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Survey of the relative prevalence of potential yellow fever vectors in north-west Nigeria

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The yellow fever epidemic in Nigeria in 1969–70 emphasized the lack of data concerning the possible importance of Aedes aegypti *and other* Stegomyia *mosquitos as vectors. An entomological survey was therefore undertaken in September 1973 in 6 areas in the north-west of Nigeria to determine the prevalence of* Stegomyia *populations in the villages. An examination of over 6 700 water pots showed that 11–53% contained* A. aegypti *larvae, and in some areas larvae of* A. vittatus *were found in up to 18% of pots. In villages in the relatively dry Sudan savanna neither leaf axils nor tree-holes were important* Stegomyia *larval habitats, but in the more southern Kontagora area of the wetter northern Guinea savanna, these habitats were probably important breeding sites. In the early evening the most abundant man-biting mosquito in the villages was* A. aegypti. A. vittatus *was also caught at bait in some villages. It was concluded that the only potential yellow fever vectors in the area were* A. aegypti *and* A. vittatus. *There were large populations of* A. aegypti, *closely associated with man, in all the areas surveyed, but they should not present a risk of yellow fever transmission unless the disease were to be introduced into the area by man, or unless virus reservoirs, such as monkeys, were also present. Although monkeys were common in the Kontagora area they were rare in the Sudan savanna.*

The 17 years of quiescence that followed the 1951–52 yellow fever outbreaks in Nigeria (12) were broken in late 1969 by a widespread rural epidemic on the Jos Plateau (5). The following year a more limited epidemic occurred on the Okwoga district of the Benue Plateau area, some 340 km south of the 1969 Jos epidemic area (15, 26). Lee & Moore (10) reported very low *A. aegypti* larval indices from the area of the Jos epidemic and considered it doubtful whether this species had been the vector responsible for the outbreak. On the basis of a single virus isolation from a pool of 6 fragments of *Aedes (Stegomyia)* spp. that were not from *A. aegypti* L. or *A. vittatus* (Bigot) but were thought probably to be from *A. luteocephalus* Newstead, it was considered that the last named was the most likely vector (10). Surprisingly, *A. aegypti* was not found in the Okwoga district immediately after the 1970 outbreak, and was consequently discounted as a vector (26). In contrast to these findings, Hayes et al.[a] found that *A. aegypti* was not uncommon in village pots in the Enugu area; in the Garki area, which is some 80 km east of Kano, very high larval indices were recorded in the dry season of 1970–71.[b] Moreover, in French-speaking West Africa high larval indices have been reported for several areas, especially in the north (8, 19).

Despite these and a few other surveys, there is very little information on the distribution of *A. aegypti* in Nigeria. A check list of known localities published in 1963 shows that the species was not recorded over large areas of Nigeria (21); there is even less information on its abundance. Because of this paucity of information on the distribution and prevalence of *A. aegypti* in Nigeria, and the disturbingly high larval indices recorded in the Sudan savanna,[b] an *A. aegypti* survey was undertaken during September 1973 in the north-west of Nigeria in the Kano, Katsina, Gusau, Birnin-Kebbi, Sokoto, and Kontagora areas.

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[a] Hayes, R. O. et al. (1973). Geneva, World Health Organization, mimeographed document No. WHO/VBC/73.457.

[b] Shidrawi, G. R. et al. (1973). Geneva, World Health Organization, mimeographed document No. WHO/VBC/73.420.

DESCRIPTION OF THE AREAS

In all the villages surveyed, most dwellings were round or rectangular, thatched-roofed mud huts, whose size and structure varied in different areas. Only huts for sleeping were used in the calculation of the various hut indices of *A. aegypti*. The Kano, Katsina, Gusau, Sokoto, and Birnin-Kebbi areas are in the Sudan savanna of Nigeria, but whereas Kano, Gusau, and Birnin-Kebbi are within a zone where the annual rainfall is 750–1 000 mm, Katsina and Sokoto, areas farther north, are in a zone where the rainfall is 500–750 mm (Fig. 1). Kontagora was the most southerly area surveyed and is situated in the wetter northern Guinea savanna with an annual rainfall of 1 000–1 250 mm.

