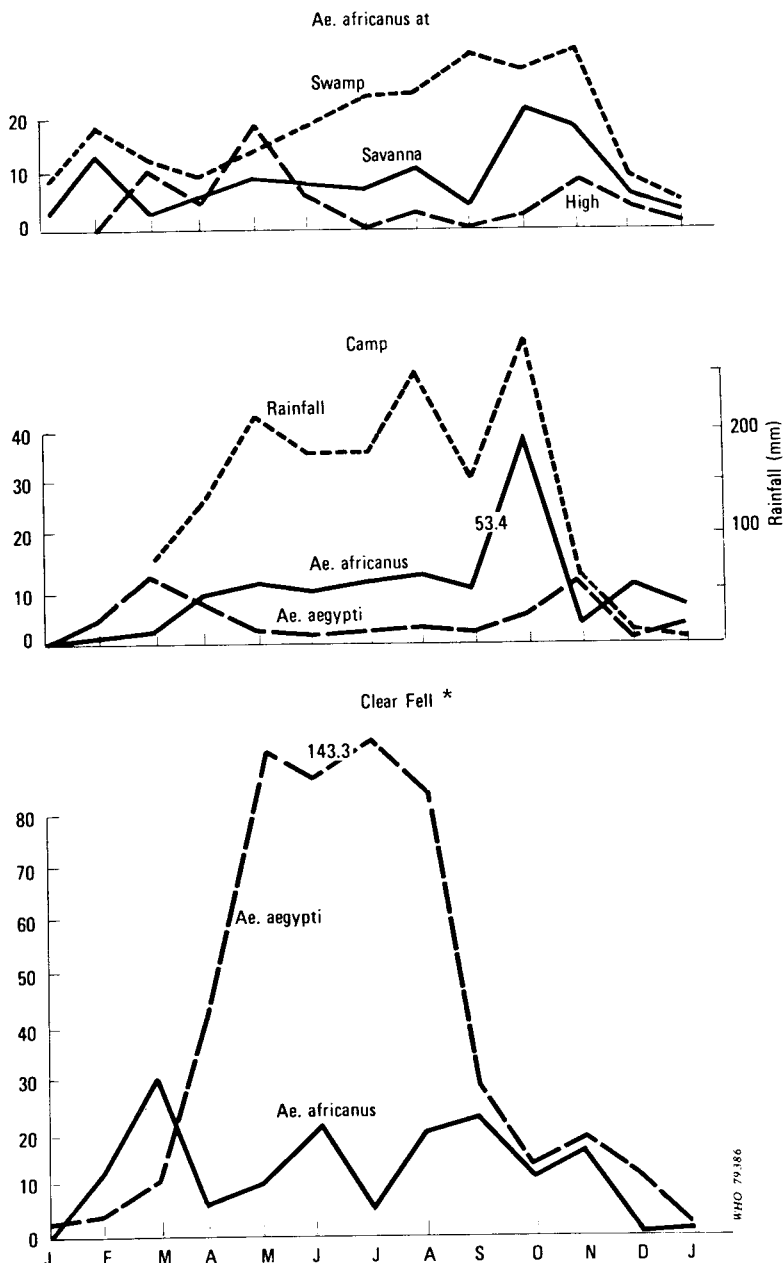


Fig. 4. Seasonal changes in biting density of *Ae. africanus* and *Ae. aegypti* in four vegetation types and the forest camp: number per 10 man-evenings.

\*In the Clear Fell graph, the height of the July value (143.3 per 10 man evenings is shown lower than the true one in order to save space.

WHO 79.186



area. It is observed ovipositional preference for tree holes is in agreement with the findings of Dunn (1927) near Lagos and those of Bang et al. (1980) in the Udi Hills near Enugu. *Ae. africanus* was seldom found in the larval surveys of domestic water containers and leaf axils in the forest camp. Moreover, oviposition by this species was infrequent in the ovitraps exposed in bedrooms, compounds, and the camp area, being largely confined to the ovitrap sites in the gmelina plantations, within 50 and 100 m of the edge of the camp area (see Fig. 2).

