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YELLOW FEVER IN THE GAMBIA, 1978–1979: EPIDEMIOLOGIC ASPECTS WITH OBSERVATIONS ON THE OCCURRENCE OF ORUNGO VIRUS INFECTIONS*

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Abstract. An epidemic of yellow fever (YF) occurred in the Gambia between May 1978 and January 1979. Retrospective case-finding methods and active surveillance led to the identification of 271 clinically suspected cases. A confirmatory or presumptive laboratory diagnosis was established in 94 cases. The earliest serologically documented case occurred in June 1978, at the extreme east of the Gambia. Small numbers of cases occurred in August and September. The epidemic peaked in October, and cases continued to occur at a diminishing rate through January, when a mass vaccination campaign was completed. The outbreak was largely confined to the eastern half of the country (MacCarthy Island and Upper River Divisions). In nine survey villages in this area (total population 1,531) the attack rate was 2.6–4.4%, with a mortality rate of 0.8%, and a case-fatality rate of 19.4%. If these villages are representative of the total affected region, there may have been as many as 8,400 cases and 1,600 deaths during the outbreak. The disease incidence was highest in the 0- to 9-year age group (6.7%) and decreased with advancing age to 1.7% in persons over 40 years. Overall, 32.6% of survey village inhabitants had YF complement-fixing (CF) antibodies. The prevalence of antibody patterns indicating primary YF infection decreased with age, in concert with disease incidence. The overall inapparent:apparent infection ratio was 12:1. In persons with serological responses indicating flaviviral superinfection, the inapparent:apparent infection ratio was 10 times higher than in persons with primary YF infection. Sylvatic vectors of YF virus, principally *Aedes furcifer-taylori* and *Ae. luteocephalus* are believed to have been responsible for transmission, at least at the beginning of the outbreak. Eighty-four percent of wild monkeys shot in January 1979 had YF neutralizing antibodies, and 32% had CF antibodies. Domestic *Aedes aegypti* were absent or present at very low indices in many severely affected villages (see companion paper). In January, however, *aegypti*-borne YF 2.5 months into the dry season was documented by isolation of YF virus from a sick man and from this vector species in the absence of sylvatic vectors. Thus, in villages where the classical urban vector was abundant, interhuman transmission by *Ae. aegypti* occurred and continued into the dry season. A mass vaccination campaign, begun in December, was completed on 25 January, with over 95% coverage of the Gambian population. A seroconversion rate of 93% was determined in a group of vaccinees. This outbreak emphasizes the continuing public health importance of YF in West Africa and points out the need for inclusion of 17D YF vaccination in future programs of multiple immunization.

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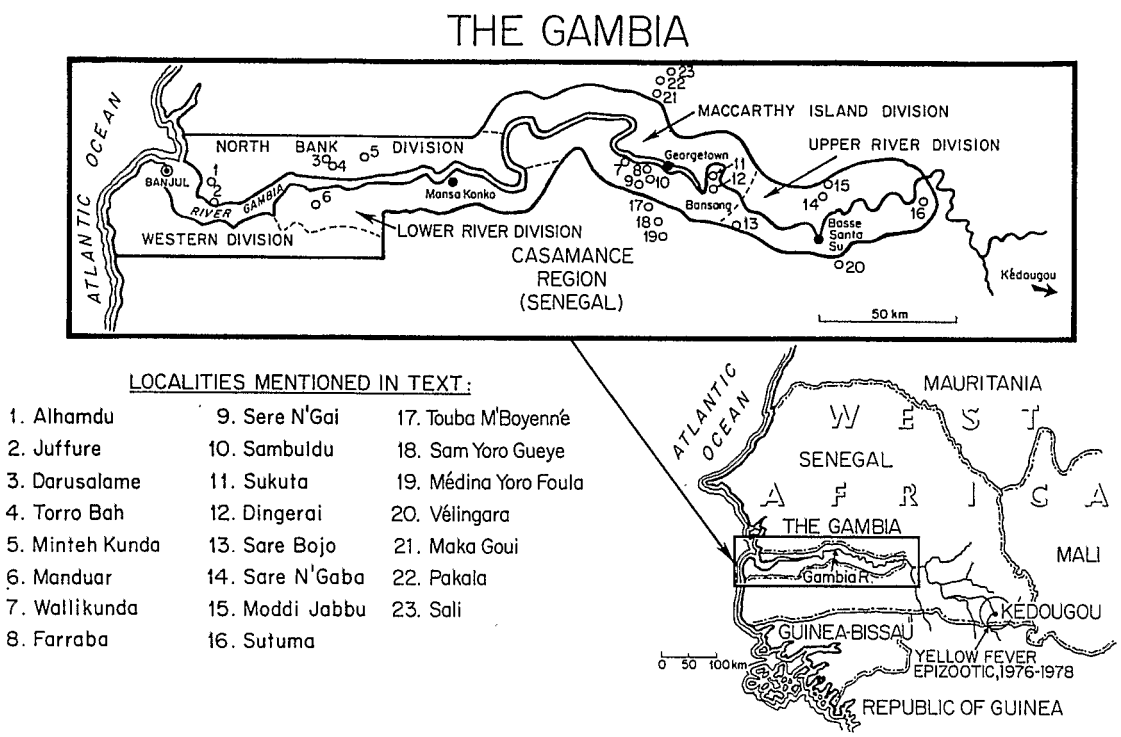

FIGURE 1. Map of the Gambia, showing localities mentioned in text and geographical proximity to the Kédougou area of eastern Senegal, where an epizootic of yellow fever has been in progress since December 1976.

An outbreak of yellow fever (YF) in eastern Gambia was suspected on clinical grounds by one of us (KC) in October 1978. Preliminary investigations and serological testing confirmed the etiology by early December, when a country-wide mass vaccination campaign was initiated. Because of the reported high disease incidence, an apparent westward movement of the outbreak (toward the capital city of Banjul), and uncertainty of the vector species involved in YF virus transmission, a multinational team was organized under the auspices of the World Health Organization (WHO) to conduct an epidemiological study. The team began investigations on 2 January 1979; it was comprised of physicians and scientists from the Ministry of Health (MOH), the Gambia; the Center for Disease Control, Fort Collins, Colorado, and Atlanta, Georgia, U.S.A.; L'Office de la Recherches Scientifique et Technique Outre-Mer (ORSTOM), Dakar, Senegal; the Medical Research Council Laboratories, Fajara, the Gambia; the Medical Research Establishment, Porton Down, England; and the Virus Research Laboratory, Ibadan, Nigeria.

Before this outbreak, yellow fever cases had not been recognized in the Gambia since 1935.[1] Serologic surveys conducted in 1944[1] and 1955 (I. A. McGregor, pers. comm.), however, indicated that the virus was either endemic or intermittently active in the Gambia. Various serosurveys conducted in Senegal (which surrounds the Gambia) have yielded similar results.[2] The most recent of these surveys confirmed human YF infections in two areas of Senegal:[3,4] the Kédougou department of southeastern Senegal and the upper Casamance (the former lies 200 km (125 miles) southeast of, and the latter forms the southern border of, the Gambia). The Kédougou region is especially important in the context of this epidemic. Between 1976 and 1978, multiple isolations of YF virus have been made from *Aedes furcifer-taylori, Ae. luteocephalus, Ae. neoafricanus,* and *Ae. vittatus* mosquitoes and from wild monkeys during intensive field studies conducted by ORSTOM (ref. 5–7 and unpublished observations). Human infections,[5] but no report of disease, have also been documented in the Kédougou area. These results indicate that an intense sylvatic YF epizootic oc-

curred over a 3-year period in gallery forests of the Gambian riverine system (Fig. 1), and suggest a possible source of the present epidemic.

