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# REPORT ON A VISIT TO LIBERIA TO INVESTIGATE THE YELLOW FEVER SITUATION 21 July - 9 August 1967

by

Dr Y. Robin[1]

and

Mr G. Pichon[2]
WHO Consultants



[1] Virologist, Pasteur Institute, Dakar.

[2] Medical entomologist, Office de la Recherche scientifique et technique Outre-Mer.

CONTENTS

## 1. PURPOSE OF THE VISIT

Following its notification of two cases of yellow fever, confirmed 10 June 1967 by the Pathology Laboratory of the Pasteur Institute, Dakar (Professor R. Camain), the Government requested the assistance of a consultant in studying the situation.

Dr Y. Robin and Mr G. Pichon, an epidemiologist and an entomologist, were appointed for the consultantship, which took place between 21 July and 9 August 1967.

The aim of the visit was:

(1) to determine the epidemiological and entomological circumstances which had given rise to the two cases of yellow fever;

(2) to assess the importance and the risk of spread of the focus;

(3) to determine suitable measures to control the existing focus, and

(4) to make recommendations for measures to prevent further outbreaks of yellow fever.

## 2. SOME GEOGRAPHICAL FEATURES WITH A POSSIBLE INFLUENCE ON THE YELLOW FEVER SITUATION

### 2.1 General

The country, which has an area of 43 000 square miles, can be divided into three belts lying parallel to the coast; they are, from south to north:

- a coastal belt, low-lying about 50 miles wide and 350 miles long, with creeks, shallow lagoons and mangrove marshes;
- a forest plateau with an average elevation of 1500 feet;
- a mountain plateau about 2500 feet high, with some peaks rising above 4000 feet (Mount Nimba, 4200 feet; Mount Watesi, 4500 feet).

This mountain mass is the source of six rivers which flow from north-east to south-west, namely: the Cavalla, the Cestos, the St John, the Lofa and the Mano.

The temperature is not very high: it rises to 90°F in February and March, and falls to 65°F during August in the interior of the country. The mean annual temperature is about 82°F.

The yearly rainfall is among the highest in West Africa: it can reach 200 inches per year in the coastal belt (see Annex 3(A) for a pluviogram recorded in Ganta in 1927-1930).

There are two distinct seasons: a rainy season, from April to November, and a dry season, from December to April.

The average relative humidity in the coastal belt is 82 per cent. during the rainy season and 78 per cent. during the dry season.

There is an extensive communications system, comprising:

Ports: Monrovia (Free Port), Buchanan, Greenville and Harper.

Airports: Robertsfield (international services) and Payne Airfield (internal services).

Railways: Four lines serving the iron mines, the Bomi Hills, the Man River, and the Nimba and Bong Mines.

A network of 2000 miles of primary and secondary roads, of which 1000 miles are all-weather (200 miles paved and 800 miles laterite).

From Monrovia, a road runs north-east to Gbanga, where it forks north through Zorzor and Voinjama to Sierra Leone, and east to Guinea and the Ivory Coast.

## 2.2 Demographical data

The last census taken in 1963 indicated a population of 1 016 443 with a natural rate of increase of 11.2 per thousand. The population in 1967 can therefore be estimated at 1 070 000. The population is not equally distributed between the nine counties which have constituted the administrative divisions of the country since 1964.

| Counties | Administrative Capital | Total Population | Under 10 years[1] | Over 10 years | % of total population |
|---|---|---|---|---|---|
| Grand Bassa | Buchanan | 139 100 | 41 600 | 97 500 | 13.0 |
| Grand Cape Mount | Robertsfield | 34 240 | 10 240 | 24 000 | 3.2 |
| Maryland | Harper | 66 340 | 19 840 | 46 500 | 6.2 |
| Montserrado | Monrovia[2] | 271 780 | 81 280 | 190 500 | 24.4 |
| Sinoé | Greenville | 58 850 | 17 600 | 41 250 | 5.5 |
| Nimba | Saniquellie | 169 060 | 50 560 | 118 500 | 15.8 |
| Grand Gedeh | Tchien | 62 060 | 18 560 | 43 500 | 5.8 |
| Bong | Gbang | 139 100 | 41 600 | 97 500 | 13.0 |
| Loffa | Voinjama | 129 470 | 38 720 | 90 750 | 12.1 |
| Total | | 1 070 000 | 320 000 | 750 000 | |

[1] Calculated on the basis of 30 per cent. of the total population (1963 census).
[2] National capital

The mines and the rubber plantations attract the majority of the inhabitants who are settled along the roads that have been built to transport products to the coast, and to Monrovia, in particular. Thus, more than half of the total population live in the three counties of Loffa, Bong and Montserrado. The distribution of the population by ethnic groups is shown in Map I in the Annex.

2.3 The Salayea area

All the confirmed or very probable cases were reported in the Salayea area (see Map II).

The village of Salayea is situated in Loffa County, on the road between Gbanga and Zorzor, 25 miles from Gbanga, seven-and-a-half miles from Zorzor and 10 miles from the frontier with Guinea. The area is deeply undulated and lies at about 1000 feet above sea level. The soil is laterite and the forest sparse, with extensive clearings. The climate is typically humid and tropical but is milder than in the coastal belt. There are two distinct seasons, with most rainfall occurring between April and November.

The rainfall is fairly heavy, about the same as that recorded in Ganta (see Annex 3 A). The following daily rainfall figures were recorded in the month of May by Mr Louis Bowers, Jr., of the Lutheran Training Institute:

| | | |
|---|---|---|
| 1 ..... 14 mm | 11 ..... 9 mm | 21 ..... 0 |
| 2 ..... tr. | 12 ..... 43 mm | 22 ..... 27 mm |
| 3 ..... 45 mm | 13 ..... 12 mm | 23 ..... 1 mm |
| 4 ..... 17 mm | 14 ..... 0 | 24 ..... 0 |
| 5 ..... tr. | 15 ..... 44 mm | 25 ..... 10 mm |
| 6 ..... 17 mm | 16 ..... 0 | 26 ..... 1 mm |
| 7 ..... 1 mm | 17 ..... 3 mm | 27 ..... 0 |
| 8 ..... 0 | 18 ..... 27 mm | 28 ..... 0 |
| 9 ..... 0 | 19 ..... tr. | 29 ..... 0 |
| 10 ..... 0 | 20 ..... 0 | 30 ..... 0 |
| | | 31 ..... 4 mm |

Total: 275 mm

Unfortunately, it was not possible to obtain equally detailed data for April. However, everyone questioned agreed that the rainfall in April had been normal for the time of year, i.e. between 180 and 200 mm. (See Annex 3(B) for rainfall figures recorded in Voinjama in 1962 and 1963).

At the time of the survey (end of July - beginning of August) the temperature was cool, falling at night to below 68°F which was not ideal for capturing female insects on human bait. In addition, it rained almost every day. The total rainfall in July was 220 mm.

Salayea village has a population of about 1500. The St. Paul River flows by the village at a distance of about a quarter of a mile.

The Lutheran Training Institute, where two of the three fatal cases occurred, lies three miles north of Salayea, in open grassland with a few remaining clumps of trees.

## 3. ENTOMOLOGICAL SURVEY

Following a survey in 1956 on the mosquitos of Liberia, Peters reported that Aedes aegypti was uncommon in the country. He found the following species of Aedes, each belonging to the subgenus Stegomyia:

Aedes simpsoni (Theobald) 1905
Aedes apicoargenteus (Theobald) 1910
Aedes africanus (Theobald) 1901
Aedes luteocephalus (Newstead) 1907
Aedes vitatus (Bigot) 1861

The purpose of the present survey was twofold: (1) detection of Aedes aegypti larvae and (2) typing the adult mosquitos collected by various methods.

### 3.1 Detection of Aedes aegypti larvae

#### 3.1.1 General data on water collection and larval rates

It is well known that the different methods of water collection have a considerable influence upon the proliferation of Aedes aegypti (Brès et al., 1967). In fact, this appears to be the major factor in rural areas. The method of water collection depends on two basic conditions (G. Pichon and J. Hamon, 1967):

(1) Scarcity of water and/or the distance to supply points, obliging the people to use it sparingly and to keep it as long as possible - a favourable condition for the complete development of Aedes aegypti larvae. People living in areas where there

are water problems generally keep supplies in large jars, either buried or half buried, which are never completely emptied and therefore constitute a favourite breeding place for Aedes aegypti.

(2) The particular customs of the local ethnic group, which explain the presence in large numbers, or the complete absence of Aedes aegypti in areas where water supply conditions are identical. It has been established that the areas of distribution of Aedes aegypti often corresponds exactly with the areas inhabited by particular ethnic groups (Pichon et al., 1967, a, b, c, d, e, f, g, h) (Hamon et al., 1967).

In the survey area, there seems to be no particular problem of water supply. Each village has several wells and the water is not far below the ground even during the dry season. During the rainy season, an increasing number of villagers avoid the task of fetching water by installing 40 gallon drums under the gutters of their houses. Thus, at the time of the survey, the villagers of Salayea were drinking and cooking with rainwater; they used the river, about 200 yards away, for washing only.

