OBSERVATIONS IN THE PROTECTORATE OF SIERRA LEONE.

By

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PART I.

INTRODUCTION.

The purpose of this paper is to record some of the observations and opinions of the writer following experience in the Protectorate of Sierra Leone.

Late in 1930 the Sierra Leone Development Company Limited commenced operations in the Protectorate. To develop haematite deposits near Marampa, Northern Province, (See MAP of Sierra Leone) it was necessary to construct a railway to the sea, shown by the dotted line on the map, a shipping installation at Pepel and a layout of the mine at Marampa. This works necessitated the employment of a considerable European staff and a very large native labour force, and was completed early in 1933. Numerous temporary camps for both European and native staff were used during this Construction period. Permanent camps, at Marampa for both European and native staff, at Pepel for European staff only were laid out and constructed.

In 1933 the Company commenced alluvial gold operations the area covered being roughly that in the square bounded by latitudes 9 degrees and 9 degrees 15 minutes North, longitudes 11 degrees 30 minutes and 11 degrees 45 minutes West. Several Europeans engaged in this work resided in various camps throughout the district.

From the beginning of operations in 1930 until June, 1935 the writer was responsible for the medical and sanitary care of all Company staff resident in Sierra Leone. The numbers employed, the large area covered, the nature of the operations necessitating many camps of different nature gave unusual opportunity for observation. The possibility was offered by facilities in the permanent headquarters camp at Marampa after 1933 of transforming opinions the result of previous experience into ascertained facts, and this paper is a record of such work. The practically complete absence of any publications on conditions in the Protectorate, added to the fact that the operations of the Sierra Leone Development Company are the first large scale industrial undertaking in the country, indicate that it would be of value to record observations on such problems as have proved of importance.

I have to acknowledge my indebtedness to the Sierra Leone Development Company Limited for permission to use the data in this paper. I am grateful to numerous members of the Company staff for assisting with problems while in the country. I have to thank the staff of the Sir Alfred Jones Laboratory, Freetown for helpful criticism of schemes, for advice, for encouragement and for their unfailing interest throughout the time I was in Sierra Leone.

PART 2.

THE PHYSIOGRAPHY, GEOLOGY AND METEOROLOGY OF THE PROTECTORATE OF SIERRA LEONE.

Section 1. Physiography.

Sierra Leone lies between latitudes 7° and 10° North, and longitudes 10°21' and 13°13' West. It can be divided into three main divisions:-

(1) The mountainous peninsula of the Colony.
(2) The Coastal belt.
(3) The inland plateaux and mountains.

(1) The mountainous Colony peninsula is outside the scope of this paper and need not therefore be discussed further.

(2) The Coastal Belt extends inland for a distance up to 100 miles from the Coast. It is an extremely flat plain rising to about 500 feet at the foot of the scarp marking the edge of the plateaux region. While from the plain numerous low hills rise to heights of a few hundred feet the major portion of this low plain is a series of undulations, low ridge succeeding low ridge with intervening shallow valleys occupied by swamps and small streams, the general formation resembling a magnification of a flat sandy beach rippled by waves or wind.

This Coastal Belt can be further subdivided into two sections:-

(A) A TIDAL FRINGE along the seaboard and the sides of the main rivers, where the water is subject to tidal influence. The main rivers are tidal for many miles inland. This fringe can be classified into a SALINE BELT along the coast line and in the estuaries of the rivers, and a FRESH WATER BELT further inland.

(B) In the remainder of the Coastal Belt the rivers are not tidal, a NON-TIDAL FRESH WATER AREA.

It can be readily appreciated that natural drainage over such a large flat plain is of necessity poor, particularly in the Tidal Fringe, and that the large amount of rainfall in the wet season leads to a very rapid and extensive increase in the area of swampy ground. It is estimated that from 5 to 20 per cent of the total area of the Coastal Belt is occupied by swamp, the higher figure representing conditions in the wet season, the lower those in the dry season.

