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YELLOW FEVER IN THE GAMBIA, 1978–1979: ENTOMOLOGICAL ASPECTS AND EPIDEMIOLOGICAL CORRELATIONS*

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Abstract. An entomological survey was conducted in the Gambia in January 1979, during the last phase of a yellow fever (YF) outbreak which began during the previous rainy season. In the dry conditions which prevailed in January, *Aedes aegypti* was the only YF vector present. Two YF virus strains were isolated from females of this mosquito species caught in a village of western Gambia, where active human cases were documented. The *Ae. aegypti* breeding sites were exclusively of the domestic type. Larval indices varied greatly from place to place, but generally appeared to correlate with the incidence of disease. A better understanding of the conditions that prevailed at the onset and during the early phase of the epidemic will require further entomological investigations. Nevertheless, it appears probable that initial transmission was by sylvatic vectors such as the *Ae. furcifer-taylori* group and possibly others such as *Ae. luteocephalus*, *Ae. metallicus*, and *Ae. vittatus*. As the outbreak progressed, interhuman transmission by *Ae. aegypti* also occurred, and this mixed epidemiological pattern later gave way to transmission by *Ae. aegypti* only when sylvatic vector populations declined in the dry season. We speculate that a prolongation of the rainy season during 1976–1978 was important in the origin of the outbreak. The relationship of this epidemic to the established focus of sylvatic YF in southeastern Senegal is discussed. The Gambian outbreak is considered the result of a recent northwesterly extension of the YF Emergence Zone.

During the second half of 1978, the Gambia was affected by an epidemic of yellow fever (YF) which ended in January 1979 with the completion of a mass vaccination campaign. An epidemiological survey, organized under the auspices of the World Health Organization, was conducted in January 1979, results of which have been reported by Monath et al.[1] The present paper deals with entomological data obtained during these investigations. An earlier entomological survey in the Gambia, conducted by Port and Wilkes in November–December, had indicated that YF virus transmission was probably effected by the sylvatic vector *Aedes* (*Diceromyia*) *furcifer-taylori*.[2] Our findings indicate a more complex situation, with potential for associated transmission by other sylvatic vectors, e.g., *Ae.* (*Stegomyia*) *luteocephalus*, and documentation of *Ae. aegypti*-borne YF.

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SUMMARY OF MAJOR EPIDEMIOLOGICAL ASPECTS

The geographic and ecologic features of the Gambia have been described in the companion paper by Monath et al.[1]

The first serologically confirmed YF case occurred in June 1978 near Georgetown, MacCarthy Island Division (Fig. 1), but clinically suspect cases were recorded in May at the eastern extreme of the country. From May to October all cases were confined to the MacCarthy Island and Upper River Divisions. In November, a case appeared in the Lower River Division (Mansa Konko), and in December and January cases occurred in the North Bank Division, in the western part of the country. Active surveillance was discontinued at the end of January, when a mass vaccination campaign was completed. The peak incidence of YF was in October, and the two eastern Divisions were established as the epicenter of the outbreak.

A total of 271 suspect YF cases were registered, 94 with confirmatory or presumptive laboratory diagnoses. It was estimated on seroepidemiologic grounds that over 8,000 cases probably occurred