There are two ethnic groups in the survey area: the Kpelle in the south and the Loma in the north.

3.1.2 Water collection in the Kpelle and Loma districts

At first view, the ethnic factor did not seem to apply in the survey area, as both the populations, the Kpelle and the Loma, appeared to be using open metal drums for water collection.

The villages of Salayea, Zolowo and Wenshu in the Kpelle district, and Zorzor, Zorzor Leper Colony, Konia and Yeala in the Loma district (Schwab, 1947; Brasseur and Savonnet, 1960) were surveyed. In the localities along the main road, 80 per cent. of the houses were square constructions in permanent material or mud, with a hipped corrugated iron roof. The other dwellings which are becoming less common today were traditional round huts in mud with a high conical straw roof; a ceiling of loosely arranged branches separates the lower part of the hut from the roof, forming a loft and food store.

As it is shown in Annex 2C, water was mainly stored indoors in pails and basins. The use of earthenware pots has virtually been abandoned even in villages far from the main road, such as Yeala or Zolowo. The water stored in these containers was for daily needs and as it was renewed several times a day, no mosquito larvae were found in these potential breeding places.

In all the localities surveyed, a fairly large number of open 40 gallon drums were noted. Such drums are placed under the gutters of the houses and provide the villagers with an adequate supply of water during the rainy season as an alternative to going to the well. These water drums often constitute a good breeding places for Aedes aegypti, particularly in urban areas. However, during the survey, the consultants did not find any drums containing Aedes aegypti larvae. As there was almost daily rainfall at the time, it appears that the water was being used everyday and was not allowed to stand for longer than three days. Moreover, in Salayea, the repeated visits of the vaccination team probably induced the villages to empty the drums more often than usual. Although the drums placed under the gutters were free of Stegomyia, larvae were found in small collections of rainwater at the bottom of abandoned drums.

This same method of water collection was used at the Lutheran Training Institute at Salayea, but on a larger scale, since every house had its own drum, and the large buildings, such as the dormitory, were surrounded by them. At the time of the survey, all these drums had been emptied, due no doubt to the fact that during Dr Thomas' visit to the Lutheran Training Institute two weeks earlier he had found some larvae in these breeding places and had threatened the Director with fines and prosecution. Although running water is supplied to the Lutheran Training Institute from a water tower fed by a pond, rainwater is collected in these drums for watering the garden and flowers. The water probably remained in the drums long enough to permit the complete development of Aedes aegypti at the pre-imaginal stage, particularly at the beginning or the end of the rainy season when the drums would have taken longer to fill.

During his visit, Dr Thomas took specimens of larvae breeding in the drums as shown in the following list kindly supplied to the consultants:

| | |
|---|---|
| Aedes aegypti | 7 |
| Aedes vittatus | 1 |
| Aedes sp. | 3 |
| Eretmapodites gr. chrysogaster | 3 |
| Culex ingrami var. galliard | 1 |

In addition, he obtained two adult specimens: one Aedes aegypti and one Aedes vittatus.

3.1.3 Other breeding places

As it can be seen in Annex 3D, there does not seem to be a close correlation between the presence of Aedes aegypti at the time of the survey and any particular method of water collection.

However, there is a tribal custom in some villages which appears to favour the pullulation of Aedes aegypti. Some families prepare traditional medicines by soaking various herbs in small earthenware pots which are usually kept uncovered indoors. These medicines may remain unused for a long time and therefore constitute a very favourable medium for the rapid development of Aedes aegypti larvae. Similar conditions were observed in the Korhogo area (Ivory Coast) where Aedes aegypti larvae and adults were pullulating, and where traditional medicine was found to be the principal breeding medium. However, in the survey area, these potential breeding places were always found negative in respect of Aedes aegypti larvae. This might be explained by the fact that the strongly polluted water of most of these containers was suitable for Culex larvae only; however, a number of the containers, filled with clear water, were also free of Aedes aegypti larvae. Some medicinal herbs may act as a repellent to gravid females, as has been proved in the case of certain traditional medicines used in the Korhogo area. Other data would seem to indicate that the absence of Aedes aegypti larvae in these and all other potential indoor breeding places is more probably related to a biological characteristic of the adults in the area.

Larvae were also sought in breeding places in the vicinity of dwellings, such as discarded containers (old basins, tins, etc.) filled with rainwater which often attract Aedes aegypti. In most of the breeding places thought to harbour Aedes aegypti larvae, the consultants found larvae of another Stegomyia, in the

apicoargenteus group, probably Aedes (S.) apicoargenteus, which has already been reported in Guinea (Adam and Bailly-Choumara, 1964) and in Liberia (Peters, 1956). Larvae of this species were found in a variety of breeding places: once in cut bamboo and nine times in man-made sites (twice in association with Aedes aegypti).

The Aedes aegypti breeding places were found in the immediate vicinity or even the interior of the forest, but never in the built-up areas surveyed. A very large colony of Aedes aegypti larvae was found in a pot in the middle of a rubber plantation, more than two miles from the nearest dwelling.

The small number of breeding places found, their nature and their outlying location, do not therefore seem to correspond with the classic picture of the entomological conditions supposed to favour the occurrence and spread of urban type epidemics of yellow fever.

### 3.2 Collection of the adult specimens

Although detection of breeding places is the best method of assessing the real density of Aedes aegypti, adult specimens were also collected, using various techniques.

#### 3.2.1 Collection of the adult insects resting inside dwellings

##### 3.2.1.1 Hand-capture

The results of this operation were disappointing. Adults of the following species only were caught (by decreasing numbers): A. gambiae, A. funestus, Culex nebulosus and Culex pipiens fatigans. Moreover, all these species were encountered in relatively small numbers. The collection was in fact undertaken in rather bad conditions: most of the time, the dwellings were filled with smoke and the ceilings of branches separating the rooms from the thatched or corrugated iron roofs prevented the capture of adult insects that flew up to the roof. In any case, no adult Aedes aegypti were seen inside the dwellings.

##### 3.2.1.2 Spray collection

As it was impossible to transport much equipment, the consultants had to do with small-size commercial aerosol preparations for this operation. Brown paper was put on the floor before spraying, to catch the insects. This long and tedious method was used in Salayea village only. To prevent the insects from escaping

during the spraying, the operation was limited to rooms with more or less closely fitting ceilings. This operation was even more disappointing than the previous one: not a single mosquito was found in the nine rooms sprayed.

3.2.2 Capture in low vegetation

A list of the Aedes and Eretmapodites caught in low vegetation is given in Annex 3E. With the exception of one Eretmapodites gr. chrysogaster female caught near Salayea, no mosquitos (and particularly no Aedes of the subspecies Stegomyia) which could be proved capable of transmitting the yellow fever virus were caught by this method.

3.2.3 Capture on human bait

3.2.3.1 Around villages

The operation was carried out in two continuous stages, one from 12 to 8 p.m., the other from 4 to 8 p.m. in localities in Salayea and in the Zorzor Leper Colony respectively. Results: Salayea, nil; Zorzor Leper Colony, two females A. gambiae.

3.2.3.2 In the forest

Results obtained (a) in relatively dense forest near the Salayea village, near the St Paul River, with four with four collectors:

| | |
|---|---|
| 12 noon - 3 p.m. | Nil |
| 3 p.m. - 4 p.m. | A. aegypti: one female |
| 4 p.m. - 5 p.m. | Nil |
| 5 p.m. - 6 p.m. | Nil |
| 6 p.m. - 7 p.m. | A. aegypti: one female |
| 7 p.m. - 8 p.m. | Culex gr. annulioris: one female |
| 8 p.m. - 9 p.m. | Nil |

(b) in a relatively dense grove in the grounds of the Lutheran Training Institute of Salayea, with three collectors:

| | |
|---|---|
| 5 p.m. - 7 p.m. | Nil |
| 7 p.m. - 8 p.m. | A. ingrami: one female |
| 8 p.m. - 9 p.m. | Nil |

The A. aegypti female caught between 6 p.m. and 7 p.m. hesitated a long time before alighting on the collector's arm and hesitated another full minute before biting. Though it is not possible to draw a definite conclusion on the basis of the small number of females caught, one explanation for this lack of voracity could be that Aedes aegypti females in the survey area are not particularly anthropophilic.

3.2.4 Capture using the light method and a CDC light trap

The following mosquitos were caught by the light method at the Lutheran Training Institute, Salayea: two females Anopheles ziemanni and one female Anopheles hancocki.

With the CDC light trap - which was not operating at full efficiency as it was powered by two 4.5 volt batteries - three night collections in the park of the Lutheran Training Institute, Salayea, produced the following insects:

| | |
|---|---|
| Aedes (aedimorphus) tarsalis group | : one female |
| Aedes (aedimorphus) mattinglyi group | : one female |
| Anopheles hancocki | : two females |
| Culex sp. | : one female |

The possible role of these two species of Aedes as a vector of the yellow fever virus has never been proved.