(3) The North Eastern portion of the Protectorate is an elevated plateaux region, the bulk of which is between 1,000 and 2,000 feet above sea level. Rising above this are other plateaux and mountain ranges of which the most important are:-

1. The Loma mountains from 2,000 to 5,000 feet with several peaks over 5,000 and up to 6,450.

2. The Tembikondo highlands between 2,000 and 3,000 feet with numerous peaks over 4,000 and up to 6,100.

3. The Sula and Kangari mountains between 2,000 and 3,000 feet.

4. The Kambui and Nimi hills up to 2,400 and 2,100 respectively.

5. The Saionya or Talla plateaux.

6. The Kisi mountains and the Wara-Wara mountains.

In the inland plateaux region the country is more mountainous, the fall in streams and rivers is much greater, and drainage is consequently more efficient. Swamps are infrequent, the rivers running rapidly in rocky channels through thickly wooded valleys with steep sides, in contrast to meandering over alluvial plains, as in the Coastal belt.

<u>Section 2</u>. <u>Geology</u>: (See Provisional Geological Map of Sierra Leone.)

Granitic rocks cover about 60 per cent of the total area of Sierra Leone. Metamorphic rocks 17 per cent, Pleistocene and recent sediments 12 per cent and the Rokel river series 10 per cent.

Geologically the Protectorate of Sierra Leone may perhaps best be viewed as a granite country, upon which lie a series of other rocks in the form of a number of belts arranged roughly parallel to the coast.

The Pleistocene and recent sediments occur as a narrow strip along the coast extending inland up to a distance of 20 miles, and consist of alternating beds of sand and clay with here and there a little lignite.

Passing inland the next rocks met are the Crystalline Schists and Gneisses. These form a wide belt and are chiefly composed of gneisses and granulites.

The Marampa Schist belt is then entered, but these rocks are relatively thin and the underlying granite is exposed over considerable areas. The Marampa Schists consist largely of altered argillaceous and arenaceous sediments in which the deposits of haematite occur.

Next to the North and East of the Marampa Schists, lie the Rokell River Series, composed of sandstones, shales and conglomerates with subordinate contemporaneous volcanic rocks. The sediments from these form plains covered by grass and orchard bush with small patches of forest. In the rainy season the plains are often flooded, while at the height of the dry season all but the larger streams traversing these rocks cease to flow and most of them dry up.

East of the Rokell River Series the whole of the country is occupied by granites with the important exception of the Kambui Schists. These are highly metamorphosed schists of igneous and sedimentary origin and lie out in the granite country in the form of long belts or islands. They are hard rocks and give rise to such features as the Sula and Kangari mountains and the Kambui and Nimi hills, which have already been mentioned.

Granite is, therefore, the most common rock in the Sierra Leone Protectorate, and this fact has considerable bearing on the formation of the numerous swamps, particularly in the Coastal Belt.

As/

As swamps will be shown later to be an important factor in the production of malaria in the Protectorate, it is of interest to examine their formation in detail.

Swamps can be classified into four distinct types.

(a) In the Inland Plateaux region swamps form on the hard bare rock surfaces, due to water from run off and to a much smaller extent, from seepage being unable to percolate through the rock. The amount of water in these swamps is small, it is seldom over an inch or two in depth, it is present only during the rains, and the water is seldom completely stagnant. These swamps are of little importance with regard to malaria.

(b) Occasional swamps in the Inland Plateaux region and practically all the very numerous swamps in the Coastal Belt have a similar structure. Overlaid by a few feet of soil followed by a thin layer of quartz sand and pebbles lies a thick bed of sericite and kaolin. Such bores as have been put down by us in the Coastal Belt showed granite below the stratum of sericite and kaolin. The diagram overleaf shows the strata. The quartz sand and pebbles, the sericite and kaolin all being products of the degeneration of the omnipresent granite, the large number, the wide-spread and the common composition of this type of swamps becomes at once explicable.