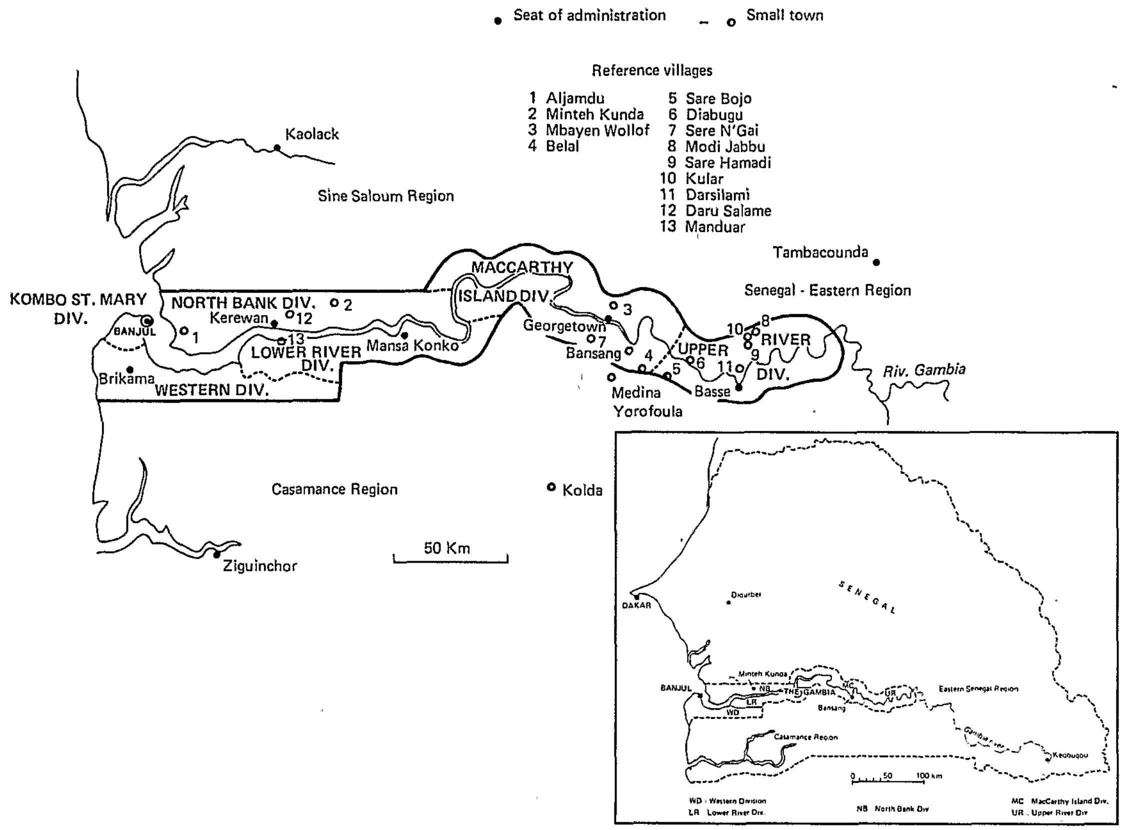

FIGURE 1. Map of the Gambia showing administrative Divisions and some reference localities. Inset is a general map of the Gambia and Senegal showing the main areas involved in the epidemiological discussion.

during the epidemic in eastern Gambia.[1] The case incidence was higher in males than females, was highest in the 0- to 9-year age group, and decreased with advancing age.

A high prevalence of Orungo virus complement fixing and neutralizing antibodies was observed in the village populations. A similar serological pattern was observed in nearby areas of Senegal (Casamance Region) during a survey carried out at the end of December. In the Gambia, many sera contained antibodies to both YF and Orungo viruses. These findings are presented elsewhere.[1]

METHODS

Since the entomological investigations were carried out in January 1979, when the epidemic was nearing its end, the main objectives were to evaluate what potential remained for YF virus transmission and, as far as possible, to retrospectively make a judgment regarding virus-vector relationships earlier in the outbreak. The survey dealt principally with the two eastern Divisions, the North Bank Division and the capital city, Banjul (Fig. 1). Survey sites were selected on the basis of data from the human case-finding studies.[1]

Larval surveys

Since breeding sites for sylvatic mosquito species were dry in January, this part of the investigation dealt mainly with *Ae. aegypti* (L.), the domestic YF vector. The prevalence of *Ae. aegypti* was evaluated by inspection of houses and their surrounding areas to identify breeding sites, determine the presence of larvae, and collect larval samples for species identification. Adults were reared from some larval collections and frozen in liquid nitrogen for virus isolation attempts. Generally, 25–50 houses and their premises were inspected in each locality. The data were expressed in terms of various indices, as follows.

TABLE 1

Aedes aegypti *larval indices in MacCarthy Island Division, the Gambia, January 1979*

Locality	No. houses inspected	Breteau index	Container index	Density value	Peridomestic potential breeding sites/100 houses
Njoben	47	0	0	0	160
Fitu Fula	51	0	0	0	110
Njie Kunda	35	0	0	0	291
Bansang	50	2.0	1.8	1	806
Bakadagi	50	0	0	0	130
Mbayen Wollof	37	8.1	6.7	2	213
Medina-Tamsir-Toure	50	0	0	0	264
Belal	21	9.5	6.5	3	ND*
Sambuldu	26	0	0	0	ND
Brikama-Ba	68	0	0	0	496
Sere N'Gai	74	1.5	1.4	1	535
Sukuta	39	0	0	0	164
Sare Dadi	3	0	0	0	ND

* ND, not determined.

Breteau index. The number of containers positive for *Ae. aegypti* larvae per 100 houses. We considered as one house each structure or room in which one or more persons slept, as well as the area immediately adjacent to the house. This widely-accepted definition[3] allows comparisons between rural and urban localities. In the Gambia, we found the mean number of inhabitants per sleeping room to be 2.5 (ranging from 1.5 to 4, according to place). This number tended to be highest in towns, with the maximum observed in urban Banjul.

Container index. The number of containers with *Ae. aegypti* larvae (or pupae) per 100 containers holding water.