Water for drinking and cooking was drawn from wells or streams and stored in earthenware jars kept outside, and sometimes also inside, the village huts. In all the villages visited in the Kano and Katsina areas, water was collected from wells, which in the very dry Katsina area were up to 140 m deep. In the Kontagora area, water was collected from wells in all the villages surveyed, but because the water table was nearer the surface the wells were only about 8–12 m deep. People in both of the villages surveyed in the Gusau area fetched their water throughout the year from nearby streams. In villages in the Sokoto area, water was collected from either wells or streams.

The custom of storing water in pots kept inside the huts varied considerably between the areas. For example, very few huts in the Sokoto, Birnin-Kebbi, and Katsina areas had water pots, whereas in the Kontagora area almost every hut had one large water pot, and occasionally more. The number of pots associated with each hut varied between areas, villages, and also between compounds in the same village. There were significantly ($P < 0.001$) fewer water storage pots per hut (2.2) in the Kontagora area than in the drier northern areas, especially in Katsina (9.3) and Sokoto (8.4). The only other containers with water in the villages at the time of the survey were 16 tin cans, 15 metal drums (0.18 m^3 capacity), 3 motor tires, and 5 assorted utensils. During September, which was when the survey was undertaken near the end of the rainy season, the mean number of pots per hut that contained water was 2.3–2.9, except in the Kontagora area where it was only 1.3.

Water pots with a narrow neck and a 6 cm diameter opening were very common in all the villages except those in the Gusau and Kontagora

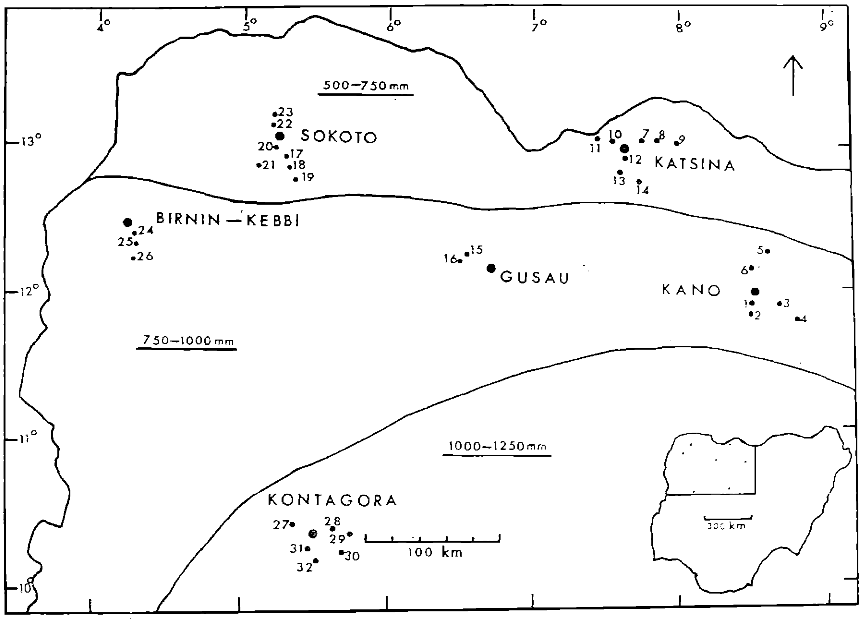

Fig. 1. North-west Nigeria showing the localities surveyed (No. 1–32), rainfall zones, and inset map of Nigeria.

areas, and they were used to transport water from the wells or streams to the huts. The water was usually completely emptied from most, but not all, of these pots every 1–3 days; only rarely was all the water emptied from the wide mouthed pots, which were refilled with water when nearly empty.