In this paper we describe the epidemiologic aspects of the human outbreak in the Gambia. A companion paper deals with entomologic investigations. Our results show that this was a large epidemic, and they remind us of the importance of YF as a continuing public health problem in West Africa and emphasize the desirability of including YF vaccine in future multiple immunization projects.

GEOGRAPHICAL CONSIDERATIONS

The Gambia is the smallest independent state in West Africa, with a total area of 4,361 square miles, lying between latitude 13°04′N to 13°50′N and longitude 13°47′W to 10°49′W. The country is a narrow enclave in Senegal, 7–12 miles wide and 295 miles long, bisected lengthwise by the River Gambia. There are five political divisions (Fig. 1), with a total population (1973 census) of 534,458. The population is predominantly rural and dispersed in villages of less than 1,000 inhabitants; the capital (Banjul), lying at the extreme western end of the country, has a population of 41,568, and there are only four other settlements with more than 3,000 inhabitants. The typical village is composed of several or more compounds in which extended families live in mud-walled, thatch-roofed huts within a common wall or fence. Immediately surrounding the village and extending for some miles around it are cultivated fields and partially cultivated savannah accessible by footpaths. During planting and harvest times, men, women, and children share the labor in the fields, and children too young to work are generally carried to the farms.

The population is predominantly Muslim and comprised of five major tribal groups, of which the Mandingo and culturally related Serahuli are the largest, followed by Fulani, Wolof, and Jola. Farming (ground nuts, sorghum, rice, etc.) and cattle grazing are the major occupational pursuits. The country is accessible by road from Senegal, from which, however, it is politically and economically largely isolated. Movements of people back and forth across the borders are, however, commonplace, and during crop harvests as many as 20,000 laborers from Senegal and Guinée Bissau enter the Gambia to work.

The River Gambia dominates the geography. Its source lies 700 miles southeast in the Fouta Jallon highlands of Guinea, and before reaching the eastern end of the Gambia, it flows through the Kédougou area of southeast Senegal, a region of epizootic YF in 1976–1978. After reaching the eastern border of the Gambia, it flows for 200 miles through a gently rolling sandstone plateau. A mosaic of gallery forest, parkland, open freshwater swamps, and grassy flats characterize the area along the river. Further inland, there are typical guinea savannah and transitional guinea-sudan savannah habitats, with forests along drainage channels. The last 100 miles downriver is characterized by mangrove forest and saline swamps bordering alluvial estuarine flats, which then give way to savannah uplands. Nonhuman primate populations are high throughout the country. In the mangrove and riverine forests, two species predominate (*Colobus badius* and *Cercopithecus aethiops*); in the savannah uplands, baboons (*Papio papio*) and *Erythrocebus patus* are numerous. *Galago senegalensis* are also present.

There are distinct rainy (June–October) and dry (November–May) seasons. The mean annual rainfall for the past 10 years is 361 in. at Banjul on the coast and 296 in. upriver at Georgetown (Fig. 1). Rainfall over the past 3 years (1976–1978) was not significantly greater than the 10-year average, but the rainy season (6.4 months at Georgetown) lasted nearly 2 months longer than during the period 1972–1975 (4.0 months). This prolongation of the rainy season may have been a factor in the YF epizootic extending from areas farther south (e.g., Kédougou) to the Gambia. The mean monthly temperature is approximately 24°C at Banjul and 28°C at Georgetown.

MATERIALS AND METHODS

Search for and surveillance of human cases

In October 1978 the occurrence of unusual numbers of patients with jaundice and a high mortality was recognized at Bansang Hospital, MacCarthy Island Division (Fig. 1). In November, AA conducted initial investigations, which resulted in the identification of suspect cases who had been hospitalized at Bansang and Basse (Upper River Division), and collection of diagnostic serum samples from more than 40 survivors who had returned to their home villages. During follow-up visits in December and January, AA ob-

tained second and, often, third serum specimens from many of these patients. Serologic tests performed at the Medical Research Establishment, Porton Down, confirmed the etiology in December.

An intensive program of active surveillance was initiated in January 1979. Medical personnel at hospitals with inpatient services (Bansang, Basse, Banjul) and at selected rural health centers were asked to immediately report all cases suspected to be YF on the basis of fever and jaundice. Frequent contact was made with the responsible physician or health inspector, and persons with suspected YF were visited (in the hospital or in their home villages) to obtain historical and clinical information and diagnostic specimens. Two other case-search methods were employed. In one, special teams comprised of health inspectors of the Gambian MOH, with or without a member of the multi-national team, visited villages in the North Bank, MacCarthy Island, and Upper River Divisions; village chiefs and elders were interviewed to identify persons who currently had jaundice or who had recovered from it, and to obtain serum samples. In the other, MOH teams undertaking systematic village-to-village YF mass vaccination were instructed to inquire about the presence of active illness with jaundice and to report suspect cases for follow-up or, when appropriate, to transport patients to the hospital.

In addition to these means of identifying patients, a retrospective search was conducted by review of inpatient records at Bansang and Basse hospitals and by house-to-house surveys in selected villages (below).

Village surveys to define morbidity-mortality rates

Nine villages in MacCarthy Island and Upper River Divisions (Farraba, Sere N'Gai, Sambuldu, Sukuta, Dingerai, Sare Bojo, Sare N'Gaba, Moddi Jabbu, and Sutuma; Fig. 1) were surveyed between 11 and 25 January. Villages were selected on the basis of location within the region most severely affected by YF, the occurrence of one or more suspect YF cases identified by the active case search or review of hospital records, and a population size allowing completion of the survey within 1 day. The complement-fixation (CF) test was used exclusively for serodiagnosis because of the need to assess recent infection and to distinguish vaccine-induced from wild YF viral infection. Villages were visited 1 day in advance to inform the chief of the purpose of the survey and to solicit the cooperation of village inhabitants. During the survey each compound in the village was visited; compound members (both those present and absent) were enumerated by age and sex, and interviews were held to define a history of illness compatible with YF. Serum samples were taken from all those with a history of suspect illness and from approximately 25–90% of all other village residents.

For the purpose of retrospective identification of suspect YF cases in these surveys, a "case" was defined as any illness with the criteria of fever and scleral icterus. It was recognized that many other etiologies could be responsible for these symptoms and that YF often causes illness without jaundice. Although more detailed clinical histories were obtained from many surviving patients, their lack of accuracy and completeness (because of translation difficulties and the population's lack of general medical knowledge) dictated a broad and oversimplified approach to case identification.