Density value. The previous indices can be integrated into a scale of density values[4] which extend from 0–9. A potential for *Ae. aegypti*-borne epidemic YF exists at a density value of 2, and a high threat at a value of 6 or above.

Peridomestic potential breeding site index. The abundance around houses of dry, artificial containers which would be potentially filled during the rainy season led us to define this last index as the number of potential peridomestic breeding sites per 100 houses. We registered as potential containers only those which would have been filled by rainwater in their present location and orientation.

Sylvatic breeding sites. Investigations also involved some paradomestic and sylvatic breeding sites which were dry in January. Some treeholes were scraped for collection of mosquito eggs, others were artificially flooded and water was collected several days later to obtain larvae. Ovitraps were used in one location.

Adult mosquito surveys

Biting catches using human bait were made indoors and outdoors within villages, in tree-savanna habitat around villages, and in one location (Bakendik, near Aljamdu), in a small forest. Collections were made between 1500 and 2000 hours (roughly 4 hours before and 1 hour after sunset), to include the peaks of activity of both urban and sylvatic YF vectors. The number of catchers varied from 8 to 16. Mosquitoes were captured in cotton-plugged test tubes, identified and pooled by species in the field, and frozen in liquid nitrogen.

A CDC light-trap collection was made in Wallikunda, MacCarthy Island Division. Additionally, some mosquitoes were aspirated while resting on indoor walls or inside bed nets.

Virus isolation

Virus isolation attempts were performed at the Institut Pasteur, Dakar, or at the Vector-Borne Diseases Division, Fort Collins. Suspensions of pooled mosquitoes were inoculated by the intracerebral route into infant mice (Dakar) or into monolayer cultures of primary duck embryo and Vero cell culture for plaque assay (Fort Collins). Virus strains were identified by the complement-fixation test.

TABLE 2

Results of man-biting catches of female Aedes aegypti *and* Mansonia africana *between 3:00 and 8:00 P.M., the Gambia, January 1979*

Location	No. of mosquitoes/man/hour*							
	Aedes aegypti				*Mansonia africana*			
	Before sundown		After sundown		Before sundown		After sundown	
	Out	In	Out	In	Out	In	Out	In
MacCarthy Island Division								
Bakadaji	0	0	0	0	0	0.17	5.66	0.50
Bansang Town	0	—†	0	—	0.03	—	0.62	—
Bansang Hospital	0	—	0	—	0	—	8.00	—
Belal	0	—	0	—	0	—	1.18	—
Mbayen Wollof	0.28	0.14	0	0.33	0	0	0	0
Sambuldu	0	0	0	0	0.77	0.14	6.08	0.22
Upper River Division								
Darsilami	0	—	0	—	0	—	0	—
Modi Jabbu	0.02	—	0	—	0	—	0.08	—
Saré Hamadi	0.14	—	0.08	—	0	—	0	—
North Bank Division								
Aljamdu	0.15	—	—	—	0.07	—	—	—
Bakendik Forest	0	—	0	—	0.31	—	4.88	—
Minteh Kunda	0.54	1.31	1.00	1.25	0	0	0	0

* Out, outdoor; In, indoor.
† No catch made.

RESULTS

Aedes aegypti *surveys*

A total of 1,657 houses were inspected in 29 towns and villages. The *Ae. aegypti* breeding was confined almost exclusively to water storage jars; these containers comprised 96% of the positive sites. Other positive sites included a single pot containing medicinal liquid, one cast-iron cooking pan, and one metallic fuel drum. In Banjul, *Ae. aegypti* larvae were found in a sink holding clear water. Other mosquito species were sometimes found breeding in association with *Ae. aegypti*, including *Culex nebulosus* Theo., *Cx. cinereus* Theo., *Cx. decens* Theo. group, *Cx. pipiens quinquefasciatus* Say (=*Cx. p. fatigans* Wiedeman) and *Cx. duttoni* Theo.

Peridomestic breeding sites were usually numerous, particularly in the larger towns, and with rare exceptions were dry when the survey was done. They consisted of discarded tin cans, bottle or jar remains, discarded tires, and calabash fragments.

MacCarthy Island Division. This Division, where the epidemic was mainly focused in 1978, was surveyed between 10 and 20 January. The results are presented in Tables 1 and 2.

In the central quarter of Bansang (Fig. 1), an urban environment, the *Ae. aegypti* larval density was below the risk threshold as defined by WHO.[4] No adult vectors were obtained in biting catches (Table 2). The peridomestic potential breeding site index (Table 1) was very high (806), suggesting the possible occurrence of high *Ae. aegypti* populations during the rainy season.