With regard to its biting habits, Lumsden (1951) found it to be essentially a tree-canopy species in Uganda, but in the Udi Hills in southeastern Nigeria Bang et al., (1980) obtained high biting rates in compounds and inside houses, and in the forest camp at Mamu River we found it to enter settlements and dwellings for blood meals. It is possible that after taking a blood meal *Ae. africanus* returns to the forest areas several kilometers away, where tree holes and cavities are available for oviposition. Germain et al., (1972), in mark-release recapture experiments in western Cameroon, found that *Ae. africanus* females were able to cover distances of about 3 km in 4–8 days. It is evident that *Ae. africanus* along with *Ae. aegypti* are the most likely to act as vectors for yellow fever virus within settlements such as the forest camp, and in the clear-fell areas where there is a considerable chance of human contact.

*Ma. africana* was present in all the vegetation types and the camp in the Mamu River reserve, but in low biting density. This contrasts with its predominance in human-bait collections from the Niger delta (Boorman and Service 1960) and the Nupeko forest of the upper middle Niger river (Lee et al. 1974). *Ae. circumluteolus* also occurred in small numbers at all sites at Mamu River, characteristically during the dry months and especially in the clear-fell area. At least 12 different arboviruses have been isolated from *Ae. circumluteolus*, but not those of dengue or yellow fever (McIntosh 1970, Berge

1975). Nevertheless, it is potentially important because of its association during the dry months with clearings that may be frequented by man. Although *Ae. vittatus* is principally a rock-hole breeder, it is of interest because it reached a significant biting density in the clear-fell area, where it was breeding in tree holes. This species was suspected of being a vector of yellow fever from monkeys to man in the epidemic along the border of Sudan and Ethiopia in 1959 (Satti and Haseeb, 1966). Therefore *Ae. vittatus*, along with *Ae. circumluteolus* and *Ma. africana*, must be taken into account as relatively unimportant but potential vectors.

It is evident that plantation programmes such as that in the Mamu River Forest Reserve result in the creation of additional habitats for *Aedes* (*Stegomyia*) vectors, because of the clearing and slashing of the forest that precedes planting. The practice of taungya farming which accompanies the planting increases the man-vector contact in such clear-fell areas. This situation may persist for 5 years or so, but after 10–15 years the growth of the gmelina or teak plantation has resulted in a poor habitat for *Aedes* less productive of these mosquitoes than the original forest, although it remains to be seen whether this desirable outcome holds good until the plantation matures. Meanwhile, consideration should be given to the further investigation and utilization of this habitat as a means of environmental abatement, possibly in the form of plantation belts near areas of continued enzootic cycles of arbovirus transmission.

There remains the question of the maintenance of YF virus during the dry season, and particularly where the densities of simian reservoirs are low. In Uganda, *Ae. africanus* is known to survive throughout the dry season in the adult stage (Haddow and Mahaffy 1949). From our dry-season catches at Mamu River, and from biting-density surveys at many points in eastern Nigeria (Bang et al. 1979a), there is good evidence that *Ae. africanus* is able to survive dry periods, at

least between sporadic interim falls of rain. Germain et al. (1976), from their studies of *Ae. africanus* in the Central African Empire, describe a zone of emergence of YF transmission existing within derived savanna habitats (ecotones) where there is a high vector-man contact. In view of the results of this study in the Mamu River reserve, along with studies in the Udi Hills (Bang et al. 1980), there is evidence for the existence of an enzootic cycle of YF virus transmission among the numerous forest reserves of Nigeria. With the ever-increasing expansion in the numbers and size of the reserves, combined with the practice of taungya farming in the new plantations, these areas could act as sources for the emergence of yellow fever. The enhanced contact between man and vector, and the survival of *Ae. africanus* during the dry season, permit the conclusion that this zone is vital in the epidemiology of mosquito-borne diseases in Nigeria.

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