Other serologic surveys and assessment of YF vaccine efficacy

Serum surveys without a census, or interviews for history of illness, were also conducted in four villages in the North Bank Division (Torro Bah, Aljamdu, Darusalame, Juffure) and one village in Lower River Division (Manduar; see Fig. 1). In these surveys, villagers were bled on a voluntary basis before YF jet-injector vaccination during the mass campaign. Inhabitants of two of these villages (Torro Bah and Darusalame) were re-bled 25 days post vaccination to determine the seroconversion rate and vaccine efficacy under routine field conditions. This aspect of the investigations is described in more detail in another publication.[8]

A limited survey was conducted in December 1978 by staff of the Pasteur Institute, Dakar, ORSTOM, and the Ministry of Health, Senegal, in areas of Senegal bordering the Gambia (Fig. 1). The aim of these surveys was to determine the etiology of approximately 30 cases and two deaths of acute grippe-like illness accompanied by icterus and occasional hemorrhagic manifestations in two villages (Touba M'Boyenné and Sam Yoro Gueye; Fig. 1). Two hundred and forty-four sera were obtained; 55 sera were from the affected villages—20 from persons with a history of illness (not well defined) and 35 from persons without illness. An additional 189 sera were obtained in another vil-

TABLE 1

Number of persons with suspect yellow fever identified by various methods, and number from whom adequate diagnostic specimens were obtained, the Gambia, 1978–1979

Case-finding method	No. of suspect cases identified	No. from whom adequate diagnostic specimens obtained
Review of hospital records	118	33
Active case search by mobile teams and hospital surveillance (January only)	85	51
Interviews in nine survey villages	68	47
Total	271	131

TABLE 2

Summarized results of diagnostic tests on sera from persons with suspected yellow fever (YF), the Gambia, 1979

Diagnostic conclusion	No. of cases
Confirmed yellow fever	
Serology only*	10
Serology and virus isolation	1
Presumptive yellow fever†	83
Inconclusive‡	10
Not yellow fever§	27
Total	131

* ≥Fourfold rise in YF CF titer in appropriately timed paired sera; antibody pattern (monotypic or mixed homotypic) specific for YF.
† YF CF titer ≥ 16 in a single convalescent serum.
‡ YF CF titer = 8 in a single acute or convalescent serum.
§ YF CF titer < 8 in a single convalescent serum or appropriately timed paired sera.

lage in Casamance (Medina Yoro Foula), in Velingara 50 km east, and in three villages (Sali, Pakala, and Maka Goui) on the northern border of the Gambia. Sera were tested at the Pasteur Institute, Dakar, by CF test against a variety of antigens. Forty-three sera were also sent to Dr. Karl M. Johnson, CDC, Atlanta, Ga., for indirect fluorescent antibody (IFA) tests to detect immunity to Lassa, Marburg, and Ebola viruses.

Survey of nonhuman primates

Monkeys were shot in forested areas near the River Gambia in MacCarthy Island Division (near Wallikunda; Fig. 1) and in North Bank Division (near Aljamdu). Blood was obtained by cardiac puncture, and samples of spleen and liver were taken for virus isolation attempts. Species, sex, and estimated age were recorded.

Serological and virological techniques

Blood samples were obtained by antecubital venepuncture, with evacuated tubes. For virus isolation attempts, whole blood was immediately frozen in liquid nitrogen. Sera were separated at ambient temperature without centrifugation and stored in a mechanical freezer or in liquid nitrogen. Samples were returned to the Fort Collins laboratory on Dry Ice for testing. Tests for virus isolation were performed by intracerebral (IC) inoculation of infant Swiss mice (NIH strain). Complement-fixation tests were performed in microtiter plates by standard techniques;[9] beta propriolactone-inactivated sucrose acetone-extracted antigen of a variety of flaviviruses and Orungo virus were used. Plaque-reduction neutralization (PRN) tests against YF, Zika, West Nile, Uganda S, Usutu, Koutango, Banzi, and Orungo viruses were done in Vero cell cultures, as described elsewhere.[10] PRN tests against Ntaya virus were performed in primary duck embryo cell cultures. Sera inhibiting ≥90% of plaques were considered positive.

Sample ampoules of YF 17D vaccine that had been taken to the field during the mass vaccination campaign were returned to the Pasteur Institute, Dakar, Senegal, where potency was assessed by titration in weanling mice inoculated intracerebrally and by plaque assay in porcine kidney (PS) cells; titers were compared with those obtained after original manufacture of the same lots of vaccine.

RESULTS

Search for, and diagnosis of, cases

Retrospective case-finding methods and active surveillance led to the identification of 271 suspect cases of YF; from 131 of the cases, adequate diagnostic specimens were obtained (Table 1). In 11 of these 131 cases, a diagnosis was confirmed by a fourfold or greater rise in CF antibody titer, and in one of these cases, YF virus was isolated from blood (see below). An additional 83 cases were presumptively diagnosed by the presence of CF antibodies at a titer ≥16 in a single convalescent-phase serum (Table 2). In 10 cases no diagnostic

TABLE 3

Examples of serological responses, yellow fever cases, the Gambia, 1978–1979

Case	Age/Sex	Date of onset	Date serum obtained	Complement-fixation titer*					Serological response	YF infection
				YF	ZIKA	WN	DEN-1	UGS		
1	7/M	29 Oct	11 Nov	<8	<8	<8	<8	<8	Monotypic	Primary
			7 Dec	32	<8	<8	<8	<8		
2	21/F	?20 Oct	7 Dec	16	<8	<8	<8	<8	Monotypic	Primary
			27 Jan	≥1,024	<8	<8	<8	<8		
3	28/M	24 Nov	4 Dec	<8	<8	<8	<8	<8	Monotypic	Primary
			27 Dec	128	<8	<8	<8	<8		
4	7/F	Oct	24 Jan	≥1,024	<8	<8	<8	<8	Monotypic	Primary
5	24/M	9 Nov	17 Nov	128	32	32	16	8	Mixed homotypic†-monotypic	Indeterminate (Prob. primary)
			11 Jan	256	<8	<8	<8	<8		
6	10/M	Sep	16 Jan	≥1,024	16	16	64	32	Mixed homotypic	Indeterminate
7	23/F	3 Nov	17 Nov	128	32	16	16	<8	Mixed homotypic	Indeterminate
8	20/F	Sep	11 Jan	≥1,024	≥1,024	64	512	64	Heterologous cross-reactions	Superinfection
9	40/M	31 Nov	22 Dec	128	16	32	128	<8	Heterologous cross-reactions	Superinfection

* YF, yellow fever; WN, West Nile; DEN-1, dengue 1; UGS, Uganda S.
† Fourfold higher titer to YF than to other antigens tested.

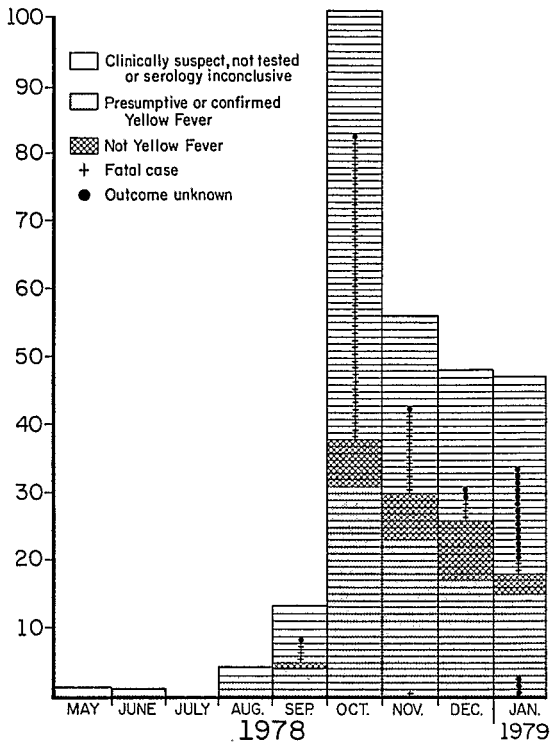

FIGURE 2. Epidemic curve, showing the monthly distribution of clinically suspect and serologically diagnosed yellow fever (YF) cases and deaths. Cases of jaundice shown by serologic tests not to be caused by YF are also shown.

conclusion could be reached, and in 27 cases YF infection was ruled out (at the level of sensitivity of the CF test).