Thirteen small villages were visited and in only two, Mbayen Wollof and Belal (Fig. 1), did density values (of 2 and 3, respectively) denote a moderate epidemic risk. In Belal a clinically suspect YF case was observed at the beginning of January. In Mbayen Wollof, where every house in the village was inspected for larvae and adult mosquito biting collections were made, eight females and six males of *Ae. aegypti* were caught within a radius of 10 m from the three domestic breeding sites identified. This finding is consistent with the limited dispersal of this vector demonstrated in other studies.[5,6] Two of the containers positive for larvae were in the house occupied by a young woman with serologically-confirmed YF and onset of illness on 4 January. In both of these villages,

TABLE 3
Aedes aegypti *larval indices in Upper River Division, the Gambia, January 1979*

Locality	No. houses inspected	Breteau index	Container index	Density value	Peridomestic potential breeding sites/100 houses
Basse (a)*	30	0	0	0	466
Basse (b)†	30	0	0	0	1,270
Basse (a + b)	60	0	0	0	868
Sare Bojo	52	9.6	6.7	3	ND‡
Sare N'Gaba	46	0	0	0	65
Modi Jabbu	50	14.0	7.5	3	79
Sare Hamadi	28	50.0	29.8	6	100
Kular	33	21.2	12.3	4	251
Darsilami	50	2.0	1.0	1	188
Diabugu	25	120.0	30.0	8	180

* Traditional habitat (Mansajang Kunda).
† Center of the town, commerical quarter.
‡ ND, not determined.

scrapings from dry tree holes yielded eggs of *Ae. aegypti*.

The potential peridomestic breeding site index for the 13 villages was quite variable from one village to another (Table 1).

Upper River Division. This easternmost part of the Gambia was surveyed from 22–25 January. Results are presented in Tables 2 and 3. No larval breeding site was found positive for *Ae. aegypti* in the town of Basse (Fig. 1), where two quarters were inspected. The first of them, Mansajang Kunda, is a suburb in which housing is of the traditional native type. The other, highly urbanized, makes up the commercial center of the town. As shown in Table 3, a high index of potential peridomestic containers characterized the latter part of the town.

Seven villages of various sizes, six of which are situated on the north bank of the Division (Yorobawal and Diabugu areas, Fig. 1) were visited. Breteau indices were variable, but were generally higher than in the villages of MacCarthy Island Division (Tables 1 and 3). In five villages, the density value exceeded 1, and in two (Sare Hamadi, Diabugu) indices indicated a high risk of transmission. In two of the villages (Sare Bojo, Modi Jabbu) *Ae. aegypti* density values of 3 indicated a moderate risk; in both villages, clinical and serologically-confirmed YF cases were recorded during December and January. *Ae. aegypti* adults were captured in biting collections in two villages with larval density values ≥3, but not in a village with a low density (Table 2). Potential peridomestic breeding sites were generally lower than in the villages of MacCarthy Island Division, probably due to less utilization of industrial products in this remote area.

North Bank Division. Extension of YF to this western part of the Gambia in December and January and the threat that this posed to residents of Banjul, led us to visit it as soon as the investigations began, from 5–13 January. Five villages and the small town of Kerewan were inspected (Table 4). In three villages no *Ae. aegypti* larvae were found. In one of these villages, Aljamdu, where a clinically suspect YF case occurred at the beginning of January, adult *Ae. aegypti* were nevertheless caught (12 parous females, Table 2). Since the entire village was inspected and found negative for larvae, these adults were probably part of a residual population originating from peridomestic or paradomestic breeding sites already dry at the time of the survey. In two localities (Daru Salame and Kerewan) a low to moderate risk of *Ae. aegypti*-borne infection was present.

The most interesting place was decidedly the Mandingo-Fulani village of Minteh Kunda (Fig. 1) which lies about 30 km east of Kerewan, in dry savanna habitat. The village was visited on 12 January. A death from suspect YF had just been recorded; another, acutely ill patient discovered while the entomological investigations were carried out was later confirmed as YF by virus isolation from blood and serological conversion.[1] Larval indices were high (Breteau index: 104, density value: 8) and adult *Ae. aegypti* appeared very active both outdoors and indoors at the end of afternoon and beginning of night (Table 2). As discussed below, two YF virus strains were later

TABLE 4
Aedes aegypti *larval indices in North Bank Division, the Gambia, January 1979*

Locality	No. houses inspected	Breteau index	Container index	Density value	Peridomestic potential breeding sites/100 houses
Torro Bah	43	0	0	0	ND*
Daru Salame	30	6.2	6.2	2	ND
Aljamdu	33	0	0	0	725
Minteh Kunda	24	104.0	47.0	8	153
Waya Worr	25	0	0	0	67
Kerewan	33	24.2	16.3	4	ND

* ND, not determined.

isolated from adult female *Ae. aegypti* from Minteh Kunda.