3.3 Capture using laying traps

3.3.1 Technique

It is often possible, by this method, to detect the presence of Aedes Aegypti females in areas apparently free of the species (Service 1965, in North Nigeria; Hamon et al., 1967, in North Dahomey) and to determine the extent of the infestation in areas of low Stegomyia density (Fay and Eliason, 1966).

A few twigs wrapped in blotting paper were placed in various containers (tins, etc.) half filled with water to collect any eggs deposited. Half of the traps were equipped with a vial containing ethyl acetate, which is believed to induce oviposition (R. Galun, 1965; Fay and Eliason, 1966).

3.3.2 Findings

Thirty of the traps were placed in Salayea, in sheltered places (under verandas, etc.) and 15 in the Lutheran Training Institute, Salayea (12 around the building where the two yellow fever victims were lodged).

Because of the short time available for the survey, it was necessary to empty the traps after seven days at Salayea and five days at the Lutheran Training Institute. All traps were negative at Salayea, while five (i.e. 33 per cent.) at the Lutheran Training Institute contained Aedes eggs.

A simple theory to explain this difference is that the Aedes aegypti in the survey area are "wild" and that the females do not deposit eggs in villages as big as Salayea. This hypothesis is strongly supported by the consultant's studies on the number, type and location of the breeding places surveyed, and by the evidence of lack of aggressiveness on the part of the females.

The Aedes eggs collected at the Lutheran Training Institute were sent to Mr J. Mouchet for evaluation of their susceptibility to insecticides.

3.4 Discussion

In contrast to the classic picture of an urban-type yellow fever epidemic, the Stegomyia density in the survey area seemed very low. The density was probably higher at the time the fatal cases occurred, but it seems unlikely that it would have reached the minimum level required for the development of an epidemic. The only possible vectors found in the area were: Aedes aegypti, Aedes vittatus, Eretmapodites gr. chrysogaster and, perhaps, Aedes apicoargenteus.

Aedes (St) aegypti appeared to be uncommon, even in villages near Salayea, where no control measures had been taken. Judging from the small number, the nature and the location of the breeding places, it would appear that the females are of a "wild" type. Like certain strains in Senegal (Cornet, 1967), these mosquitos probably rest on leaves, are active only during the rainy season and rarely bite human beings. This appears to be the most common type of Aedes aegypti in Sierra Leone, since Allan (1935) reported that out of 1289 tree holes inspected, 749 contained larvae of this species (in Burton, 1964). Instances of slightly or non-anthropophilic strains of Aedes aegypti are fairly frequent in Africa. Neri (1965) reported that in Ethiopia this mosquito is very common in the larval state, but does not appear to bite human beings (see also Sérié et al., 1964). Simpson et al. (1965) were unable to catch Aedes aegypti on human bait in Uganda even though the species exists in larval form in this country. Likewise, Lumsden and Buxton (1951) found only two Aedes aegypti among 475 mosquitos collected on human

bait in Uganda. Robinson had similar results in Northern Rhodesia (1950). In Gambia, five fatal cases of yellow fever were recorded in 1934 in an area where Aedes aegypti was rare (Findlay et al., 1937).

Although Aedes vittatus was not encountered during the survey, it is certain that this species was present when the cases of yellow fever occurred. Moreover, the species is more numerous at the beginning of the rainy season; it decreases as the rainfalls become heavier, probably due to flooding of its breeding places and multiplication of its natural enemies. It was shown to be responsible for the severe epidemics which occurred in Sudan in 1940 (Kirk, 1941; Lewis, 1943). It is very active in West Africa where it attacks human beings, even during the day (Hamon, 1963). It breeds by preference in holes in rock (Boorman, 1961); and a large stone slab with many crevices was in fact found about twenty yards from the building where the two deceased girls had lived. Also, Dr Thomas found some larvae of the species in the drums used to collect rain water. This mosquito, which is not exclusively anthropophilic (Service, 1965) could have fed on a reservoir of yellow fever virus and have been responsible for the cases recorded.

Eretmapodites gr. chrysogaster was never caught on human bait during the survey, but its larvae were found in many breeding places. This species may also have had an accidental role in the transmission.

Aedes (St) apicoargenteus larvae were present in many breeding places where the consultant expected to find Aedes aegypti. No adults were caught on human bait. Although Garnham et al. (1946) reported that this species was often predominant in many collections of adult insects, Peters (1956) reported that in Liberia attempts at artificial breeding had always failed as the females refused to feed on human beings or on guinea pigs. It would be interesting to study the trophic preferences of this species by using animals in net traps to determine whether it plays a role in the sylvan transmission.

The consultants did not find any other species of Stegomyia such as Aedes africanus, Aedes luteocephalus and Aedes simpsoni with a proven role in the transmission of yellow fever.

Aedes africanus, which is an important vector of yellow fever in Uganda (Simpson and Coll. 1965), seems fairly uncommon in Liberia. Bequaert (1930, in Peters 1956) found this species biting man along a forest track at Kakatown.

Peters thought the species involved may have been Aedes pseudoafricanus Chwatt. No females were caught on human bait.

Aedes luteocephalus is also responsible for transmitting yellow fever virus between monkeys in Uganda (Lumsden and Buxton, 1951) and for transmitting other arboviroses in Senegal (Cornet, 1967). It is common in savannah areas, where it attacks human beings (Hamon, 1963). It was not found during the present survey and has been recorded only once in Robertsfield by Briscoe (1950).

Aedes simpsoni Transmits yellow fever from monkeys to man in Uganda (Smithburn and Haddow, 1946; Gillet, 1951). In Nigeria, it never bites man in the open (Bruce-Chwatt, 1950). It was reported by Peters in one locality only in Liberia. Its larvae was sought in plants with sheath-like leaves, without success. This species is not supposed to be anthropophilic in West Africa: in Dahomey, Togo (Hamon and coll., 1956) and the Ivory Coast (Hamon, pers. comm.) the females do not seem aggressive in spite of the high density of larvae.

To conclude, the small number of cases notified can be explained by the scarcity of Aedes aegypti in the survey area. This feature had already been noted by Peters: "On the whole, this species was conspicuous by its scarcity". In the case of the two girls infected at the Lutheran Training Institute, Salayea, it is very likely that the same mosquito - probably an Aedes aegypti or Aedes vittatus - was responsible for transmitting yellow fever to them. Thus, in view of the fact that they shared the same room and that none of the other boarders at the Lutheran Training Institute showed symptoms, even uncertain ones, the possibility of an epidemic must be ruled out a posteriori.

## 4. EPIDEMIOLOGICAL SURVEY

### 4.1 Previous immunitary status

#### 4.1.1 Previous outbreaks of yellow fever

The last outbreak of yellow fever to be reported in Liberia occurred in 1929 in Monrovia, with 16 cases of which three were suspected only and six were fatal. Prior to this and until this year, no cases of yellow fever had ever been notified. It seems that until 1925 Liberia was thought to be free of this disease. However, in the "Bulletin de la Société de Pathologie exotique" of 1925, G. Bouet, Chargé d'affaires and French Consul in Liberia and a physician, described an epidemic that

affected four Europeans, four Syrians and one Liberian in Monrovia during the last week of May 1925; all these people lived within 150 m. of each other. Five deaths occurred: the four Europeans and one Syrian. The author was of the opinion that the disease had in fact been known for a long time as "yellow jaundice" in its non-fatal and "black jaundice" in its fatal form. Wehrle (1928) was of the same opinion and he reproduced G. Bouet's article word for word.

After 1929, there is a report from Smith (1931) on the health situation and yellow fever control in Liberia. He encountered a fatal case in Monrovia in 1930. He considered that the town offered ideal conditions for the propagation of Aedes and that yellow fever had existed for a long time although it was almost never declared. It seems that yellow fever has existed for a long time in Liberia, where the situation is not very different from that in Sierra Leone or in the Ivory Coast.

4.1.2 Previous vaccinations

There have been no previous vaccination campaigns against yellow fever in Liberia. The only vaccinations administered in the past were to travellers, in accordance with the International Sanitary Regulations.

4.1.3 Serological surveys

The consultants looked up the findings of three serological investigations of yellow fever carried out in Liberia.

1. Beeuwkes and Mahaffy (1934) applied the sero-protection test to sera collected in 1932 at the Firestone Plantation, from donors from various villages in the interior. Of 96 sera from donors aged over 15 years, six were positive.

2. In the course of a medical and sanitary survey carried out in 1935-1936, Anigstein (1937) collected 20 specimens of serum, of which two proved positive in sero-protection tests.

3. In the report of the Virology Laboratory of the Rockefeller Foundation, Theiler (1961) gave the results of hemagglutination inhibition tests performed on 101 sera collected in Liberia: 44.6 per cent. were negative for group A; 66.4 per cent. were negative for group B; 49.6 per cent. were negative for group Bunyamwera.

These studies are clearly very incomplete, but they nevertheless indicate that a very large proportion of the population is susceptible to the disease.