The layer of sericite and kaolin is impermeable to water. It lies close to the surface in swampy ground, seldom deeper than a few feet. The first and and I think the main subsoil water table in the Coastal Belt lies on and above this impermeable stratum.

During the dry season the swampy areas are kept wet by seepage from the contiguous ridges, the water travelling along the top of the impermeable layer. As the rainy season progresses the influx of water from run off, seepage and direct precipitation increases; the water table rises and the low lying swampy ground becomes more and more water-logged. With the end of the rains the water table level falls and the swamps dry from the periphery inwards. If no "small rains" around January fall the swamps are practically dry on top all over by February, the only water being in slow channels. In the tidal belt this drying of the swamps in the dry season does not occur to the same extent, only the upper reaches of swamp drying while the lower parts are kept wet by the diurnal tidal rise.

(c) In the Saline Belt of Tidal Fringe, which corresponds roughly to the area covered by Pleistocene and recent sediments, alternating beds of sand and clay are present. The swamps there are very low lying areas, over which water extends at high tide. These areas are frequently covered by mud deposited from the river water. In all the rise of the tidal water prevents natural drainage. Where their level is above that to which the tide rises the ground of the swamp has usually a high salt content and the water in the swamps is brackish.

(d) Where the drainage of a valley is blocked by the configuration of the ground a lake usually forms. In Sierra Leone the rapid growth of dense vegetation and the deposition of/