Examples of the serological responses observed are given in Table 3. Responses were classified by serological pattern with respect to YF (monotypic, mixed homotypic, and heterologous cross-reaction, either non-specific or heterotypic) according to a previously published scheme.[11] This allowed an assessment of whether YF infection had occurred in the absence of previous heterologous flaviviral exposure or represented a flaviviral superinfection. As shown in Table 4, 88% of the cases had serological responses indicating primary YF infection. The frequency of primary infection was slightly (not significantly) higher in the 0- to 9-year age group and lower in patients over 40 years than in YF patients between 10 and 39 years; conversely, superinfection patterns were more frequent with advancing age.

TABLE 4

Frequency of primary and superinfection serologic responses by age, yellow fever cases, the Gambia, 1978–1979

Age (years)	No. (%) with primary yellow fever*	No. (%) with indeterminate or superinfection patterns†	Total
0–9	34 (94)	2 (6)	36
10–19	12 (86)	2 (14)	14
20–29	24 (86)	4 (14)	28
30–39	8 (89)	1 (11)	9
40+	2 (67)	1 (33)	3
Unspec. adult	2 (67)	1 (33)	3
Age unknown	1 (100)	0	1
Total	83 (88)	11 (12)	94

* Monotypic response.
† Mixed homotypic, nonsepcific heterologous, or heterotypic antibody responses.

Chronology and geographic spread of the outbreak

The epidemic curve is shown in Figure 2. The earliest clinically suspect and serologically diagnosed cases occurred in May and June 1978, respectively. Small numbers of cases were documented in August and September. The incidence rose dramatically in October, when the epidemic peaked. Cases continued to occur at a slightly diminishing rate through January, when the mass vaccination campaign was completed and surveillance activities ceased. As shown in Figure 2, the case-fatality rate (deaths/clinically suspect and laboratory-diagnosed YF cases with known outcome ×100) was highest in October (47%) and higher in September and November (27 and 27%, respectively) than in December (8%) and January (7%). These findings probably reflect increasing recognition of milder, nonfatal clinical forms of YF as the outbreak progressed and emphasize that the true incidence of YF between September and November was undoubtedly much higher than our data indicate.

The incidence of suspect cases shown by laboratory tests not be be YF was relatively constant throughout the epidemic (Fig. 2); there was also no difference in age or sex distribution between YF and non-YF cases (data not shown). The Gambia is hyperendemic for viral hepatitis, a disease with which YF was easily confused because our surveillance methods allowed detailed and expert clinical and historical observations in only a few cases. Jaundice from numerous other infectious and noninfectious causes also occurs in the Gambia.

Figure 3 shows the geographic distribution of clinically suspect and diagnosed YF cases. The

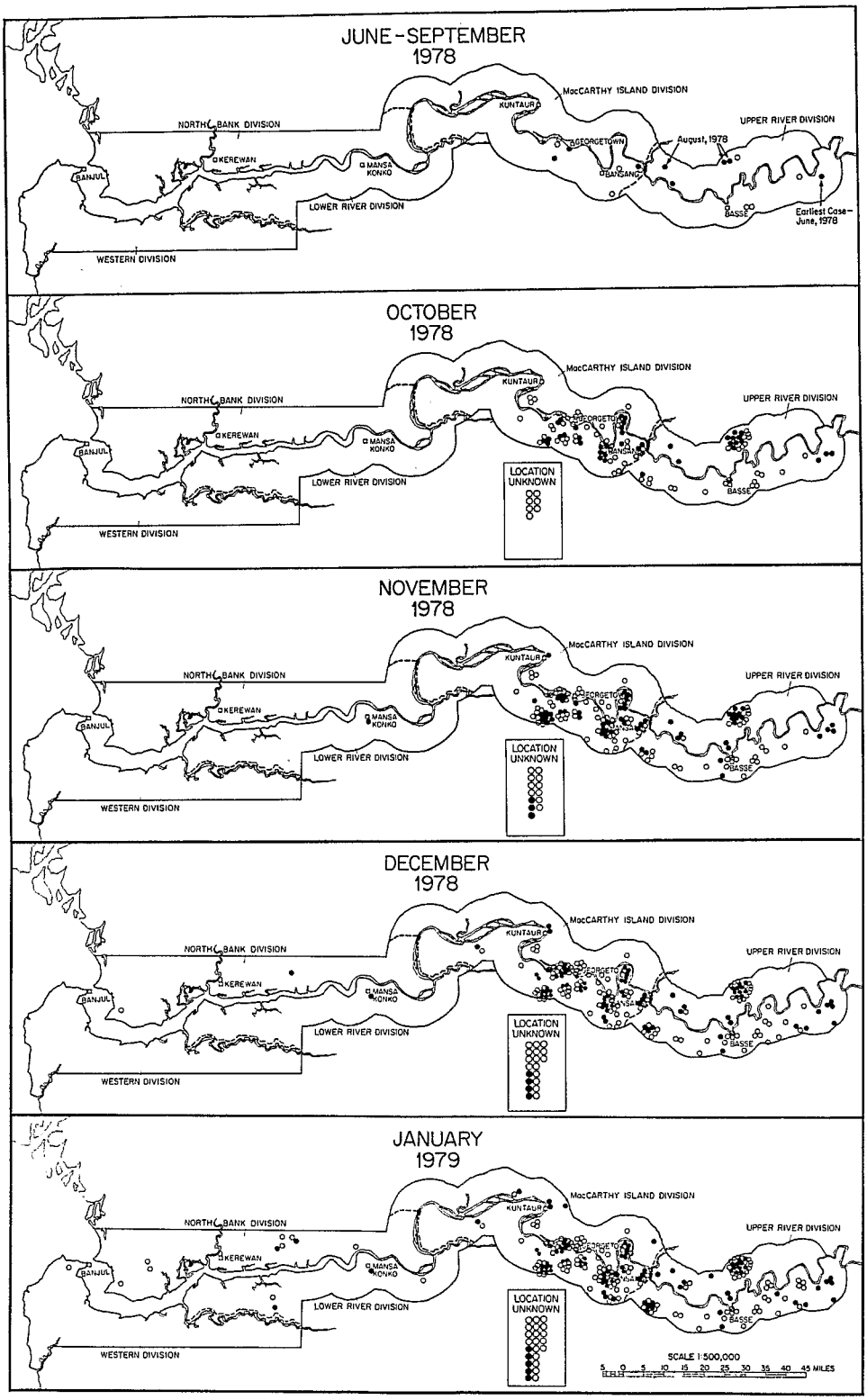

FIGURE 3. Location of serologically diagnosed yellow fever cases (black circles) and clinically suspect (open circles) cases, the Gambia, 1978–1979.