Lower River Division. Only one village, Manduar, was visited on 8 January in the western part of the Division and had a moderate density value (Table 5).

Banjul. A larval survey was carried out in the capital city on 27 January in two very urbanized and densely populated quarters (Gloucester Street and Iman Omar Sowe Avenue). The *Ae. aegypti* density was low (Table 5).

On 11 January, a biting catch was carried out in the Royal Victoria Hospital from 1600 to 2000 hours. Thirteen females of *Ae. aegypti* were caught (0.8 per man hour). In order to explain this finding, the hospital compound was searched for larvae on 27 January, and *Ae. aegypti* larvae were found in a drainage sink containing clear water. Other sinks contained polluted water and dense populations of larval *Cx. p. quinquefasciatus*.

Adjacent areas of Senegal. In mid-December 1978, a brief survey was conducted south of Bansang, in the bordering part of the Casamance Region of Senegal, where a few suspect cases of jaundice, some with hemorrhagic manifestations, had been reported in early November. The *Ae. aegypti* density values were low: 0 and 1, respectively, in two villages near Medina Yorofoula (Sam Yoro Gueye and Touba Mboyene), 0 and 1 again in Medina Yorofoula and the town of Kolda (Fig. 1).

Other potential vectors of arboviruses

Aedes aegypti was the only *Stegomyia* species found to be active during the survey. The single other record for this subgenus during the investigation concerns three larvae of *Ae. luteocephalus* (Newstead) collected from tree holes which were artificially filled with water in the gallery forest of the Gambia river, at Wallikunda (near Georgetown, MacCarthy Island Division, Fig. 1). In the same place, ovitraps were used without success. No *Ae.* (*Diceromyia*) of the *furcifer-taylori* group was obtained during the biting catches, nor *Ae.* (*Aedimorphus*) *vittatus* (Bigot). The same situation prevailed in the adjacent part of Senegal, which was visited in mid-December.

The most active anthropophilic mosquito species was *Mansonia africana* (Theo.) (Table 2). This species was captured in most villages, mainly biting outdoors at night, a pattern well known.[5] It was abundant in a small forest at Bakendik, near Aljamdu (North Bank Division) in association with *Ae.* (*Aedimorphus*) of the *tarsalis* (Newstead) group. *Mansonia africana* was, however, absent or rare in villages of the Upper River Division as well as in Minteh Kunda, probably be-

TABLE 5
Aedes aegypti *larval indices in Lower River Division and Banjul, the Gambia, January 1979*

Locality	No. houses inspected	Breteau index	Container index	Density value	Peridomestic potential breeding sites/100 houses
Manduar	46	10.8	8.0	3	ND*
Banjul	235	0.85	1.2	1	155

* ND, not determined.

cause these areas were quite dry. *Mansonia uniformis* (Theo.) was far less frequent in the catches. It was abundant only in Bakadagi, on the north bank of the MacCarthy Island Division.

Anopheles funestus Giles and *An. gambiae* Giles group, species implicated in Orungo and Tataguine virus transmission in Uganda, Nigeria, and Central African Empire[7–9] were found biting outdoors and indoors and were collected in bednets in many localities: Darsilami (Upper River Division), Bakadagi, Mbayen Wollof, Sambuldu, Sere N'gai, Sukuta (MacCarthy Island Division), Aljamdu, Bakendik Forest, Minteh Kunda, Kerewan, and Juffure (North Bank Division). A single strain of Tataguine virus (79V-1463) was isolated at the Vector-Borne Diseases Division (VBDD), Fort Collins, from a pool of *Anopheles* spp. collected in Juffure (North Bank Division) on 6 January. This virus strain was identified by Dr. C. H. Calisher, VBDD, Fort Collins, Colorado. Tataguine virus was originally recovered from man and mixed *Culex* and *Anopheles* species mosquitoes in Senegal. Subsequently it was isolated from *Anopheles funestus* in Ibadan, Nigeria; *Anopheles gambiae* from Bandia, Senegal; Bangui, Central African Republic and Yaounde, Cameroon; and from *Coquilletidia aurites* in Yaounde.[10]

At Banjul, in an all-night biting catch, the following mosquito species were present, in order of prevalence: *Cx. p. quinquefasciatus, Cx. thalassius* Theo., *An. gambiae* group, and *Ma. africana.*

Two overnight light trap catches in Wallikunda yielded small numbers of *Cx. univittatus* Theo. group, *Ma. africana, Culex* (*Cx.*) spp., *Cx. simpsoni* Theo., and *Cx. poicilipes* (Theo.).