4.2 Analysis of the human cases

The three fatal cases of yellow fever amongst human subjects, all from Salayea, took the form of a typical hepatonephritis. Without this very familiar clinical picture, and particularly if the first two victims had not been two young boarders at the Lutheran Training Institute, it is very probable that this manifestation of the virus would have passed unnoticed.

4.2.1 Chronological analysis

The first two cases of yellow fever were officially notified on 10 June, after being confirmed by histopathological examination of liver specimens sent to the Laboratory of Pathological Anatomy of the Pasteur Institute, Dakar (Professor R. Camain). The victims were two girls aged seventeen and twenty years, who were students at the Lutheran Training Institute at Salayea.

After attending a meeting on Saturday 13 May at Gbanga between the Lutheran Training Institute and the Methodist School, the two girls spent the Saturday evening and the following Sunday with one of their families. On the Sunday evening, they felt tired and feverish. One of the girls decided to stay with her parents at Gbanga; the other returned to Salayea and was hospitalized the next morning at the Memorial Lutheran Hospital in Zorzor, following an attack of black vomiting. After a slight improvement, her condition deteriorated on the Friday with the onset of anuric nephritis which terminated in death on 20 May. Her friend, who had remained in Gbanga, was driven to the Phebe Hospital near Gbanga on 17 May and died on the way.

These two girls shared a room with two other friends, one of whom developed a fairly severe hepatitis, and the other a benign fever. However, both girls recovered.

Since the disease manifested itself on 14 May, the infection must have occurred between 8 and 11 May, while the girls were at the Lutheran Training Institute.

At Salayea village, a fatal case occurred on 21 June in a man and was subsequently confirmed. Another adult, a Syrian, who was examined by the doctor at Zorzor Hospital, showed clinical symptoms of acute yellow fever, from which he recovered.

But in view of the difficulties of clinical diagnosis of yellow fever and the fact that the laboratory tests were limited to postmortem specimens, only the three fatal cases can be taken as certain. According to the people questioned in the villages surveyed, there seems to have been no abnormal mortality at this time, and certainly no cases showing symptoms of severe hepatonephritis.

The staff of the Zorzor Hospital thought there was a fairly large number of cases of mild fever towards the end of May, both at the Institute and in the village. It seems therefore that this manifestation of yellow fever virus must have occurred between mid-May and mid-June.

4.2.2 Age

The three fatal cases and those strongly suspected on clinical grounds occurred in individuals aged 17 to 40 years. It is very probable that a good many children had mild attacks of the disease, which were not noticed and which could only be revealed by the results of the serological investigation.

4.2.3 Criteria of etiological diagnosis

As no blood samples were available for isolation of the virus or serological diagnosis, etiological diagnosis could only be carried out by pathological examination of postmortem specimens.

The Laboratory of Pathological Anatomy at the Pasteur Institute, Dakar, submitted the following reports:

8 795 D - J. H. (Professor Camain). Typical picture of a yellow fever hepatitis with mesolobular necrosis of acidophilic type (Councilman bodies ++); micro and macro vacuolar steatosis; preservation of a periportal and centrolobular corona of less severely affected hepatocytes; very little infiltrate.

8 796 D - G. K. (Professor Camain). Clear picture of yellow fever hepatitis (somewhat less apparent than in J. H.'s specimen); nevertheless with multivacuolar steatosis, oxyphilic necrosis and good Councilman bodies. Mesolobular trabecular degeneration and preservation of a double corona of less severely affected hepatocytes in the periportal and centrolobular areas. Very little infiltrate.

8 935 D - F. W. (Dr H. Sarrat). Mediolobular necrosis with remaining perportal and centrolobular coronae of more or less severely affected hepatocytes; diffuse micro and macro vacuolar steatosis. No evidence of Councilman bodies.

Inflammatory infiltrates particularly noticeable in the portal spaces. Conclusion: yellow fever hepatitis. According to Professor Camain, this picture corresponds with a yellow fever hepatitis of long standing.

4.3 Epidemiological review

4.3.1 Extent of the outbreak

A general picture of the geographical and demographical extent of this outbreak of yellow fever can only be obtained by methodical study of the data collected on the spot. Four hundred blood slides were taken from unvaccinated individuals in all age-groups (see figure 2). These sera are presently being examined at the Pasteur Institute, Dakar.

4.3.2 Origin and predisposing conditions

Were there any conditions particularly favourable to the occurrence of this epidemic?

1. Abnormal pullulation of Aedes aegypti? During the first survey carried out by Dr H. Thomas, a fairly large number of Aedes larvae were found in the numerous metal drums used for collecting rainwater at the Lutheran Training Institute. Adult insects were also found in the immediate vicinity of the room occupied by the two deceased girls.

At the time of the consultants' visit, Aedes aegypti were very difficult to find. However, the few specimens collected were found at Salayea, and the laying traps placed near the building where the girls lived produced Aedes eggs, presently under classification at the Centre Muraz, Bobo-Dioulasso. While it cannot be said that there was abnormal pullulation of Aedes, the conditions for transmission certainly existed.

2. The susceptibility of the population who, in the absence of vaccination, could only have been immunized through previous unnoticed or mild attacks? In view of the limited extent of the epidemic, it seems reasonable to suppose that a large proportion of the population is immunized, and that this manifestation of yellow fever was therefore only a reactivation of an endemic focus; however, this cannot be confirmed until the results of the serological survey are available. It should also be noted that there is a large population of monkeys in the area, which are hunted for eating, and that the staff at the Zorzor Hospital remembered an epidemic of fever

with icterigenic syndromes which occurred around 1947-1948 in the village of Zorzor, 2.5 miles west of Salayea and caused a fairly large number of deaths. The serological investigation may also shed some light on this question.

4.3.3 Control measures taken

1. Vaccination

As soon as the cases were confirmed, as requested by Geneva, 50 000 doses of 17 D yellow fever vaccine, drawn from the WHO emergency stock, were sent to Liberia by the Pasteur Institute, Dakar. The doses were distributed as follows: 5000 for Salayea and Zorzor; 5000 for Gbanga and 40 000 for Monrovia.

At the request of the French Ambassador in Monrovia, the Pasteur Institute, Paris, sent a further 4500 doses for use in these three areas.

However, the vaccine was not always handled correctly in regard to transportation, dilution and administration. It was sometimes transported without refrigeration, both dried doses and even reconstituted doses which were sometimes hydrated a long time before use. Saline for dilution of the vaccine was supplied in plastic bags of one litre to cover a full week's requirements. Finally, as sterilization posed problems, it was necessary to use the same syringe and even needle for several vaccinations.

The consequence of these technical errors was the development of abcesses, which the consultants saw for themselves at Zorzor Hospital. Vaccinations have been temporarily discontinued in the area until sufficient equipment has been supplied to the teams - who are extremely willing - to permit correct administration of the vaccine. Such practices could lead not only to negative results or even accidents, but could also discredit the vaccine in the eyes of the population.

2. Aedes control

Both the destruction of the domestic breeding places and house-spraying with insecticides appear to have been effective, since the entomologist found very few Aedes aegypti larvae and adults in Salayea village.

3. Containment of the focus

The only measure taken to prevent the extension of the focus was the vaccination of 15 000 people in the area of the focus and of 40 000 people in Monrovia.

4.4 Results of tests carried out on sera taken during the visit

During their visit, the consultants collected a number of human sera in villages around the Salayea focus. In the focus itself, where almost all the populations over one year of age had been vaccinated, only three specimens were taken from suspected cases. A total of 388 sera were tested. The following table indicates the distribution by sex and age.

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Men | 11 | 96 | 47 | 74 | 6 | 234 |
| Women | 8 | 57 | 18 | 63 | 8 | 154 |
| Total | 19 | 153 | 65 | 137 | 14 | 388 |

The sera, in a 2:2 dilution starting at 1:20, were tested by hemagglutination inhibition against 4-8 antigen units. The following antigens were used:

| | | |
|---|---|---|
| Group A : | Chikungunya | (CHIK) |
| | O'nyong-nyong | (ONN) |
| Group B : | Yellow fever | (YF) |
| | Uganda S | (UGS) |
| | Dakar bat | (DAK) |
| | West Nile | (WN) |
| | Zika | (ZIK) |
| Bunyamwera Group : | Bunyamwera | (BUN) |

The results by age and antigens were as follows:

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 8 | 23 | 65 | 8 | 104 |
| ONN | 0 | 8 | 23 | 64 | 7 | 102 |
| YF | 0 | 0 | 2 | 20 | 1 | 23 |
| UGS | 0 | 0 | 0 | 2 | 0 | 2 |
| DAK | 0 | 0 | 0 | 1 | 0 | 1 |
| WN | 0 | 0 | 0 | 2 | 0 | 2 |
| ZIK | 0 | 1 | 1 | 16 | 1 | 19 |
| BUN | 0 | 10 | 0 | 2 | 0 | 12 |

Finally the results by localities and antigens were as follows:

| Locality | No. of Sera | ANTIGENS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CHIK | ONN | YF | UGS | DAK | WN | ZIK | BUN |
| Konia | 55 | 5 | 5 | 2 | 0 | 0 | 1 | 5 | 0 |
| Bokkeza | 40 | 9 | 8 | 2 | 0 | 0 | 0 | 4 | 2 |
| Yeala | 70 | 10 | 10 | 7 | 1 | 0 | 0 | 1 | 5 |
| Telemen | 51 | 17 | 17 | 3 | 0 | 0 | 0 | 1 | 4 |
| Zolowo | 82 | 23 | 22 | 4 | 1 | 1 | 1 | 6 | 1 |
| Wenshu | 90 | 40 | 40 | 5 | 0 | 0 | 0 | 2 | 0 |
| Total | 388 | 104 | 102 | 23 | 2 | 1 | 2 | 19 | 12 |
| % | 100 | 26.8 | 26.2 | 5.9 | 0.5 | 0.25 | 0.5 | 4.9 | 3.0 |

All sera positive in hemagglutination inhibition were tested for complement fixation in order to determine whether the infection was relatively recent (positive CF) or old (negative CF).