METHODS

The survey was restricted to several villages within a radius of about 45 km of the towns of Kano, Katsina, Gusau, Sokoto, Birnin-Kebbi, and Kontagora. In each village covered by the survey, from 14 to 67 huts in several compounds were inspected and the number of water pots kept in and outside each hut, and the number of pots and other containers with water in which mosquitos could breed were recorded. A single larva was taken from each pot containing mosquitos and placed in a small tube; then up to 20 more larvae were taken from the same pot and placed in a separate tube. From each village, therefore, one tube contained larvae taken by the single-larva method from pots outside the huts and another tube contained larvae from pots inside; in addition, there were many tubes containing up to 20 larvae collected from each positive pot. This procedure enabled the single larva collecting method proposed by Sheppard et al. (23) to be compared with the more conventional method of taking larger samples from each pot. The pots were also examined for potential predators, and a number of larvae were examined for pathogens.

The presence in the villages of other potential habitats of *A. aegypti* larvae, such as rock pools, tree-holes, and plant axils was noted, but there was insufficient time to adequately sample them.

In addition to larval collections, a few bait catches were made by 1–3 men from 18 h 00–20 h 00 in a few villages and at the edge of some of the main towns. These catches provided additional information on the *Stegomyia* species associated with man and enabled the morphological forms of *A. aegypti* to be determined (McClelland [a]; 13).

RESULTS

A. aegypti *larval indices*

The pot indices, calculated by both the conventional survey and the single-larva methods, and the hut and Breteau (2) indices are tabulated in Table 1. In addition, a " density index " (25; Brown [a]) on a scale of 1–9, which can be calculated independently from all three larval indices, is given. Density indices above 5 are considered to show a high risk of yellow fever transmission in the locality (25).

The prevalence of *A. aegypti* varied considerably between different villages within the same area. Although villages in the Sokoto area usually had a smaller incidence of *A. aegypti* than villages in other areas, none of the areas was markedly different from the others. There was generally good agreement between the density indices calculated from the hut, pot, and Breteau indices, but a few discrepancies were apparent. For example, the very high density indices based on the proportion of positive pots in Wudil (9), Saye (8), Takatuku (8), and Rafin-Gora (9) compared with the lower density indices (4–7) for these villages when calculated from the hut and Breteau indices. These differences are explained by the high proportion of positive pots associated with the relatively small number of huts. Conversely, the few positive pots in Basauro were distributed among a relatively large number of huts, resulting in a low density index (4) based on pots but higher density indices (7) based on huts. References to the revised maps on *A. aegypti* indices in Africa based on the WHO Computer Survey [b] showed that the indices obtained in the present survey were among the highest in Africa. The only other quantative survey in the Sudan savannah of Nigeria was carried out in villages some 80 km east of Kano where exceptionally high density indices of 9 were recorded. [c]

In most villages the single-larva survey gave a slightly lower proportion of positive pots than the conventional survey method because other mosquito species coexisted in the same pots with *A. aegypti*. Nevertheless, in only 6 villages did this result in a density index that was 1 figure lower in the scale than that derived from the conventional survey. The main advantages of the single-larva survey are the speed and ease with which it can be performed. Whereas the conventional larval indices provide information on the proportion of pots with *A. aegypti*,

[a] McClelland, G. A. H. (1971). Geneva, World Health Organization, mimeographed document No. WHO/VBC/71.271.

[a] Brown, A. W. A. (1973). Geneva, World Health Organization, mimeographed document No. WHO/VBC/73.464.

[b] World Health Organization, Geneva, 1973. Mimeographed document No. VBC/73/11.

[c] Shidrawi, G. R. et al. (1973). Geneva, World Health Organization, mimeographed document No. WHO/VBC/73.420.