Yellow fever virus isolation

A total of 1,218 mosquitoes were pooled and tested for virus isolation (Table 6). No attempt was made to separate females of species belonging to several groups: *Ae. abnormalis* (Theo.) gr., *Cx. univittatus* gr. (*Cx.? naevei* Theo.) and *Cx. decens* Theo. gr., and in one instance *Anopheles* spp. were mixed.

Two strains (DakAr 27797 and 22798) of yellow fever virus were isolated in suckling mice at the Institut Pasteur, Dakar, from pools of 20 and 21 *Ae. aegypti* females caught while biting in Minteh Kunda, North Bank Division, on 12 January. The 64 *Ae. aegypti* females caught in this village were distributed in 4 pools for testing. From these results, it appears that the YF virus infection rate for *Ae. aegypti* was probably high at the beginning of January in this villages.

DISCUSSION

Recent studies of YF ecology in west and central Africa have focused attention on the forest-savanna mosaic and the undifferentiated savannas of relatively moist type. These habitats appear to represent the periphery of the YF endemic area of Africa where, seasonally, the conditions for sylvatic transmission to man are optimal. The term yellow fever "Emergence Zone" has been used to designate this geographical belt.[11–14] During the rainy season, densities of potential vectors are generally higher and their activity at ground level greater in the Emergence Zone than in the equatorial rain forest. There is considerable evidence that the optimal conditions for YF virus circulation occur in the second half of the rainy season.[13, 15, 16] Recently, experimental transovarial transmission and virus isolations from male mosquitoes and ticks[17–19] have provided possible explanations for the ability of YF virus to survive the dry season.

There is strong evidence that the southeastern part of Senegal, and probably also the Casamance Region (Fig. 1) belong to the Emergence Zone. In the Kedougou area, between 1976 and 1978, 123 YF virus strains have been isolated from *Ae. furcifer-taylori* gr., *Ae. luteocephalus, Ae. vittatus, Ae. neoafricanus* Cornet et al.,[14–18] and five from wild monkeys.[14]

No human yellow fever cases have been reported in the Gambia since 1935;[20] however, serological surveys in 1944[20] and 1955 indicated that YF virus was at least intermittently active.[1]

Rainfall variations during recent years seem to have played a determinant part in the genesis of the conditions which permitted the 1978 outbreak, as noted by Port and Wilkes.[2] The rains generally begin in May or June and end in October or November, with a peak in August or September. The mean annual rainfall for the last 10 years was less than 1,000 mm. The last 3 years (1976–1978) were characterized by a prolongation of the rainy season (Table 7) which probably favored virus amplification in monkey populations. Serologic data from the 1979 monkey survey showed a high prevalence of neutralizing and complement fixing antibodies.[1] YF virus may have already been present in the Gambia at the beginning of the 1976–1978

TABLE 6
*Mosquitoes tested for arbovirus isolation, the Gambia, 1979**

Mosquitoes	Division			
	North Bank	MacCarthy Island	Upper River	Lower River
Aedes aegypti (L.)				
Biting catches—females	76	9	9	—
—males	37	6	—	—
Bed net collections	1	—	—	—
Emerged adults—females	34	31	17	3
—males	28	43	8	6
Ae. tarsalis (Newst.) group	73	—	—	—
Ae. abnormalis Theo. group	2	—	—	—
Mansonia africana (Theo.)				
Biting catches	74	313	—	—
Resting collections	84	—	—	—
Light trap	1	—	—	—
Ma. uniformis Theo.	—	32	—	—
Culex cinereus Theo.	2	—	—	—
Cx. nebulosus Theo.				
Biting catches	—	1	—	—
Resting collections	—	1	—	—
Bed net collections	1	—	—	—
Cx. p. quinquefasciatus Say	—	4	—	—
Cx. (*Cx.*) spp.				
Biting catches	6	16	—	—
Bed net collections	2	—	—	—
Resting collections	6	—	—	—
Light trap	—	19	—	—
Anopheles coustani Laver. group				
Biting catches	—	1	—	—
Light trap	—	2	—	—
An. funestus Giles	—	53	—	—
An. gambiae Giles group	67	8	—	—
An. funestus + *A. gambiae* group				
Bed net collections	137	—	—	—
An. rufipes (Gough)	—	4	—	—

* Except where otherwise stated, mosquitoes were females collected in man-baited biting catches.

wet period, or it may have been introduced in the form of an epizootic wave from southeastern Senegal along the Gambia River system, or from the Casamance Region through the savanna woodlands. The explosive character of the 1978 outbreak suggests that YF virus transmission in the Gambia had been absent or minimal for some years, probably because the northern limit of the Emergence Zone had receded to the more stable areas of south and southeastern Senegal.