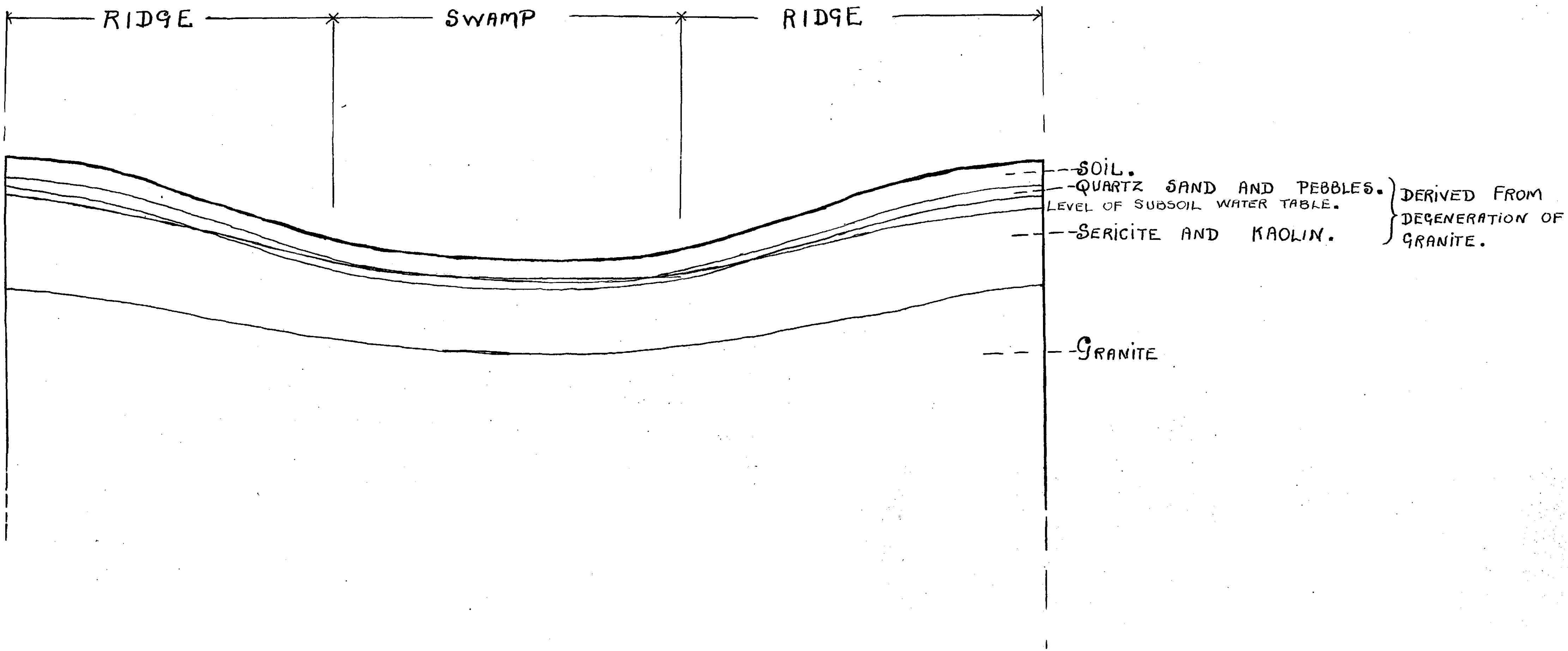


DIAGRAM OF SECTION ACROSS TYPICAL SWAMP FOUND IN COASTAL BELT.

of sediment from the contiguous quickly weathering ridges converts the lake into a species of swamp which may be covered during the rains by several feet of water. In the dry season the amount of water is much less, even disappearing entirely.

Type (B) is by far the commonest type of swamp encountered. It will be shown to be a large factor in the production of malaria in Sierra Leone.

Section 3. Meteorology.

The climate is warm and humid. Shade temperatures vary with the locality to some extent. In the Coastal Belt it ranges usually from 94° to 60° sometimes going as high as 102° but seldom below 60°. In the Plateaux Region lower temperatures are reached, down to 45° but the high limits are similar.

The rainy season begins in April or May and continues to October or November, the maximum rainfall being spread over June, July, August, September and October. In December and January the dry Harmattan wind blows. Sometimes a little rain falls in January or February but dry conditions prevail from November to April.

The relative humidity is high ranging from 90 per cent during the rainy season to 33 per cent during the Harmattan. For the large part of the year the average is between 75 and 80 per cent.

(Figures for several places in the Protectorate, supplied by the courtesy of the Director of Agriculture in Sierra Leone are shown in Appendix 1.)

SUMMARY OF PART 2:

1. The Protectorate of Sierra Leone can be divided into:-

(A) COASTAL BELT -
- TIDAL FRINGE
  - SALINE BELT
  - FRESH WATER BELT
- NON-TIDAL FRESH WATER AREA

In this Coastal Belt a large area of the country is occupied by swamp. These swamps are due to the low flat nature of the country with consequent poor natural drainage: and to the presence of an impermeable stratum of kaolin and sericite derived from degeneration of the commonest rock, granite. The impermeable stratum lying close to the surface causes a high level of the subsoil water, leading to extensive increase in the swamp area during the heavy rains in the wet season.

(B) AN INLAND PLATEAUX AND MOUNTAIN REGION where natural drainage is good and swamps are rare.

2. The climate is warm and moist.

These physiographical, geological and meteorological factors will be shown to have important effects in the production of malaria.

PART 3.

NOTES ON THE INDIGENOUS NATIVES OF THE PROTECTORATE OF SIERRA LEONE.

The indigenous natives of the Protectorate of Sierra Leone are of the negroid type. They are divided into several races or tribes, each speaking their own language, but these divisions are of little importance medically despite minor differences in habit etc., of the races. The vast bulk of the population are illiterate and ignorant, leading a primitive life. The standard of living is low. The usual house is the daub and wattle round house with grass thatch roof. Clothing is scanty. The staple foods are rice and cassava; millet, ground-nuts, okraw, yams, sweet potatoes and Indian corn are used to a lesser extent; pineapples, bananas, mangoes and kola nuts are eaten; palm oil from the kernels of the palm (Eloeis guineensis) is freely used for cooking. Fish, usually in the form of a dried smoked fish, is popular, Meat in any form is seldom available, being too expensive as an article of diet for the average native. Milk is a rarity.