Table 1. *A. aegypti* and *A. vittatus* larval indices in north-west Nigeria

Map no. and village	No. huts examined	No. pots examined	A. aegypti hut index	A. aegypti pot index (single-larva survey)	A. aegypti pot index (conventional survey)	A. aegypti Breteau index	A. aegypti density index	A. vittatus hut index	A. vittatus pot index	A. vittatus Breteau index	A. vittatus density index
Kano area:											
1 Na'iba I	76	281	47.4	20.3	20.3	75	6–7	0	0	0	0
2 Na'iba II	41	161	48.8	21.1	21.7	85	6–7	0	0	0	0
3 Yargaya	125	317	18.4	12.6	13.9	35	4–5	0	0	0	0
4 Wudil	124	142	23.4	41.5	42.3	48	4–9	0	0	0	0
5 Saye	68	119	27.9	35.3	35.3	62	4–8	0	0	0	0
6 Dankatari	108	267	34.3	20.5	24.0	59	5–6	0	0	0	0
Katsina area:											
7 Kayauki	97	312	57.7	20.2	22.8	73	6–7	30.9	14.1	45	4–5
8 Makurda	77	278	35.1	13.3	19.4	70	5–6	29.0	18.1	65	5–6
9 Moshi	65	184	26.2	14.7	18.5	52	4–6	15.4	10.9	31	3–4
10 Daddare	120	366	30.0	15.0	17.2	53	5–6	10.0	6.8	21	3–4
11 Kwangala	107	387	39.3	14.0	16.7	61	5–6	17.8	10.1	36	4–5
12 Morawa	96	154	28.1	30.5	30.5	49	5–7	0	0	0	0
13 Kaukai	80	232	45.0	19.0	19.8	58	5–6	3.8	1.3	4	1–2
14 Abukur	84	161	27.4	14.3	18.0	35	4–5	25.0	13.7	26	4
Gusau area:											
15 Bungudu	90	281	68.9	32.7	38.4	116	8	0	0	0	0
16 Danmarke	79	152	29.1	19.7	19.7	38	5	0	0	0	0
Sokoto area:											
17 Shuni	23	62	43.5	17.7	19.4	52	5–6	8.7	3.2	9	2–3
18 Denge	78	204	39.7	18.6	19.1	50	5–6	2.6	1.0	3	1
19 Amanawa	72	129	25.0	15.5	15.5	28	4–5	0	0	0	0
20 Kasarawa	86	188	45.3	29.8	29.8	65	6–7	0	0	0	0
21 Takatuku	89	144	36.0	31.3	32.6	53	5–8	0	0	0	0
22 Runji	108	224	7.4	2.7	3.6	7	2–3	0	0	0	0
23 Kware	153	302	19.6	10.6	10.6	21	4	0	0	0	0
Birnin-Kebbi area:											
24 Sabon Gori	58	111	25.9	17.1	19.8	38	4–5	0	0	0	0
25 Lagido	158	394	25.3	10.9	11.4	28	3–4	0	0	0	0
26 Basauro	79	275	49.4	24.0	24.0	84	4–7	0	0	0	0
Kontagora area:											
27 Usufu	78	139	85.9	52.5	71.9	128	8–9	2.6	1.4	3	1
28 Tadali	89	114	31.5	28.1	30.7	39	5–7	6.8	5.4	7	2–3
29 Rijandaji	58	66	27.6	28.8	37.9	43	4–8	0	0	0	0
30 Kanfanin-Waya	60	128	46.7	18.8	21.9	47	5–6	5.7	3.2	7	2
31 Tungun-Wada	118	310	42.4	18.7	19.4	51	5–6	1.7	0.6	2	1
32 Rafin-Gora	67	119	44.7	41.2	42.9	76	6–9	0	0	0	0