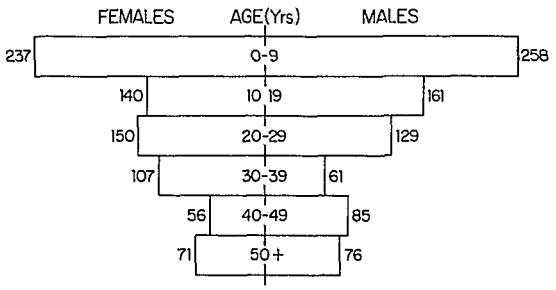

FIGURE 4. Age and sex distribution of 1,531 residents in nine villages in MacCarthy Island and Upper River Divisions surveyed in January 1979.

earliest known case with serological evidence of YF infection occurred at the eastern extreme of the country in June 1978. All cases occurring between May and October were confined to the Upper River and MacCarthy Island Divisions of eastern Gambia. In November a single case was identified in Mansa Konko, Lower River Division, and in December and January increasing numbers of cases were found in the western part of the country (Fig. 3). Intensive active surveillance activities were undertaken in the North Bank Division (NBD) of western Gambia in January 1979 because of the threat that YF might reach Banjul (where *Aedes aegypti* was believed to be abundant) and because of the location in the NBD of a popular tourist attraction, the village of Juffure (the heritage site in Alex Haley's *Roots*[12]). Nevertheless, both the distribution of cases shown in Figure 3 and the attack rates by geopolitical division (Table 5) clearly indicate that the epidemic was focused in the eastern half of the Gambia, with highest incidence (50–135 cases/100,000) in MacCarthy Island Division.

Census, interview, and serological surveys in nine villages

The nine survey villages, located in the area most severely affected by YF, ranged in size from 30–437 inhabitants, with a total population of 1,531. The age and sex distribution of the survey population is shown in Figure 4. A history of illness clinically suspected to be yellow fever was elicited in 67 cases, 13 (19.4%) fatal. In 39 cases a presumptive serological diagnosis was made (Table 6). Attack rates were calculated on the basis of serologically defined cases (low estimate) and of clinically suspect and serologically diagnosed cases (high estimate). The low and high estimates of clinical YF incidence in the survey villages were 2.5 and 4.4%, respectively, with a mortality rate of 0.8% (high estimate based on clinically suspect deaths). The incidence of infection during the outbreak, estimated on the basis of YF CF antibody prevalence, ranged from 9.1–66.7% in the survey villages (Table 6). There was a rough correlation between prevalence of CF antibody and attack rate in most villages. However, in two villages (Dingeri and Sutuma) the antibody survey results and morbidity data were discordant. We interpret this to reflect either sampling error or inaccurate historical information about disease.

Table 7 shows age- and sex-specific attack rates and the prevalence of YF CF antibodies (presumed to represent the incidence of recent YF viral infection) in the survey villages. The attack

TABLE 5

Yellow fever attack and mortality rates by geopolitical division, the Gambia, 1978–1979

Division	Population*	No. cases (deaths)		Estimated attack rate per 100,000		Mortality rate per 100,000§
		With serologic diagnosis	Total†	Low‡	High§	
MacCarthy Island	110,003	55 (1)	148 (48)	50.0	134.5	43.6
Upper River	80,944	35	76 (14)	43.2	93.9	17.3
North Bank	74,058	2	15 (2)	2.7	20.3	2.7
Lower River	42,914	2	3 (1)	4.7	7.0	2.3
Western	226,539	0	1	—	0.4	—
Unknown		0	1	—	—	—
Total	534,458	94 (1)	244 (65)	17.6	45.7	12.2

* 1973 census.
† Clinically suspect and with serologic diagnosis. Does not include 27 suspect cases shown by serologic tests not to be due to yellow fever (see Table 2).
‡ Based on number of serologically diagnosed cases.
§ Based on total cases (deaths) serologically diagnosed and clinically suspect.

TABLE 6

Incidence of yellow fever cases and deaths, case-fatality rates, and prevalence of yellow fever complement-fixing antibodies in villages of the Gambia, 1978–1979

Survey village (Fig. 1)	Population	Days elapsed between yellow fever vaccination and survey	No. cases (deaths)		Estimated attack rate (%)		% mortality (high estimate)	Case-fatality rate (%)	No. CF§ pos./tested (% pos.)
			With serologic diagnosis	Total*	Low†	High‡			
Sere N'Gaba	129	5	9	14 (3)	7.0	10.9	2.3	21.4	20/47 (42.6)
Sukuta	86	1	6	8 (1)	7.0	9.3	1.2	12.5	14/31 (45.2)
Sambuldu	73	2	2	4 (0)	2.7	5.5	—	—	28/42 (66.7)
Modi Jabbu	147	4	1	8 (3)	0.7	5.5	2.0	37.5	13/47 (27.7)
Farraba	256	4	6	10 (2)	2.3	3.9	0.8	20.0	11/46 (23.9)
Sere N'Gai	437	6	8	15 (4)	1.8	3.4	0.9	25.7	18/83 (21.7)
Sutuma	138	8	3	3 (0)	2.2	2.2	—	—	4/44 (9.1)
Sare Bojo	235	3	4	5 (0)	1.7	2.1	—	—	28/87 (32.2)
Dingerai	30	0	0	0	0	0	—	—	10/21 (47.6)
Torro Bah	—	0	—	—	—	—	—	—	12/64 (18.8)
Darusalame	—	0	—	—	—	—	—	—	2/50 (4.0)
Alhamdu	—	1	—	—	—	—	—	—	4/29 (13.8)
Juffure	—	1	—	—	—	—	—	—	3/21 (14.3)
Manduar	—	0	—	—	—	—	—	—	22/86 (25.6)
Total	1,531		39	67 (13)	2.5	4.4	0.8	19.4	189/698 (27.1)

* Clinically suspect and with serologic diagnosis.
† Based on number of serologically diagnosed cases.
‡ Based on total cases (deaths) serologically diagnosed and clinically suspect.
§ Yellow fever complement-fixation titer ≥16.

rate was highest in the 0- to 9-year age group (6.7%) and decreased with advancing age to 1.7% in persons over 40 years. The disease incidence in persons <20 years of age was significantly greater ($P < 0.01$) than that in persons >20 years. The attack rate was higher (not significantly) in males in all but the ≥40-year age group. The prevalence of CF antibodies also was highest in children 0–9 years old and declined with age. The antibody prevalence in persons <20 years of age was significantly higher ($P < 0.01$) than in older adults. CF antibody prevalence was higher in males in all but one age group (30–39 years). The differences in sex-specific antibody prevalence are significant ($P < 0.05$) in all but the 10- to 19-year age group.

There were 13 deaths with jaundice in the nine survey villages between September 1978 and January 1979; none was decumented by laboratory tests. Assuming all 13 deaths were due to YF, the mortality rate was 1.0% in males, 0.7% in females, and 0.8% overall. The mortality rate was

TABLE 7

Age and sex-specific yellow fever attack and infection rates, survey villages, the Gambia

Age (years)	Attack rate* (%)			Infection rate† (%)		
	Males	Females	Total	Males	Females	Total
0–9	7.0	6.3	6.7	52.8	33.3	43.0
10–19	5.6	4.3	5.0	39.5	38.7	39.0
20–29	3.9	2.7	3.2	44.1	23.8	30.9
30–39	4.9	1.9	3.0	10.5	39.4	28.9
≥40	0.6	3.1	1.7	23.1	17.0	20.5
Total	4.7	4.1	4.4	35.9	29.5	32.6

* High estimate (serologically diagnosed and clinically suspect cases/population × 100).
† Yellow fever CF (titer ≥16) prevalence. The number of sera tested in each age-sex grouping ranged from 19 to 63, with a median of 34; 448 sera were tested.