Water for domestic purposes has to be carried and, therefore, houses and villages are invariably found to be situated close to a water supply. Most commonly the water supply is taken from small streams or swamps; the water of the larger rivers is too muddy during the rainy season for domestic use, and while villages may be found along their banks they are also sited close to swamp or small streams from which domestic water is obtainable all the year. In certain parts the absence of a suitable swamp or stream supply leads to the use of wells, which are shallow in depth, placed near the village (sometimes in the compound) and often near to cesspit latrines, uncovered and unprotected from pollution. In the streams from which domestic water is drawn the natives bathe, wash their clothes, and frequently defaecate and urinate. This proximity of habitations to water favours the spread of diseases due to vectors breeding in water: the excremental pollution of the water leads to spread of diseases such as dysentery and schistosomiasis.

Farming is by far the largest industry of the people, although in recent years an increasing number have found employment in other and newer industries such as mining.

The general agricultural system is as follows:- Each individual or village owns the farming rights over a certain area. The ground is covered by a low dense bush. To prepare a farm this bush is cut, and, after leaving for some time to dry, the cut bush is burned off. The crop is then sown, tended and harvested. After this the bush is allowed to grow up again, and this area is not farmed on again for a number of years varying from 3 to 7. In the ensuing year a new area of bush is cut, burned, farmed and abandoned. This method is necessitated by lack of artificial fertilisers and ignorance of scientific crop rotation. All the work of farming is done by hand and the life of the agriculturalist is one of hard unremitting toil.

The two main crops grown are rice and cassava. There are two varieties of rice grown, upland or hill rice and swamp rice. The former is sown on ridges and hills, the latter is planted in the swamps and in the alluvial mud flats along the banks of the larger rivers. When swamp rice is to be grown, the growth over the swamp, including trees if present, is cut down. Such of it as/

as dries and can be burned is burned off, but usually the larger sticks and tree trunks do not burn and gradually sink into the soft swampy ground. This blocks the drainage and the swamp becomes a sodden mass. The rice is sown on a small area first, then after germination is planted out over the swamp when the steady rains of the wet season set in. With the onset of the rains the swamp becomes a morass full of irregular pools due to the blocked drainage, with a rice crop growing over it through which the sun can freely reach the water pools. This forms an ideal breeding ground for mosquitoes. Sweet potato is also grown on swampy ground. The ground is heaped up into mounds about one foot high and three to five feet across inside which the sweet potatoes are planted: between the mounds are narrow irregular channels in which water stagnates in the rainy season, and where mosquitoes breed.

Fishing is commonly done, the scarcity and high price of all forms of meat elevating fish to the position of the principal non-carbohydrate article of diet. Apart from sea fishing, which is an important industry, two methods of fishing are in general use. In the smaller swamp streams and when the water is low in the dry season in the larger streams, one method is to segregate a length of stream with two dams, one up and one down stream. The dams are made of mud, (frequently the kaolin sericite clay present in the stream bed is used) strengthened with sticks and palm leaves. The impounded water is then bailed out and the stranded fish are caught. In the second method a fish trap is employed. Essentially this consists of a very strong fence of stout poles. The upstream face of the fence is covered with smaller sticks on the surface of which intertwined palm leaves make a dam impenetrable to fish. The fence is built right across the stream from bank to bank: sometimes a small spillway for water is left at a high level at the side; more often no provision is made for the egress of water. In the fence, under water, are apertures. Attached to the downstream side of the fence opposite the apertures are conical woven basket traps, the larger open end facing upstream. At the smaller end of these conical traps is a narrow opening. Fish going downstream enter the wide open end of the trap, become wedged in the narrow portion and are thus caught.

After their period of usefulness is over no effort is made by the natives to remove either of these types of barrier to the free flow of water. Debris brought down by the rains impinges on these obstructions and further dams the flow, until the water often must overflow the stream banks to escape. The stagnation of water behind these dams favours mosquito breeding. Over a period of years these practices must inevitably have greatly interfered with natural drainage and certainly greatly increased the amount of swamp in the country.