Detailed results are given for each village according to age and antigens; and the sera positive for yellow fever are indicated with their HI and CF titres (see Annex 4 A, B, C, D, E and F). Sera with a titre equal to at least 1:20 in HI and 1:8 in CF were considered positive.

Of the three pairs of sera taken in the epidemic focus, two were completely negative; the third, taken from one of the room-mates of the two deceased girls at the Lutheran Training Institute, Salayea, showed a barely significant increase in the rate of antibodies to the Chikungunya and D'nyong-nyong viruses.

| Name | Serum No.* | CHIK | | ONN | | YF | |
|---|---|---|---|---|---|---|---|
| | | HI | CF | HI | CF | HI | CF |
| Sodey Lake | 67-2072 | 160 | 8 | 80 | 8 | n | - |
| | 67-1940 | 640 | 8 | 1280 | 8 | n | - |

*Serum taken at approximately two month's interval.

As the early serum had not been preserved in the best conditions, this increase in titre could have been artificial only.

Discussion of the findings

1. Yellow fever: No antibodies were found in the 0-15 years age-group, only three per cent. in 15-24 years group and 14.5 per cent. in the 25-59 years group. As regards the distribution by sex, antibodies were found in 18 men out of 234, and five women out of 154. This difference is not significant and there is therefore no correlation between infection and occupation. On the other hand, the percentage of positive reactions increased the nearer the subjects lived to the Salayea focus. Thus, it seems that infection occurred in the focus itself during the extensive and easy travel which takes place in this area, particularly since the lack of antibodies in children indicated that the virus was not circulating outside the focus. Also, some of the positive reactions may have been due to vaccinations received in a neighbouring country. A total of 5.9 per cent. of the population studied had yellow fever antibodies. Thus, a considerable proportion of the population is susceptible around the Salayea focus and should be protected by vaccination.

2. Other arboviruses: In group A, Chikungunya was rather active, particularly towards the south of the area where the forest is less dense.

In group B, Zika was the most widespread (4.9 per cent.) after yellow fever. Of the 19 cases positive on hemagglutination inhibition, two were also positive on complement fixation.

Of the 12 sera positive to Bunyamwera, 10, curiously enough, were taken in the 5-14 years age-group.

Conclusion

The absence of positive serological reactions to the yellow fever antigen in the child population proves that the virus did not circulate beyond the Salayea focus. Only 5.9 per cent. of the inhabitants in contact with the focus had antibodies. Thus, there exists a large susceptible population which should be immunized rapidly.

Apart from Chikungunya O'nyong-nyong, the viruses were of very low endemicity, as could be expected in a forest area. However, it is possible that other arboviruses, which are not included in our list of antigens, are active in this area.

## 5. RECOMMENDATIONS

### 5.1 From an entomological point of view

The occurrence of three confirmed yellow fever fatalities in a country where the vast majority of the population has not been vaccinated will necessitate a number of studies:

5.1.1 Detailed study of the methods used by various sections of the populations for storing water, to determine the areas where pullulation of Stegomyia is highest and where, in consequence, the risks of epidemics are greatest.

5.1.2 Study of the trophic preferences and aggressivity cycles of the major Stegomyia: Aedes aegypti, Aedes vittatus, and Aedes apicoargenteus in order to define the role played by each of these species in the epidemiology of the yellow fever or other arboviruses.

5.1.3 Stegomyia control measures

Although man-made breeding places did not show a high density of Aedes aegypti larvae, the risks of pullulation must be limited by careful supervision of metal drums used for collecting rainwater, which will probably become more common in the future. Owners should be obliged by law to place a covering of fine-mesh nylon net on the open end. On the other hand, in view of the adult's preference for outdoors, house-spraying does not seem indispensable.

### 5.2 From an epidemiological point of view

5.2.1 In the immediate future, the introduction of infected vectors or persons into population centres must be strictly avoided, especially into Monrovia where vectors abound and where there is a large susceptible population.

Apart from systematic control and disinsectising of vehicles (in view of Aedes aegypti's predilection for luggage boots) vaccinations should be carried out in the three counties at greatest risk, namely: Loffa, Bong and Montserrado. Taking into account the vaccinations already carried out, the following doses would be required:

| | |
|---|---|
| Montserrado County ..... | 230 000 doses |
| Bong County ..... | 130 000 doses |
| Loffa County ..... | 120 000 doses |

In view of the difficulties encountered in administering 17 D vaccine, this strain could be used for the 0-10 years age-group, and the Dakar strain, which can be administered by scarification, for the older age-groups. Thus, the requirements would be:

| | 17 D | Dakar Scarification |
|---|---|---|
| Montserrado County | 69 000 | 161 000 |
| Bong County | 39 000 | 91 000 |
| Loffa County | 36 000 | 84 000 |
| Total | 144 000 | 336 000 |

5.2.2 In the future

The occurrence of three confirmed fatalities, three cases strongly suspected on clinical grounds and certainly a fairly large number of unrecognized cases in an unvaccinated population would seem to confirm there was an outbreak of yellow fever in this endemic area. It is therefore almost certain that the virus will reappear, either in the form of isolated cases or of small local epidemics. It would be advisable to include Liberia in the permanent surveillance system proposed by Dr P. Brès, Director of the Regional Reference Center for Arboviruses, Dakar (WHO document PA 66 274).

The Hospital of Zorzor could act as the sentinel hospital for this region. There would be no difficulties as regards communications with the National Laboratory at Monrovia (Director: Dr Cox) as the road can be used the whole year round. Saniquellie Hospital in Nimba County could also act as a sentinel hospital in this system.

To prevent a recurrence of the yellow fever, two kinds of measures will be necessary:

- Mass vaccination of the population. This cannot be done at present owing to the lack of Ped-O-Jets and of properly trained teams. However, a vaccination campaign against measles and smallpox is due to be undertaken in Liberia by US/AID at the end of the year, and the campaign teams and facilities could be made available for yellow fever vaccination. Excluding the counties of Montserrado, Bong and Loffa, where vaccinations were carried out during the first phase, 530 000 doses would be needed as follows:

| County | 17 D | Dakar Scarification |
|---|---|---|
| Grand Bassa | 42 000 | 97 000 |
| Grand Cape Mount | 10 000 | 24 000 |
| Maryland | 20 000 | 46 000 |
| Sinoé | 17 000 | 42 000 |
| Nimba | 50 000 | 120 000 |
| Grand Gedeh | 18 000 | 44 000 |
| Total | 157 000 | 373 000 |

- Surveillance of the virus reservoir would involve a considerable amount of work: obtaining specimens from animals, collecting mosquitos and sending them to specialized laboratories in conditions which cannot at present be met in Liberia.

CONCLUSION

The occurrence of a few cases of yellow fever in a region where vaccinations have not been carried out previously would seem to indicate a revival of an endemic focus in the Salayea area. However, in view of the ease and frequency of travel in the territory and the presence of Aedes aegypti in Monrovia and probably in other towns, further outbreaks in other areas are quite possible.

Under present conditions, the first measure to be envisaged is vaccination, initially in the three counties at greatest risk and subsequently throughout the territory. This campaign could be integrated with the campaign against measles and smallpox due to be undertaken by US/AID in the very near future.

Acknowledgments

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They would also like to thank Dr W. A. Karunaratne, WHO Representative, for the arrangements he made to facilitate the survey, and Mr Le Mire, Ambassador of France, for the many data he provided. They are grateful to all these personalities for having put such abundant documentation at their disposal.

They wish also to thank the administrative and medical authorities who helped them in the execution of their mission; they cannot overlook Dr Paul Mertens and Dr Esther Bacon of Zorzor Hospital, whose information proved invaluable, and also the vaccination team of Zorzor.

Their thanks are also due to the two entomological technicians who collaborated in the survey, and in particular to Mr Benedict K. Manson, who showed great initiative and ability.

The consultants are very grateful to Mr J. Hamon*, Inspector General of Research, for his continuous guidance and help in drafting this report, and to Mr J. Coz* and Mr J. Brenguez*, whose experience proved invaluable in preparing the survey. The maps and graphs in the annex were drawn by Mr P. Sales.