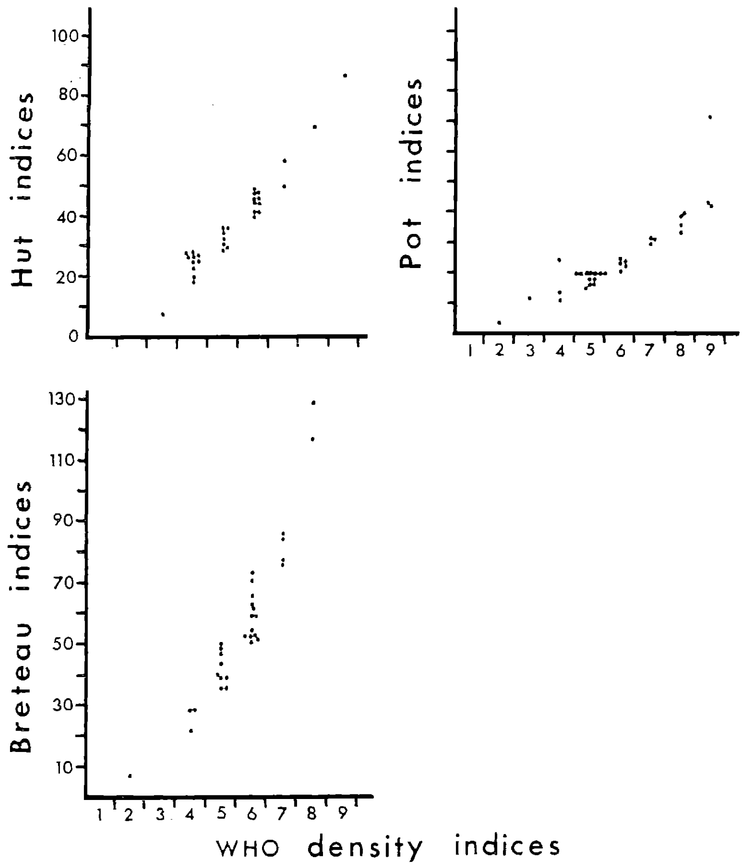

Fig. 2. A scatter diagram showing the relationships between *A. aegypti* WHO density indices and the conventional hut, pot, and Breteau indices.

the critical level above which it was considered that yellow fever transmission was likely.[a]

In the present survey, 76 of the 88 female *A. aegypti* mosquitos that were examined for the degree of pale scaling on the abdominal tergites were classified as grade F of McClelland [b], i.e., there were no pale scales on tergite I. Two of the 9 adults caught in the Kontagora area were grade G, i.e., with a very pale scale on tergite I, and the remaining 7 were grade F. All species fitted the definition of subspecies *formosus* of Mattingly (14).

[a] World Health Organization, Geneva, 1973. Mimeographed document No. VBC/73/11.

[b] McClelland, G. A. H. (1971). Geneva, World Health Organization, mimeographed document No. WHO/VBC/71.271.

DISCUSSION

The high larval indices clearly show that in northwest Nigeria, unlike in the wetter southern areas (3, 10, 26), *A. aegypti* is a prolific breeder in water pots. The population of *A. aegypti* depends not only on the number of pots containing larvae but also on the number of larvae in the pots. Surtees (24) in Nigeria and Pichon & Gayral (18) in Upper Volta counted the larvae of *A. aegypti* in a limited number of water pots, and used this information to calculate the changes in larval population size. Although these methods can provide useful information on the population dynamics of *A. aegypti*, they are too time-consuming to be used in surveys. In fact, the use of the single-larva collection method of Sheppard et al. (23) has the advantage of speeding up surveys, since it enables a greater area to be surveyed. As shown in the scatter diagram (Fig. 2), there is a very good correlation between the WHO density indices and the hut, pot, and Breteau indices. Moreover, the survey clearly demonstrated for the first time that there could be good agreement between the density indices, as calculated independently from the hut, pot, and Breteau indices; a reliable density index could therefore be derived from any one of these 3 indices.

Adults of *A. aegypti* are generally considered to be markedly exophilic, and in the northern Guinea savanna and further south very few were caught inside huts. But in the drier Sudan savanna adult behaviour differs. For example, in September 1961 I caught 90 female and 19 male *A. aegypti* mosquitos in pyrethrum catches in 47 village huts in the Maiduguri area, and in March 1969 I caught 4 female *A. aegypti* (and only 10 *An. gambiae* and 7 *An. funestus*) from 18 huts in the Potiskum area, some 220 km west of Maiduguri. Adults have also been caught in village huts near Kano (Shidrawi, personal communication, 1972). *A. aegypti* undoubtedly rests in the village huts in the drier areas of Nigeria but more information is needed on this aspect of its behaviour, e.g. whether the prevalence of adults in huts decreases in the wet season.