A large volume of disease is present among the native population. Malaria is hyperendemic, easily the most common type being Subtertian. As in other parts of tropical Africa so in Sierra Leone: every native acquires malarial infection very soon after birth, shows numerous parasites in his blood up to the ages of 4 and 5 and thereafter slowly develops an 'immunity' until, when he reaches early adult years and from then onwards, parasites are rarely to be found in the blood, and clinically he suffers little from malaria. The general ill effects of a high incidence of malaria on a population/

population are too well known to require discussion.

Yaws is almost equally prevalent, although its incidence varies from one locality to another.

Gonorrhoea is extensively present. One might say of it that the native has either had it, suffers from it, or is about to contract it. The incidence is certainly strikingly high.

Blacklock (1930) writing after his extensive survey of human diseases in the Protectorate says of these three diseases "Speaking not as a research worker but as a clinician my own view of the order of importance is (1) Malaria (2) Gonorrhoea (3) Yaws."

Dysentery, amoebic and bacillary, are in my experience fairly common, more so than found by Blacklock.

Filariasis is very common, the survey quoted showing M. Bancrofti in the night blood of nearly 15% of 259 persons examined. M. Loa was present in 2 out of 257 day bloods, in which M. Bancrofti was found in 4. In 2 day and 2 night bloods in the above examinations M. Perstans was present.

Smallpox is endemic, becoming sporadically epidemic.

Schistosomiasis is found highly prevalent in certain limited areas.

Leprosy is fairly common, some 6% of nearly 3,000 people examined by Blacklock showing the disease.

The position with regard to Yellow Fever in the Protectorate has been obscure until recently. Beeuwkes and Mahaffy (1934), have recently shown by protection test surveys that, in three out of four places examined in the Protectorate, evidence of the occurrence in recent years of yellow fever is present and that a fairly extensive epidemic had occurred at one of these places. While conditions are on the whole unfavourable for endemicity in the Protectorate, it appears undeniable that the disease is present and becomes epidemic from time to time.

Practically all the huge amount of disease remains untreated owing to the ignorance of the native, to whom ill-health seems to be such a natural condition that he has forgotten what good health is. Poverty precludes in most cases obtaining medical treatment. Quinine, for instance, is unknown to the average native. Of measures of prophylaxis he is entirely ignorant. To his hard won acquired immunities, eked out by simple native medicines,the native owes what measure of good health he enjoys.

<u>SUMMARY OF PART 3:</u>

The Protectorate of Sierra Leone is inhabited by a primitive, ignorant, illiterate negro race, inured by necessity and insensible from habit to hard physical labour; whose diet is far from ideal and to whom hunger is a frequent visitor and famine no stranger. Their primitive methods of agriculture and fishing help to spread their endemic diseases. Their housing is poor and badly sited; their clothing scanty, their vitality is attacked by numerous serious and very prevalent diseases which must shorten their average expectation of life. Their economic status is low and precludes their obtaining efficient medical treatment for these diseases which their ignorance prevents them avoiding.

PART 4.

INVESTIGATIONS INTO THE BREEDING OF CULICIDAE IN THE MARAMPA AREA, AND OBSERVATIONS FROM OTHER AREAS.

The investigations to be discussed were carried out in the vicinity of the main European Camp at Marampa and covered the area indicated in MAP No. 2.

Section 1. Methods of investigation and record.

Searches for larvae were made by two natives. The entire area to be covered by the searches was divided into roughly equal portions whose boundaries were easily identifiable natural ground features. Each portion was searched in regular rotation, the same time being devoted to each daily search, i.e. 4 hours. As far as possible all the water in the area was sampled for larvae by dipping with a ladle. When larvae were found a collection of them was made and placed in a container with some of the water in which they occurred, larvae from different breeding places being kept in separate containers. A record was made of each breeding place, showing situation, e.g. rock pool, stream, and stating whether water was stagnant or flowing; whether exposed to or shaded from sunlight; and giving site of breeding ground e.g. in the European Camp area the square reference number; in swamps outside this area whether site was towards centre or edge of swamp. A separate sheet was used for each breeding place found, and these sheets were numbered in rotation from 1 to 50, beginning at 1 again as required. (Specimen record overleaf.)