Port and Wilkes obtained the only available data on YF vectors active earlier than January 1979.[2] The town of Bansang and three villages in its vicinity were surveyed at the extreme end of the rainy season (24 November to 5 December). No *Ae. aegypti* larvae or adults were found, but 19 *Ae. furcifer-taylori* females were caught biting man in Bansang, Kurup, and Sankuli-Kunda. Although no other vector species were found by Port and Wilkes, ,ere able to confirm the presence of *Ae. luteocephalus* in the same area (Wallikunda) by collection of larvae from artificially flooded tree holes.

The isolation of YF virus from *Ae. aegypti* and man in the North Bank division documents the occurrence of *Ae. aegypti*-borne YF in the Gambian epidemic. On the basis of larval and adult surveys, interhuman virus transmission by *Ae. aegypti* was possible in 11 of the 29 places surveyed in January (Tables 1–5). Adults of this species were found biting man in several villages in both eastern and western parts of the Gambia. Table 8 summarizes the association between YF morbidity rate (see ref. 1) and *Ae. aegypti* prevalence during the rainy and dry seasons. In four of the five villages where YF cases occurred in December or January, *Ae. aegypti* indices indicated moderate or high epidemic risk. In the dry season, the highest YF attack rate was observed in the village with the highest Breteau index (Modi Jabbu). In one place only did a discordance appear between the dry season attack rate and the observed *Ae. aegypti* index (Sukuta).

Aedes aegypti larval indices were found to be highly variable from village to village in the same area. There is an obvious relationship between increasing *Ae. aegypti* density and the number of water storage jars per 100 houses (Table 9), whether the jars were predominantly inside or outside (Table 10).

No major sylvatic vector of YF virus was found active in any of the areas surveyed in January. *Mansonia africana,* which was abundant and biting man in the villages, is known to transmit YF virus under laboratory conditions,[21] but only after a long extrinsic incubation period. Its role in YF virus transmission in the field remains very conjectural.[5] Nevertheless, *Ma. africana* has been suspected as a vector in the circulation of YF virus in an area of Nigeria (Nupeko Forest) where other

TABLE 7

*Duration of the rainy season (expressed in months) evaluated for different periods between 1969 and 1978**

Period	Duration (months) Banjul	Georgetown	Basse
1969–1978	4.6	5.5	6.1
1972–1975	4.0	4.0	5.5
1976–1978	5.7	6.4	6.7
1978	5.2	6.0	6.5

* Based on data from the Gambian Meteorological Services.

potential vectors were present only in low numbers.[22] *Culex thalassius,* also known to be able to transmit YF virus,[23] appears, for the same reason, to be an inefficient and unlikely vector.

The question remaining unanswered is: what part did *Ae. aegypti* play in YF virus transmission during the 1978 rainy season? It seem probable that the density of *Ae. aegypti* was higher during the rainy season in villages found positive in January, such as Belal, Sare Bojo, and Modi Jabbu (Table 8). In many villages and towns in eastern Gambia, the abundance of potential peridomestic containers supports the contention that *Ae. aegypti* densities were higher during the rains than in January. Although the initial mechanism of epidemic spread was almost certainly sylvatic transmission, the explosive nature and high attack rates in the outbreak suggest relatively early intervention of *Ae. aegypti* and occurrence of interhuman transmission in some areas. This probably varied greatly according to locality (see Tables 1–5, the

TABLE 8

Breteau index, yellow fever cases, and attack rates in areas surveyed for Aedes aegypti

Place	District*	Breteau index (dry season)	No. cases and attack rate/1,000 inhabitants, by season† Rainy season Cases‡	Rate	Dry season Cases‡	Rate
Sukuta	MC	0	7 (6)	81.4	1 (0)	11.6
Sambuldu	MC	0	4 (2)	54.8	0	0
Basse	UR	0	1	?	0	0
Sere N'Gaba	UR	0	14 (9)	108.5	0	0
Sere N'Gai	MC	1.5	15 (8)	34.3	0	0
Bansang	MC	2.0	14 (6)	?	3 (1)	?
Belai	MC	9.5	3	19.7	1	6.6
Sare Bojo	UR	9.6	2 (1)	8.5	3 (3)	12.8
Modi Jabbu	UR	14.0	2	13.6	6 (1)	40.8

* MC, MacCarthy Island Division; UR, Upper River Division.
† Rainy season, from May to end of November; dry season, from December to end of January.
‡ Cases—total clinical cases. Figures in parentheses = confirmed cases.