The only potential yellow fever vectors discovered were *A. aegypti* and *A. vittatus*, and although there were large populations of the former closely associated with man in the north-west of Nigeria, it does not necessarily follow that they present a risk of yellow fever transmission. Much depends on the existence of virus reservoirs; whereas in East Africa monkeys are important in maintaining a yellow fever reservoir (7), no such enzootic cycle has been described in West Africa (8), although it probably exists (4,6). There is also the possibility of the disease being introduced into the area by the human population and giving rise to man-to-man transmission.

The recent yellow fever epidemic in Nigeria emphasized the lack of information on the epidemiological role, if any, of nonhuman primates in the transmission of yellow fever (5, 16). The only monkey species I have seen in the Sudan savanna is *Erythrocebas patas*, which is the most common monkey in the area (17). Neither monkeys nor prosimians are common in the Sudan savanna away from riverine vegetation, and none was seen during the present survey. I doubt whether their populations are sufficiently large to be of epidemiological importance. Further south in the Kontagora area, monkeys were very common, and both baboons (*Papio anubis choras*) and *E. patas* were seen during the survey. In these areas and in forests in the south where monkeys are more abundant and where several species occur (17), they may be epidemiologically important.

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RÉSUMÉ

ENQUÊTE SUR LA PRÉVALENCE RELATIVE DES VECTEURS POTENTIELS DE LA FIÈVRE JAUNE DANS LE NORD-OUEST DU NIGÉRIA

Des poussées de fièvre jaune se sont produites au Nigéria en 1969-70, quelque 17 ans après les épidémies de 1951-52. On s'est rapidement rendu compte du manque d'informations concernant le rôle des moustiques *Stegomyia*, dont *Aedes aegypti*, en tant que vecteurs. Ce dernier n'était pas très répandu dans les zones d'épidémie, mais des indices larvaires très élevés ont été trouvés dans le nord du Nigéria en 1970-71. Afin d'obtenir des données sur la prévalence de l'espèce, des enquêtes ont eu lieu en septembre 1973 dans les régions de savane soudanaise de Kano, Katsina, Gusau, Sokoto et Birnin-Kebbi et dans la région de Kontagora en savane guinéenne.

On a utilisé à la fois la méthode de récolte d'une seule larve par récipient et la méthode plus classique de récolte de plusieurs larves, dans 26 villages. Au total, 6703 récipients dans 2811 habitations ont été examinés. Dix espèces, dont le complexe *Anopheles gambiae*, *Culex*

nebulosus, *C. tigripes* et *C. duttoni/watti* ont été identifiées, *A. aegypti* étant le plus abondant et présent dans 11-53% des récipients contenant de l'eau. On a noté une corrélation très satisfaisante entre les indices OMS de densité d'*A. aegypti* et les indices par habitation, par récipient, et de Breteau. Les indices de densité s'étageaient de 3 à 9 (valeur la plus élevée) mais étaient habituellement de 4 ou 5. *A. vittatus* a été trouvé dans 18% des récipients dans la région de Katsina, mais moins fréquemment dans les régions de Sokoto et Kontagora.

Quelques captures sur homme, effectuées entre 18 et 20 heures, ont permis de récolter 8 espèces. La plus commune était *A. aegypti* avec un taux d'agressivité de 2,1 à 4,3/heure. *A. vittatus* a été capturé dans les régions de Katsina et de Kontagora.

On a trouvé d'importantes populations d'*A. aegypti* en contact étroit avec l'homme dans toutes les régions étudiées. Cela n'implique cependant pas un risque potentiel de transmission de la fièvre jaune, les réservoirs de virus, notamment les singes, étant peu nombreux dans la savane soudanaise. Dans la savane guinéenne et dans le sud du Nigéria, les singes sont plus abondants et peuvent jouer un rôle épidémiologique important. La maladie est aussi susceptible d'être introduite par l'homme et de se propager par transmission interhumaine.

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