TABLE 8

Frequency of primary yellow fever (YF) infection and flaviviral superinfection in YF cases and in persons without a history of illness in two villages (Sukuta and Sambuldu), the Gambia

Serologic pattern	No. ill with jaundice/total population [attack rate (%)]	No. without illness and seropositive/tested* (% pos.)	Inapparent: apparent infection ratio
Primary YF infection†	4/188 (2.1)	2/51 (3.9)	2:1
Flaviviral superinfection‡	4/188 (2.1)	24/51 (47.1)	22:1
Both patterns	8/188 (4.3)	26/51 (51.0)	12:1
Undetermined, inconclusive, or negative§	4/188 (2.1)	25/51 (49.0)	—

* Denominator differs from that in Table 6 because only individuals tested for complement-fixing and neutralization antibodies to YF and seven other flaviviruses are included in the analysis.
† YF complement-fixation (CF) titer ≥ 16; YF neutralization (N) titer ≥ 20; no detectable CF or N antibodies to Zika, West Nile, Uganda S, Usutu, Ntaya, Koutango, or Banzi viruses.
‡ Heterologous cross-reactions by CF and N tests between YF and one or more of the flaviviruses tested (see above).
§ Not tested, anticomplementary reaction, or YF titer ≤ 8.

highest in children 0–9 years (1.6%) and lower in teenagers 10–19 (1.3%) and in young adults 20–29 (0.4%). There were no deaths in adults over 30 years. The case fatality rates in persons 0–9 and 10–19 years of age were similar (24 and 27%) and were higher than in persons 20–29 (11%; not statistically significantly different) and also higher than in persons >30 years (0%, again not statistically significantly different).

In order to define the ratio of inapparent to apparent YF infections, we examined CF and plaque reduction neutralization test results in persons with and without a history of illness in two survey villages, Sukuta and Sambuldu. These villages were selected for analysis because the attack rates were high and because YF vaccinations had been performed only 1 and 2 days prior to bleeding (as compared to 3–8 days in other survey villages with YF cases). In the two villages there were eight cases of YF which could be serologically defined, four with primary YF infections (monotypic CF and neutralizing [N] antibody patterns) and four with superinfection (mixed homotypic or heterologous cross-reaction) patterns. The incidence of primary and superinfection without illness was 3.9 and 47.1%, respectively (Table 8). The ratio of inapparent:apparent infections was estimated to be 12:1 overall, 2:1 in persons experiencing primary YF infection, and 22:1 in persons with serologic patterns indicating previous exposures to one or more heterologous flaviviruses. The flaviviruses responsible for previous infection were partially elucidated (see *Neutralizing antibody prevalence* below).

In addition to the nine survey villages in the severely affected zone, serological surveys were conducted at five locations in western Gambia (Fig. 1 and Table 6). The CF antibody prevalence ranged from 4.0 to 18.8% in four villages in North Bank Division and was 25.6% (comparable to several sites in the epidemic region) at Manduar in Lower River Division.

TABLE 9

Yellow fever complement-fixation (CF) and plaque-reduction neutralization test (PRNT) results, selected villages, the Gambia, 1979

Village (see Fig. 1)	No. positive/tested (% pos.)*		Vaccination (no. days before sample)
	CF	PRNT	
Sambuldu	28/42 (66.7)	28/29 (96.6)	Yes (2 days)
Dingerai	10/21 (47.6)	20/22 (90.9)	No
Sukuta	14/31 (45.2)	33/33 (100)	Yes (1 day)
Manduar	22/86 (25.6)	69/71 (97.2)	No
Torro Bah	12/64 (18.8)	14/38 (36.8)	No
Darusalame	2/50 (4.0)	6/26 (23.1)	No

* Sera tested against YF (Asibi) virus at final dilutions of 1:2, 1:20, 1:200. Of the 170 sera with detectable YF neutralizing antibodies, 121 (71%) had antibody titers ≥200 and 143 (84%) had titers ≥20.

Neutralizing antibody prevalence

Plaque-reduction neutralizing-antibody prevalences in six villages in which vaccinations either had not been performed or had been done 1–2 days before bleeding are shown in Table 9. In two villages (Darusalame and Torro Bah) in the North Bank Division, the neutralizing-antibody prevalence was 23 and 37%, respectively, corresponding to relatively low rates of CF antibody. In Manduar (Lower River Division) and in three villages in eastern Gambia, however, 91–100% of the population was immune. This indicated extremely high rates of YF virus infections, which,

TABLE 10

Prevalence of neutralizing antibodies to flaviviruses in residents of two villages (Sukuta and Sambuldu) without a history of clinical yellow fever (YF vaccinations were performed 24–28 hours prior to bleeding)

Age	No. tested	Percent positive*							
		YF	ZIKA	WN	NTA	USU	UGS*	KOU	BAN
0–9	5	100	40	0	0	0	0	0	0
10–19	9	100	89	0	0	33	33	0	33
20–29	18	100	94	22	28	39	17	11	17
≥30	30	97	90	33	17	33	27	27	33
Total	62	98	90	23	16	34	23	16	26

* YF = yellow fever; WN = West Nile; NTA = Ntaya; USU = Usutu; UGS = Uganda S; KOU = Koutango; BAN = Banzi.

if not acquired during the 1978–1979 outbreak, was at least relatively recent (since over 90% of children under 10 years of age bled in Sambuldu, Sukuta, and Dingerai had neutralizing antibodies).

In the villages (Sambuldu and Sukuta) used to define the YF inapparent:apparent infection ratio, the prevalence of N antibodies to heterologous flaviviruses was determined (Table 10). Zika virus appeared to be most frequently responsible for prior infections; over 90% of individuals over 10 years old had Zika antibodies. Thirty-eight of 56 (68%) Zika antibody-positive individuals had titers ≥160. Antibody titers ≥160 were found only in 2 of 10 individuals positive to Ntaya virus, and in 1 of 21 individuals positive to Usutu virus.

Non-human primate serosurvey

No virus was recovered from blood, spleens, or livers of 19 monkeys. Sixteen monkeys (84%) had YF HI and N antibodies and 6 (32%) had CF titers ≥16 (Table 11). Serological reactions were specific for YF in at least 14 of the 16 seropositive animals; one monkey had evidence of Zika viral infection. Juveniles and adults had similar antibody prevalence rates. Seropositive animals were collected both in eastern (13/16 N-positive) and western Gambia (3/3 N-positive).

Isolation of yellow fever virus from a patient in North Bank Division, January 1979; evidence for Aedes aegypti-*transmitted infection*

During active surveillance activities, attention was drawn to the village of Minteh Kunda, population 890 (Fig. 1), where a 40-year-old man had died on the 7th day of illness (10 January) with a syndrome compatible with YF. On 12 January a house-to-house search for cases in the village revealed two acutely sick persons with onsets of fe-

TABLE 11

Prevalence of yellow fever (YF) antibodies in wild monkeys, the Gambia, 1979

Species	Age	Number tested	Number (%) YF positive*				
			YF monotypic		Indeterminate or heterotypic		
			HI	CF	HI	CF	N
Colobus badius	Ad	11	9 (82)	1 (9)			9 (82)
	Juv	1					1 (100)
Cercopithecus aethiops	Ad	3	2 (67)	2 (67)	1 (33)	1 (33)	3 (100)
	Juv	4	3 (75)	2 (50)	1† (25)		3 (75)
Total	Ad	14	11 (79)	3 (21)	1 (7)	1 (7)	12 (86)
	Juv	5	3 (60)	2 (40)	1† (20)		4 (80)
	Total	19	14 (74)	5 (26)	2 (11)	1 (5)	16 (84)

* HI ≥ 20, CF ≥ 16.
† Homotypic HI antibody to Zika virus, negative to YF by N test.

ver 2–3 days before. Blood samples were obtained, and yellow fever virus (strain 79H-327) was isolated from a sample from one of the patients and identified by CF and N tests. The patient was a 20-year-old man with fever, relative bradycardia, headache, severe weakness, lumbosacral pain, conjunctival injection, and red tongue at the tip and edges. Jaundice developed subsequently. The patient was re-bled during convalescence (on 28 January), and a CF test serologic conversion to YF virus from a titer of <8 to 32 was demonstrated.