## ADDENDUM

### Aede aegypti in Monrovia

During their visit to the capital, the consultants carried out a rapid survey in many districts of the town. They located numerous breeding places - generally discarded containers - in the port districts and a large number of adult insects in the vicinity. In addition, a large garage owned by the largest taxi company in Monrovia contained numerous breeding places in old tyres, scrap body work, etc. Two Aedes aegypti females were found in one of the taxis. These vehicles could therefore be playing a role in spreading infection through the town.

At the request and on the advice of the consultants, Mr B. Mason placed a number of laying traps in different parts of the town. He collected numerous Aedes aegypti eggs, which are presently being studied for their susceptibility to various insecticides, by Mr J. Mouchet.

Vigorous antistegomyia measures are therefore urgently indicated, particularly the elimination of potential breeding places. An intensive imago control campaign could be envisaged as it would also reduce the density of C.p. fatigans and A. gambiae melas which are very common in the Free Port district.

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*Medical entomologists, O.R.S.T.O.M., Centre Muraz, Bobo-Dioulasso.

ANNEX 1

## List of personalities met during the visit, in chronological order

- Mr Benjamin N. Wolo, Assistant Personnel Manager, National Public Health Services, who welcomed the consultants at Robertsfield Airport.
- Dr W. A. Karunaratne, WHO Representative.
- Dr Hans Mayer, WHO Inter-country Smallpox Adviser,
- Dr A. R. Sunder Rao, WHO, Vector Control.
- Monsieur Le Mire, French Ambassador.
- Dr H. Thomas, Director of Communicable Diseases.
- Dr J. B. Titus, Director of Preventive Medicine.
- Dr W. H. Hoffe, Deputy Director-General, National Public Health Service.
- Mr Henry Kwekwe, Lutheran Training Institute, Salayea.
- Dr Paul Mertens, Chief Medical Officer, Zorzor Hospital.
- Dr Esther Bacon, Zorzor Hospital.
- Dr E. H. Barclay, Director-General, National Public Health Service.
- President William V. S. Tubman.
- Dr Cox, Director, National Laboratory, Monrovia.

ANNEX 2

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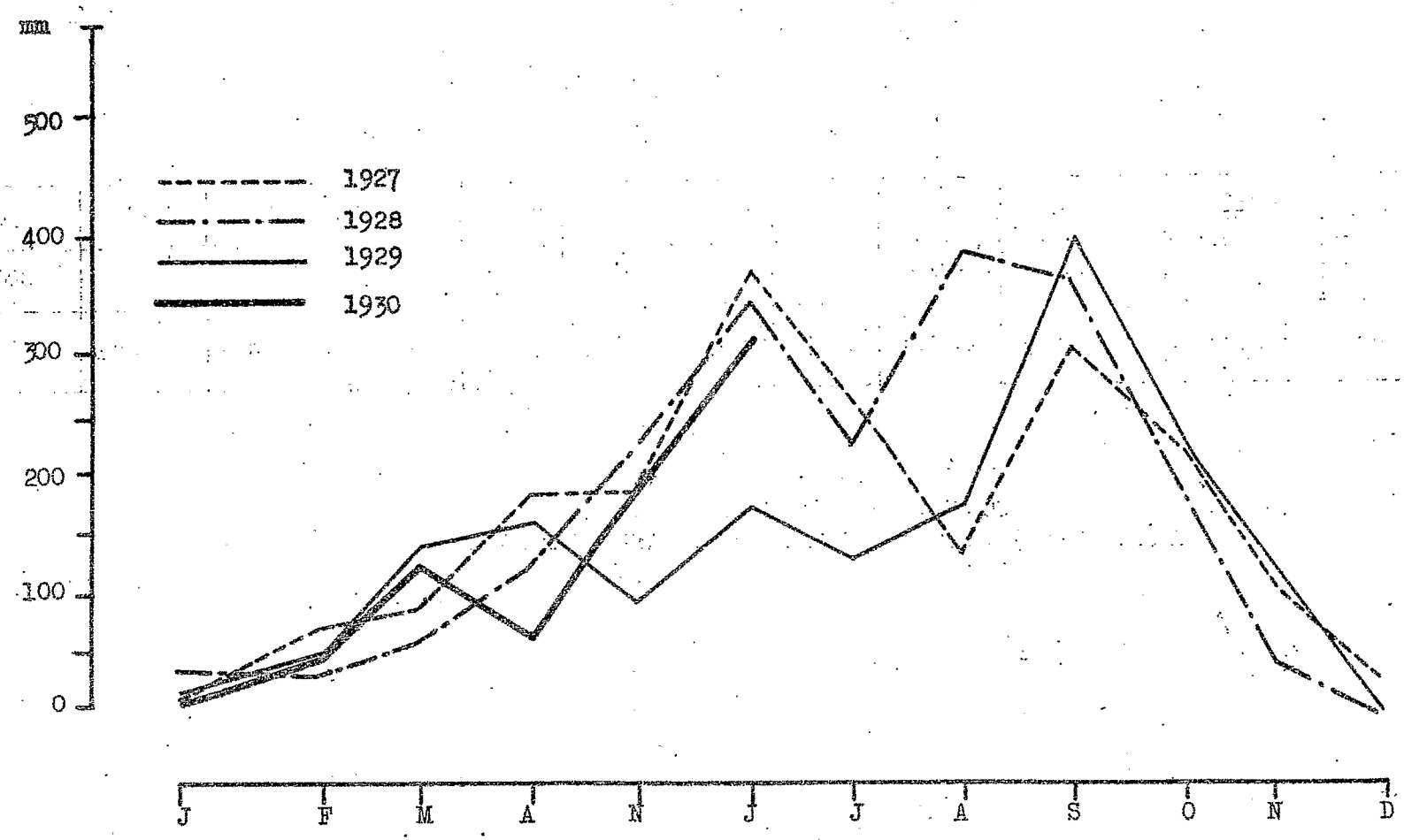
RAINFALL RECORDED IN GANTA - SCHWAB - 1947



MONTHLY RAINFALL* RECORDED IN VOINJAMA (LOFFA COUNTY)
IN 1962 AND 1963 (ANONYMOUS)

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 0 | 209 | 38 | 155 | 203 | 337 | 534 | 578 | 420 | - | 96 | - |
| 1963 | 42 | 121 | 87 | - | - | 360 | 262 | - | 236 | 376 | 227 | 17 |

*In millimetres

## WATER STORAGE AND BREEDING PLACES IN THE SALAYEA AREA

| | Area | No. of dwellings surveyed | No. of pails | No. of basins | No. of pots | No. of drums | Traditional medicines | | No. of positive breeding places | Aedes aegypti breeding places | Stegomyia[1] index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | with water | without water | | | |
| Kpelle County | Salayea | 53 | 27 | 59 | - | 12 | 4 | 9 | 8 | 1 | 1.9 |
| | Zolowo | 21 | 17 | 20 | 2 | 5 | 8 | 3 | 4 | 0 | 0 |
| | Wenshu | 17 | 20 | 25 | - | 5 | 1 | 3 | 3 | 1 | 5.9 |
| | Zorzor | 20 | 24 | 24 | - | 7 | - | 1 | 4 | 1 | 5.0 |
| Loma County | Zorzor Leper Colony | 22 | 19 | 18 | 2 | 4 | - | 1 | 4 | 3 | 13.6 |
| | Konia | 21 | 17 | 35 | 3 | 7 | 13 | 2 | 2 | 0 | 0 |
| | Yeala | 21 | 26 | 18 | - | 7 | 7 | 1 | 10 | 0 | 0 |

[1] The stegomyia index is obtained by establishing the ratio of breeding places harbouring Aedes aegypti to the number of dwellings surveyed multiplied by 100.

i.e. $\frac{\text{No. of breeding places with Aedes aegypti}}{\text{No. of houses surveyed}} \times 100$

ANNEX 3 (D)

## SPECIES FOUND IN THE LARVAE BREEDING PLACES

Salayea Lutheran Training Institute

1. Liliaceae aseils in the sun: Harpagomyia ? farquharsoni
2. In cut bamboo: Eretmapodites silvestris
11. In cut bamboo: Aedes gr. apicoargenteus
12. Big ponds with limpid water and grassy banks: Anopheles coustani, Culex guiarti, Ficalbia mimomyiaformis, Ficalbia splendens