TABLE 9
Relationship between Ae. aegypti *density value and domestic water storage, the Gambia, January 1979*

Place	Density value	No. water-holding containers/100 houses
	Density value = 0–1	
Fitu Fula	0	115
Njie Kunda	0	137
Bansang	1	110
Bakadagi	0	164
Medina T. Toure	0	166
Basse	1	88
Sare N'Gaba	1	89
Darsilami	0	198
Waya Worr	1	112
Aljamdu	0	151
Banjul	1	90
Mean		129.0
	Density value = 2–5	
Mbayen Wollof	2	121
Kular	4	172
Modi Jabbu	3	188
Mean		160.3
	Density value = 6–9	
Sare Hamadi	6	167
Diabugu	8	392
Minteh Kunda	8	220
Mean		259.6

variability of *Ae. aegypti* indices in January). In much of the Gambia there appears to be no correlation between the larval *Ae. aegypti* prevalence, which can be quite high, and the man-biting propensities of this species, which appears generally low (compare Tables 1, 2, 3 and 4). It is probable that a significant portion of the *Ae. aegypti* population in the Gambia is derived from a relatively nonanthropophilic feral stock. The similar proportion of positive outdoor and indoor breeding sites in the eastern Gambia supports such a possibility (Table 10). A similar pattern has been observed in Kédougou. In contrast, in the western Gambia (North Bank Division) the proportion of positive indoor breeding sites is significantly higher than outdoor sites ($P < 0.05$, $\chi^2 = 5.4$). In an entomological followup conducted in the eastern Gambia in October 1979 (to be published) adult *Ae. aegypti* taken in biting catches were mainly of the feral type (*Ae. aegypti formosus*), whereas, in the village of Minteh Kunda where the two strains of YF were isolated from mosquitoes (North Bank Division) in western Gambia, 50% or more of the adult *Ae. aegypti* taken in biting catches were morphologically of the urban type (*Ae. aegypti aegypti*).

It seems certain that sylvatic vectors continued to play a role in virus transmission throughout the rainy season of 1978. In the case of *Ae. furcifer-taylori* group mosquitoes, transmission was monkey-monkey and monkey-man, but this species undoubtedly also served as an interhuman vector in areas where the prevalence of this village-entering species[12] was high enough. The YF attack rate was shown to be higher in males, probably because of greater exposure to dusk-biting vectors.[1] Such differences were observed in other rural epidemics in which sylvatic vectors were implicated.[24]

To this more or less mixed epidemiological pattern which probably prevailed from the onset of the outbreak to the end of November, was added a second phase during which interhuman transmission by *Ae. aegypti* alone occurred. It was at this stage that the epidemic appeared in western Gambia (North Bank Division). Since two of the three monkeys bled in this Division had complement-fixing YF antibodies,[1] there must have been relatively recent sylvatic circulation of YF virus in this western part of the Gambia. That the outbreak occurred later there than in the East could be due to the shorter rainy season and consequently retarded amplification. It may also have been due to an east to west progression of the YF epizootic in monkey populations along the Gambia River. Finally, man may have contributed to introduction of the virus from eastern Gambia.

The Gambian YF outbreak provides an important example of the mechanisms generating an epidemic in a region which assumes a borderline position between the Emergence Zone and an area where primary sylvatic YF virus circulation probably does not occur, namely the "Potential Epidemic Area" as defined in previous attempts to describe geographical relationships of YF in West and Central Africa.[11–14]

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TABLE 10
Aedes aegypti *container indices, indoors and outdoors, the Gambia, January 1979*

Area	Indoors: No. water-holding containers	Indoors: No. positive containers	Indoors: % positive	Outdoors: No. water-holding containers	Outdoors: No. positive containers	Outdoors: % positive
EASTERN GAMBIA						
MacCarthy Island Division						
Bansang	28	0	0	27	1	3.7
Mbayen Wollof	31	2	6.4	14	1	7.1
Upper River Division						
Modi Jabbu	17	0	0	77	7	9.0
Sare Hamadi	17	7	41.1	30	7	23.3
Kular	6	3	50.0	51	4	7.8
Darsilami	15	0	0	84	1	1.2
Diabugu	22	5	22.7	76	25	32.8
Subtotal	136	17	12.5	359	46	12.8
WESTERN GAMBIA						
North Bank Division						
Minteh Kunda	32	20	62.5	21	5	23.8
Kombo St. Mary Division						
Banjul	85	0	0	82	2	2.4
Subtotal	117	20	17.1	103	7	6.8
GRAND TOTAL	253	37	14.6	462	53	11.5

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