An *Aedes aegypti* larval survey in the village revealed a high Breteau index (104 positive containers/100 houses).[13] Biting collections using baitmen were conducted between 1500 and 2000 hours with a total of 80 manhours expended. Sixty-four female *Ae. aegypti* were collected and tested for virus at the Pasteur Institute, Dakar. Two strains of YF virus were recovered.[13] No sylvatic YF vectors were captured in this village or at any other location in the Gambia in January, despite considerable effort.[13]

Mass vaccination campaign and vaccination efficacy

In December 1978, a country-wide vaccination campaign was begun. The vaccine used was 17D YF vaccine manufactured at the Pasteur Institute, Dakar, Senegal; it was generally administered by jet-injector, but sometimes, when the equipment failed, by syringe and needle. By 31 January over 546,000 vaccinations had been done, representing coverage of approximately 95.5% of the estimated 1978 population. From the antibody surveys conducted in several villages in eastern Gambia, naturally-acquired immunity rates were so high by late January that further interhuman YF virus transmission was precluded and vaccinations were unnecessary (Table 8).

Because most areas of the Gambia are remote from towns with electricity and mechanical refrigeration equipment, 17D YF vaccine was brought to the field in freeze-packs ("cold dogs"), and the cold chain was often tenuous and threatened by interruption. It was therefore important to assess the efficacy of the vaccination campaign and to investigate the potency of vaccine that had been taken to remote areas.

Neutralization tests were performed on sera from 58 individuals at Torro Bah and Darusalame villages (see Fig. 1) bled before and 25 days after jet-injector vaccination. Seventeen individuals (29%) had YF N antibodies in their sera before vaccination. (Five of these showed a rise in N antibody titer after vaccination.) Of the remaining 41 persons without prevaccination antibodies, 38 (93%) seroconverted. The seroconversion rate was similar in those (13 persons) withour prior heterologous flaviviral experience (92%) and in those (28 persons) with prevaccination heterologous HI flaviviral antibodies (93%). Seroconversion was defined as a rise in PRNT titer from undetectable in undiluted serum to ≥2 (i.e., 90% plaque reduction by undiluted serum mixed with 100 plaque-forming units of 17D YF virus). The distribution of titers in postvaccination sera from 41 nonimmune vaccinees was: titer = 2, 14 persons; titer = 20, 17 persons; titer ≥200, 7 persons.

At least two ampoules of each of four lots of 17D vaccine were titrated after having been brought to the field during the vaccination campaign, and the titers were compared to initial titers obtained after manufacture of each lot. The potency was reduced in some ampoules but equal or higher than original titers in others. In every case, the potency of vaccine brought to the field was adequate and met WHO specifications.

Investigations conducted in neighboring Senegal

In the villages of Touba M'Boyenné and Sam Yoro Gueye, the prevalence of YF CF antibodies in persons with a history of illness (25%) was identical to that in controls without illness. Overall, 14% of sera collected in Casamance, 4% at Vélingara, and 2% in villages on the northern border or the Gambia were Yf seropositive. A high prevalence of Orungo CF anitbodies was found, but there was no association with history of illness. Surprisingly, 8 of 29 sera from a single village (Touba M'Boyenné) contained IFA antibodies to Ebola virus at titers ≥4 (3 sera positive at titers ≥16). There was no clear evidence for an association between Ebola virus infection and history of illness.

Orungo virus infections

During an outbreak of yellow fever in Nigeria in 1973–1974, a high frequency of concomitant infections with an unrelated virus (Orungo) was documented.[14] This orbivirus had previously been associated with epidemic febrile illness and pos-

TABLE 12

Prevalence of complement-fixing (CF) and neutralizing (N) antibodies to Orungo virus (UGMP-359), by village, the Gambia, 1979

Village	Orungo virus No. CF pos./tested (% pos.)	No. N pos./tested (% pos.)
Dingerai	13/21 (61.9)	18/23 (78.3)
Sare Bojo	35/61 (57.4)	—*
Manduar	34/62 (54.8)	55/70 (78.6)
Sere N'Gaba	24/46 (52.2)	—
Sambuldu	20/42 (47.6)	30/42 (71.4)
Farraba	20/47 (42.6)	—
Modi Jabbu	18/47 (38.3)	—
Sere N'Gai	25/82 (30.5)	—
Sukuta	8/30 (26.7)	22/36 (61.1)
Juffure/Alhamdu	4/17 (23.5)	—
Sutuma	9/45 (20.0)	—
Torro Bah/ Darusalame	5/38 (13.2)	—
Total	215/538 (40.0)	125/171 (73.1)

* Not tested.

TABLE 13

Prevalence of Orungo viral CF antibodies among cases clinically suspected to be yellow fever (YF), by YF serodiagnostic category, the Gambia, 1978–1979

Yellow fever serologic interpretation	No. cases	No. Orungo pos./tested	%
Presumptive/confirmed	94	44/93	47.3
Inconclusive	10	5/10	50.0
Negative	27	16/26	61.5

sible deaths,[15] and although jaundice was not a described feature of the illness caused by this virus it was of interest to include Orungo in the sero-epidemiological analysis of the Gambian outbreak.

A high prevalence of Orungo CF and N antibodies was found in the village populations sampled (Table 12), and many sera contained CF antibodies to both YF and Orungo viruses. The prevalence of Orungo CF antibodies was not significantly ($P > 0.2$) higher in sera from patients with jaundice who were suspected of having, but were not shown to have, YF (61%) than in sera from persons with serologically confirmed or presumptive cases (47.3%), as shown in Table 13. Three serological conversions to Orungo were documented in patients with jaundice (Table 14). In two cases, seroconversion to YF also was shown. The chronology of illness and change in Orungo antibody titer suggested that the virus was not implicated in any of the patients' illnesses.

DISCUSSION

Yellow fever is a recurrent epidemic disease in West Africa. During the last decade, important outbreaks have been recorded in 1969 (involving more than 15,000 cases in Nigeria, Upper Volta, Ghana, Mali, and Togo[16]), and in 1970[17] and 1974[14,18] in Nigeria (involving an estimated 786 and 45 cases, respectively). The present epidemic in the Gambia is an important one in terms of morbidity and mortality. Although only 244 clinical cases (65 fatal) were recognized by various case-finding methods (Table 5), detailed village surveys (Table 6) indicated high attack rates (2.5–4.4%), with a mortality rate, based on clinically suspect cases, of 0.8%. Assuming for purposes of discussion that the incidence in the survey villages is representative of eastern Gambia as a whole (MacCarthy Island and Upper River Divisions, population 190,947), there may have been as many as 8,400 YF cases and 1,600 deaths during the epidemic.

The incidence of clinical YF and YF virus infection (determined by CF antibody prevalence) was highest in children 0–9 years of age and was significantly higher in persons <20 than in those >20 years of age (Table 7). This is best explained by the high frequency of primary YF infection in young persons. Eighty-eight percent of all serologically diagnosed clinical YF cases were in individuals with primary infections (Table 4). As the frequency of serological responses indicating flaviviral superinfection increased with age, the incidence of disease decreased.