Salayea village

3. Wooden tanning vat, with rainwater: Aedes gr. apicoargenteus
4. Drinking places for poultry made up of small iron pots, filled with clear water, thick muddy sediment: Eretmapodites gr. chrysogaster, Culex tritaeniorhynchus
5. Small collections of clear water in abandoned car wheels: Aedes gr. apicoargenteus
6. Wells adjoining village, water one metre below surface, in shade: Cules trigripes, Culex pruina
7. Broken basin, discarded, containing one pint of rainwater, in the shade, numerous specimens: Eretmapodites gr. chrysogaster
8. Small streams 100 yards away from the village, limpid water, upright and floating vegetation: Culex sp.
9. Large puddles on the road, muddy water, in the sun: Anopheles gambiae
10. In a thorny-leafed plant in the shade: Harpagomyia ? farquharsoni
13. Small pot containing leaves (traditional medicine), indoors: Culex nebulosus
14. Hole in the ground, stony, turbid water: Culex nebulosus
15. Small buried pot containing salt water for fowls: Culex tigripes
16. Drum containing rainwater: Culex sp. (eggs)
17. Hole in a tree: Toxorhynchitos gr. brevipalpis
44. Blacksmith's bucket, in the shade, containing limpid water: Aedes gr. apicoargenteus, Culex nebulosus, Eretmapodites gr. chrysogaster, Toxorhynchites gr. brevipalpis
45. Enamel bowls on a grave, containing rainwater: Eretmapodites gr. chrysogaster

Annex 3 (D)

Zolowo

46. Pot, traditional medicine, indoors, salt water: Culex nebulosus
47. Pot, traditional medicine, indoors, limpid water, sand at bottom: Culex nebulosus
48. One quart jar containing drinking water, indoors: Culex nebulosus
49. Pot, traditional medicine, indoors, limpid water: Culex nebulosus

Wenshu

50. Discarded cooking pot, indoors, salt water: Culex nebulosus

Near a rubber plantation, two miles from Wenshu

53. Small puddle, in forest, no vegetation: Anopheles obscurus
54. Small bowl of limpid water with sediment, indoors: Aedes aegypti

Zorzor

18. Small collections of water in bodywork of abandoned car: Aedes aegypti
19. Tin containing small quantity of water: Culex tigripes
20. Drum, full, under gutter: Aedes gr. apicoargenteus
21. Tin containing a small quantity of rainwater: Aedes gr. apicoargenteus

Zorzor Leper Colony

22. Drum, on its side, containing a small quantity of rainwater: Aedes aegypti
23. Tin containing rainwater: Aedes aegypti, Aedes sp., Culex nebulosus
24. Discarded drum, containing a small quantity of rainwater: Culex gr. decens
25. Discarded enamel bowl, containing rainwater, thick muddy sediment: Aedes aegypti, Aedes sp.
26. Marshes with upright vegetation: Culex gr. decens

Yeala

28. Tin containing rainwater in coffee plantation: Eretmapodites gr. chrysogaster
29. Hole in a tree: Aedes longipalpis
30. Small enamel bowl with limpid water, on grave: Aedes gr. apicoargenteus, Culex nebulosus

Annex 3 (D)

31. Pot, traditional medicine, limpid water with thick sediment: Aedes ingrami
32. Pot, traditional medicine, limpid water: Culex nebulosus
33. Container with rainwater on grave: Aedes gr. Apicoargenteus
34. Pot, traditional medicine, turbid water: Culex nebulosus
35. Tin containing rainwater: Culex tigripes, Culex nebulosus
36. Pot, traditional medicine, salt water: Culex nebulosus
37. Pot, traditional medicine, (decoction of bark): Culex nebulosus
38. Hole in rock for washing: Culex pruina
39. Hole in tree: Culex macfiei, Aedes sp.
40. Hole in tree: Aedes dalzieli, Culex macfiei
41. Hole in tree: Culex nebulosus, Culex macfiei, Toxorhynchites gr. brevipalpis

Konia

42. Buried pot, traditional medicine, limpid water: Culex nebulosus
43. Pot, traditional medicine, salt water: Culex nebulosus

ANNEX 3 (E)

## AEDES SPECIES COLLECTED AT REST IN LOW VEGETATION IN LIBERIA
(TYPING: J. HAMON)

Salayea, low vegetation in dense forest, near a river

| | | |
|---|---|---|
| Aedes (Aedimorphus) gr. domesticus (probably Ae. leptolabis) | 2 m., | 2 f. |
| Aedes (aedimorphus) gr. mattinglyi | | 1 f. |
| Aedes (Aedimorphus) gr. tarsalis* | 1 m. | |
| Aedes (Neomelaniconion) palpalis neomaculicosta | | 1 f. |
| Aedes (Neomelaniconion) punctocostalis | | 2 f. |
| Aedes (Neomelaniconion) taeniarostris | | 1 f. |
| Aedes (Neomelaniconion) sp. | 1 m. | |
| Aedes (Finlaya) ingrami* | | 1 f. |

Yeala, low vegetation in dense forest

| | | |
|---|---|---|
| Aedes (Aedimorphus) gr. domesticus | 1 m., | 1 f. |
| Aedes (Aedimorphus) gr. mattinglyi | | 1 f. |
| Aedes (Neomelaniconion) gr. carteri* | | 2 f. |
| Aedes (Neomelaniconion) punctocostalis | | 6 f. |
| Aedes (Neomelaniconion) taeniarostris | | 1 f. |
| Aedes (Neomelaniconion) sp. | 1 m. | |

Wenshu, low vegetation in rubber plantations

| | | |
|---|---|---|
| Aedes (aedimorphus) gr. domesticus | | 1 f. |
| Aedes (Aedimorphus) gr. mattinglyi | 1 m. | |
| Aedes (Aedimorphus) pubescens | 1 m. | |
| Aedes (Neomelaniconion) punctocostalis | | 3 f. |
| Aedes (Neomelaniconion) sp. | 2 m. | |

* Species already reported in Liberia (Peters, 1956).

ANNEX 4 (A)

KONIA

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 6 | 11 | 0 | 8 | 1 | 26 |
| Females | 4 | 6 | 5 | 14 | 0 | 29 |
| Total | 10 | 17 | 5 | 22 | 1 | 55 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 0 | 0 | 4 | 1 | 5 |
| ONN | 0 | 0 | 0 | 4 | 1 | 5 |
| YF | 0 | 0 | 0 | 2 | 0 | 2 |
| UGS | 0 | 0 | 0 | 0 | 0 | 0 |
| DAK | 0 | 0 | 0 | 0 | 0 | 0 |
| WN | 0 | 0 | 0 | 1 | 0 | 1 |
| ZIK | 0 | 0 | 0 | 5 | 0 | 5 |
| BUN | 0 | 0 | 0 | 0 | 0 | 0 |

2 - Sera positive for yellow fever

| Name | Serum number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Mulbah Zaza | 67-2140 | 51 M | 160 | <8 |
| Losayne Dukely | 67-2169 | 43 M | 40 | <8 |

ANNEX 4 (B)

BOKKEZA

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 0 | 11 | 5 | 17 | 1 | 34 |
| Females | 0 | 4 | 1 | 1 | 0 | 6 |
| Total | 0 | 15 | 6 | 18 | 1 | 40 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-25 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 1 | 2 | 6 | 0 | 9 |
| ONN | 0 | 1 | 2 | 5 | 0 | 8 |
| YF | 0 | 0 | 0 | 2 | 0 | 2 |
| UGS | 0 | 0 | 0 | 0 | 0 | 0 |
| DAK | 0 | 0 | 0 | 0 | 0 | 0 |
| WN | 0 | 0 | 0 | 0 | 0 | 0 |
| ZIK | 0 | 0 | 1 | 3 | 0 | 4 |
| BUN | 0 | 2 | 0 | 0 | 0 | 2 |

2 - Sera positive for yellow fever

| Name | Serum number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Korquoi | 67-2024 | 57 M | 80 | <8 |
| Laly | 67-2104 | 26 M | ± 20 | <8 |

ANNEX 4 (C)

YEALA

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 0 | 23 | 5 | 14 | 1 | 43 |
| Females | 0 | 10 | 5 | 10 | 1 | 26 |
| **Total** | **0** | **33** | **10** | **24** | **2** | 69 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | - | 1 | 1 | 8 | 0 | 10 |
| ONN | - | 1 | 1 | 8 | 0 | 10 |
| YF | - | 0 | 0 | 7 | 0 | 7 |
| UGS | - | 0 | 0 | 1 | 0 | 1 |
| DAK | - | 0 | 0 | 0 | 0 | 0 |
| WN | - | 0 | 0 | 0 | 0 | 0 |
| ZIK | - | 0 | 0 | 1 | 0 | 1 |
| BUN | - | 5 | 0 | 0 | 0 | 5 |

2 - Sera positive for yellow fever

| Name | Serum number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Monroe, Charles | 67-2099 | 49 M | 80 | <8 |
| Mulbah, Guagua | 67-2113 | 35 M | 40 | <8 |
| Karbeh, Sebeh | 67-2122 | 40 F | 80 | 8 |
| Zolo, Guagua (Sgt) | 67-2132 | 40 M | 80 | <8 |
| Yarkpa, Wolo | 67-2136 | 44 M | 40 | <8 |
| Flumo | 67-2196 | 27 M | 40 | <8 |
| Klugbor | 67-2234 | 45 F | 20 | <8 |

ANNEX 4 (D)

TELEMEN

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 3 | 7 | 1 | 6 | 1 | 18 |
| Females | 3 | 12 | 2 | 14 | 2 | 33 |
| Total | 6 | 19 | 3 | 20 | 3 | 51 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 1 | 2 | 12 | 2 | 17 |
| ONN | 0 | 1 | 2 | 12 | 2 | 17 |
| YF | 0 | 0 | 0 | 3 | 0 | 3 |
| UGS | 0 | 0 | 0 | 0 | 0 | 0 |
| DAK | 0 | 0 | 0 | 0 | 0 | 0 |
| WN | 0 | 0 | 0 | 0 | 0 | 0 |
| ZIK | 0 | 0 | 0 | 1 | 0 | 1 |
| BUN | 0 | 2 | 0 | 2 | 0 | 4 |

2 - Sera positive for yellow fever

| Name | Sera number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Darawo | 67-2143 | 26 F | 640 | 8 |
| Gehduo, Yaduah | 67-2184 | 34 F | 160 | 8 |
| Suba | 67-2219 | 26 M | 40 | <8 |

ANNEX 4 (E)

ZOLOWO

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 2 | 25 | 14 | 18 | 2 | 61 |
| Females | 0 | 5 | 1 | 12 | 3 | 21 |
| Total | 2 | 30 | 15 | 30 | 5 | 82 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 2 | 2 | 16 | 3 | 23 |
| ONN | 0 | 2 | 2 | 16 | 2 | 22 |
| YF | 0 | 0 | 0 | 3 | 1 | 4 |
| UGS | 0 | 0 | 0 | 1 | 0 | 1 |
| DAK | 0 | 0 | 0 | 1 | 0 | 1 |
| WN | 0 | 0 | 0 | 1 | 0 | 1 |
| ZIK | 0 | 1 | 0 | 4 | 1 | 6 |
| BUN | 0 | 1 | 0 | 0 | 0 | 1 |

2 - Sera positive for yellow fever

| Name | Sera number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Korkulo | 67-1921 | 38 M | 80 | 8 |
| Mulbah | 67-1954 | 34 M | 320 | 8 |
| Larbelle | 67-2005 | 56 M | 320 | 8 |
| Sumo | 67-2029 | 64 M | 80 | 8 |

ANNEX 4 (F)

WENSHU

Distribution according to age

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| Males | 0 | 19 | 21 | 11 | 0 | 51 |
| Females | 1 | 20 | 4 | 12 | 2 | 39 |
| Total | 1 | 39 | 25 | 23 | 2 | 90 |

RESULTS OF HEMAGGLUTINATION INHIBITION TESTS

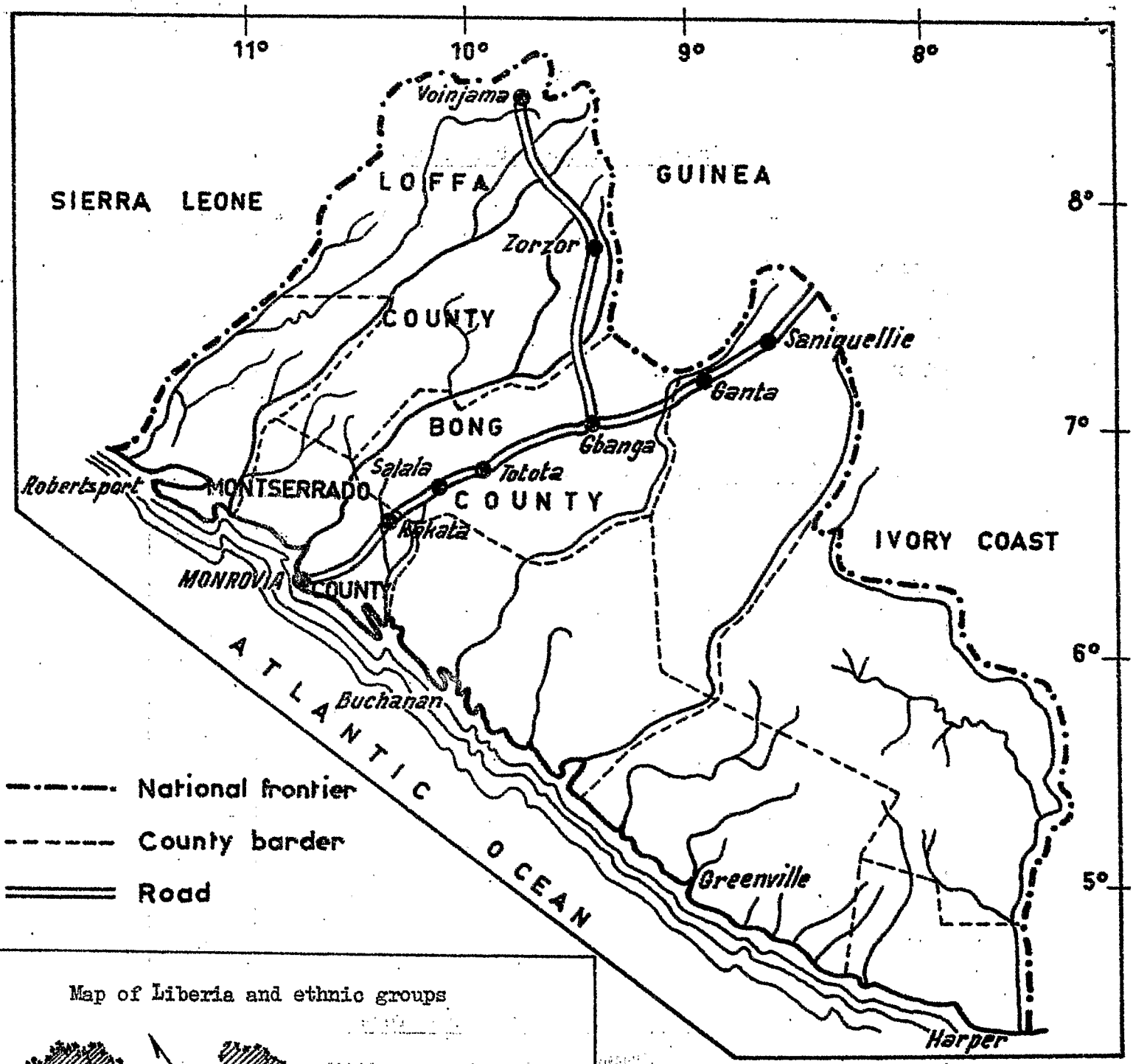
1 - Number of positive sera according to age and antigens

| | 0-4 | 5-14 | 15-24 | 25-59 | 60 + | Total |
|---|---|---|---|---|---|---|
| CHIK | 0 | 3 | 16 | 19 | 2 | 40 |
| ONN | 0 | 3 | 16 | 19 | 2 | 40 |
| YF | 0 | 0 | 2 | 3 | 0 | 5 |
| UGS | 0 | 0 | 0 | 0 | 0 | 0 |
| DAK | 0 | 0 | 0 | 0 | 0 | 0 |
| WN | 0 | 0 | 0 | 0 | 0 | 0 |
| ZIK | 0 | 0 | 0 | 2 | 0 | 2 |
| BUN | 0 | 0 | 0 | 0 | 0 | 0 |

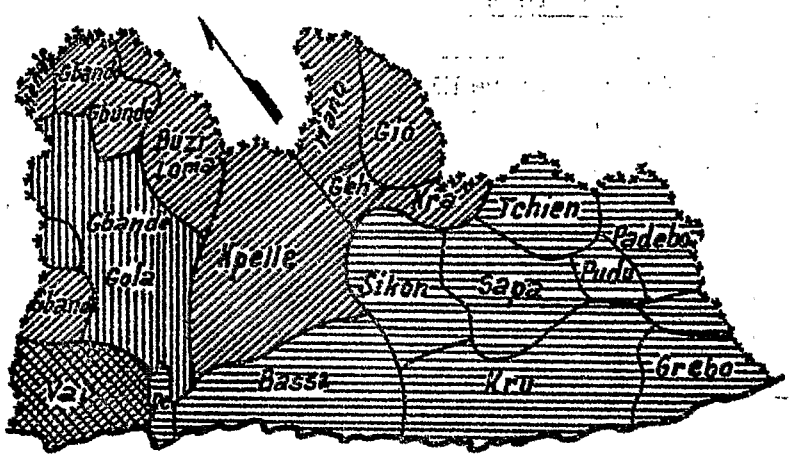
2 - Sera positive for yellow fever

| Name | Sera number | Age/sex | Titre HI | Titre CF |
|---|---|---|---|---|
| Armah, Kamara | 67-1903 | 50 M | 40 | <8 |
| Nyeesar, Yarkateh | 67-1925 | 40 F | 160 | <8 |
| Cooper, James | 67-1989 | 21 M | 20 | <8 |
| Flomo, Joseph | 67-2273 | 15 M | 20 | <8 |
| Cartercan, David | 67-2279 | 45 M | 40 | <8 |

# MAP I




Map of Liberia and ethnic groups




Scale : 1/2,500,000

10 0 10 20 40 miles

10 0 10 50 Km

Tribal Groups

- Mande - tan
- Mande - fu
- West Atlantic
- Kru

# M A P  II

## ENDEMIC FOCUS