A possible source of misinterpretation of the CF antibody prevalence data was the administration of 17D YF vaccine up to 8 days before sera were obtained in the survey villages (Table 6). Yellow fever vaccine has been shown to induce seroconversion or significant CF antibody titer rises in up to 46% of persons with prevaccination YF or heterologous flavivirus experiences,[8] but not in immunological virgins. Thus, 17D YF vaccination may have been responsible for some of the CF seropositives detected among persons with flaviviral superinfection patterns (Table 4). Consequently, we were able to analyze the effect of heterologous immunity on attack rate and inapparent:apparent infection ratio only in a small

TABLE 14

Cases of suspected yellow fever in which serologic conversions to Orungo virus were demonstrated, probably unrelated to the current illness

Case	Age	Sex*	Illness onset	Serum	Complement-fixation titer*					
					YF	ZIK	WN	D-1	UGS	ORU
1	24	M	Oct	22 Nov	<8	<8	<8	<8	<8	<8
				7 Dec	<8	<8	<8	<8	<8	256
				27 Jan	<8	<8	<8	<8	<8	32
2	7	M	29 Oct	17 Nov	<8	<8	<8	<8	<8	<8
				7 Dec	32	<8	<8	<8	<8	8
				27 Jan	16	<8	<8	<8	<8	128
3	Ad	M	Nov	17 Nov	64	<8	<8	<8	<8	<8
				7 Dec	64	<8	<8	<8	<8	<8
				27 Jan	128	<8	<8	<8	<8	256

* YF, yellow fever; ZIK, Zika; WN, West Nile; D-1, dengue type 1; UGS, Uganda S; ORU, Orungo.

sample of villagers who received 17D YF vaccine 1–2 days before the serologic survey. In this group, primary YF infections were infrequent. The ratio of inapparent to apparent infection was approximately 10 times greater in persons with prior flaviviral experience than in immunological virgins. The flaviviruses responsible for the background of immunity in this population were partially elucidated by N tests (Table 10). Homologous (YF) immunity was present in nearly 100% of the inhabitants of villages in eastern Gambia, and this finding was not explained by administration of YF vaccine (Tables 9, 10). Homologous (YF) immunity was therefore probably responsible for the reduction in disease incidence in many older individuals and in those with superinfection serological responses, although heterologous flaviviral immunity (particularly to Zika virus; Table 10) may have also played a role. Because we were unable to study either the immunological background of fatal cases or the relative clinical severity of illness, we could not determine to what extent background immunity influenced outcome of infection. The higher case-fatality rate in young persons suggested, however, that the disease was more severe in persons without prior flaviviral experience.

The incidence of disease and infection was higher in males than in females. This sex difference has been noted in other outbreaks of sylvatic YF in West Africa.[19] Although we have no supporting data, we have observed that males tend to remain out-of-doors and outside village confines for longer periods after sundown than females. This behavioral difference may explain the increased exposure of males to sylvatic vectors of YF virus.

The geographic and chronologic distribution of YF cases, the high prevalence of immunity in nonhuman primates, and information from our entomologic investigations[13] all indicate that this was, at least at the beginning, an epidemic of sylvatic YF. As the outbreak progressed, interhuman transmission was also assured by domestic *Ae. aegypti,* at least in those localities where this vector was prevalent. The outbreak peaked during the last months of the rainy season, at a time when one would expect peak populations of sylvatic vectors to be present.[7,20] Limited human bait collections made in November 1978 at localities in MacCarthy Island Division by workers of the Medical Research Council, Fajara documented the presence of two potential sylvatic vectors (*Aedes furcifer-taylori* group).[21] In addition, *Ae. luteocephalus* larvae were recovered from tree holes at Wallikunda, which had been artificially flooded in January.[13] Extensive surveys in January showed domestic *Ae. aegypti* (breeding in water storage jars) to be absent in 11 villages or present at a very low rate (Breteau indices < 5) in two of 21 villages in MacCarthy Island and Upper River Divisions. However, the peridomestic potential breeding sites for *Ae. aegypti* were generally numerous (although in January dry), and the prevalence of this species could have been much greater during the rainy season. Entomologic investigations were conducted in six of the nine census-serosurvey villages;[13] *Ae. aegypti* Breteau indices were 0 in three villages (Sambuldu, Sikuta, Sare N'Gaba), and indices of 1.5, 9.6, and

14.0 were found in Sere N'Gai, Sare Bojo, and Modi Jabbu, respectively. In two of 21 localities surveyed in eastern Gambia, a high risk of *aegypti*-borne YF was determined on the basis of Breteau indices >50. Similarly, in the North Bank Division, *Ae. aegypti* breeding was documented in January in three of six localities, including one (Minteh Kunda) with a very high Breteau index (104.0), where YF virus was isolated from a sick patient and from two pools of *Ae. aegypti* mosquitoes collected on 12 January, at a time when sylvatic vectors were absent.[13] This observation, and the laboratory documentation of 15 YF cases in the Gambia with disease onset in January, suggest that, with the rapid decline of sylvatic vector populations in the early dry season, YF virus transmission continued by the agency of *Ae. aegypti* vectors in localities supporting domestic breeding.

The occurrence of the first recognized cases at the extreme eastern end of the Gambia in May and June suggests that the virus may have been introduced as part of an epizootic wave in monkey populations inhabiting gallery forests along the Upper River Gambia. The known occurrence of an epizootic at Kédougou, 125 miles upriver from the Gambia, since at least December 1976,[5–7] supports this suggestion. As pointed out in a companion paper,[13] unusual prolongation of the rainy season during this interval may have allowed virus activity to expand northwest from the Kédougou focus.

The recent findings that YF virus is transovarially transmitted in *Ae. furcifer-taylori* in nature[5–7] suggest that the virus may persist in arthropod reservoirs in the Gambia. The high prevalence of natural or vaccine-induced immunity in the human and monkey populations, however, make it unlikely that a high rate of virus transmission will occur in 1979–1980.

The successful efforts to rapidly vaccinate the population of the Gambia are noteworthy, and reflect the experience and expertise gained during the smallpox eradication campaign of the 1960s. In a small group of individuals, a vaccine-induced seroconversion rate of 93% was demonstrated; this rate is somewhat lower than rates described in other studies.[22,23] The methods used to assess immunity in these studies have differed; we used the PRNT; others have used the mouse protection or HI test. Many other factors, such as the age distribution and nutritional status[24] of the population, as well as variations in sampling, could account for observed differences in seroconversion rates. Our study differed from other studies in that we were assessing vaccine efficacy under true field conditions rather than as part of a planned study.

The present outbreak reminds us that YF continues to be a major threat in Africa. The high attack rate, and the case-fatality rate of nearly 20% in this epidemic, illustrate the public health importance of YF and contrast with the relatively rare occurrence of other viral hemorrhagic infections, such as Lassa fever, which have been highly publicized in recent years. The abundance of the classical urban vector of YF, *Ae. aegypti,* in cities and larger towns in West Africa raises the spectre of large urban epidemics of the disease, the risk of which is attested to by the intermittent occurrence of urban, *aegypti*-borne outbreaks of chikungunya. These observations are especially disturbing because a safe, easily administered YF vaccine has been available for decades and can be administered effectively (as shown by our study and many others) under field conditions. Despite its availability and relatively low cost, 17D vaccination has been used in many African countries only in response to disease outbreaks. As multiple immunization programs are considered for use in Africa, it would be appropriate to include 17D as an integral component.

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