Following the search each sample of larvae was placed in a glass jam jar in the bottom of which was a layer of clean sand. Water was added to that in which the larvae were brought until the jar was to about 2" from the top, and some green algal growth, obtained from local pools, dropped into the jar. Small slices of cork to aid emerging imagines were floated on the water.

The jar was then placed on a table whose top was divided into 50 numbered divisions, each jar being placed in the division whose number corresponded with the serial number of the report. The report was pinned on to the same division. The sample of larvae was then examined, and a note made on the report sheet as to the type, i.e. anopheline or culicine, of larvae present and the presence of pupae.

If the cannibalistic larvae of Lutzia tigripes var fusca (which could usually be identified from their size and their habits) were present in the sample, they were separated into another jar. The jars were then covered with a hurricane lamp glass, one open end of which rested on the table, the other end being covered with mosquito gauze. A little fresh water was added to the jars twice daily. At the same time about a teaspoonful of water from jars in which green fleshy leaves had been standing for some time was added: this water teemed with flagellates which served as food for the larvae.

As adult mosquitoes developed they were taken out, killed and pinned on to the corresponding numbered square on a mounting board whose top was divided into 50 numbered sections. The work up to this stage was performed by natives.

SPECIMEN LARVAL REPORT SHEET.

DATE OF SEARCH:

20th January, 1935.

SERIAL NUMBER: 6.

PLACE OF SEARCH:

West swamp, European Camp, West side of main central drain from top to main cross drain at bottom.

Larvae found in small pool of clear stagnant water in swamp ground. Water exposed to sunshine. Pool situated in square No. 8, near peg 40:60.

Larvae:-

Small anopheline larvae

Larger culicine larvae

No pupae.

Bred out:-

Anopheles costalis

Culex decens var invidiosus.

From the numbered section the mosquitoes were taken by me, and examined to determine the species. The result was then entered on the breeding ground record sheet.

By this method it was possible to estimate -

1. The sites in which larvae were found.
2. The relative importance of the various areas where breeding occurred, since equal areas were given equal searching.
3. The character of the breeding grounds favoured by anopheline and culicine mosquitoes in the locality.
4. The species of mosquitoes breeding in the area. Though a number of larvae failed to reach maturity since it was impossible to give optimum conditions for all species, a reasonable proportion came through, and a fair estimation of the species breeding was obtained.
5. The seasonal variation in breeding grounds.

Section 2. Results of investigations.

A. The following table shows the culicidae found breeding in the area and the percentage of the total breeding sites in which each species was found.

TABLE NO. 1.

ANOPHELINE	PERCENTAGE OF TOTAL GROUNDS	PERCENTAGE OF TOTAL ANOP. GROUNDS.
Anopheles costalis	20.1	60.1
Anopheles funestus	.4	1.2
Anopheles mauritianus	8.1	24.3
Anopheles squamosus	4.0	12.0
Anopheles obscurus	.3	.9
Anopheles marshalli	.2	.6
Anopheles theileri	.2	.6
Anopheles pretoriensis	.1	.3
Total for all species	33.4	

CULICINE   **TABLE NO. 1.**

Group	Species	PERCENTAGE OF TOTAL GROUNDS	PERCENTAGE OF TOTAL CULICINE GROUNDS
Group 1	Culex decens	10.0	15.0
	" " var invidiosus	8.6	13.0
	" duttoni	.8	1.2
	" annulioris var consimilis	17.3	26.0
	" thalassius	3.3	5.0
	" cinereus	3.3	5.0
	" rima	.8	1.2
	" nebulosus	2.7	4.0
	" horridus	.5	.8
	Lutzia tigripes var fusca	3.0	4.5
Group 2	Stegomyia fasciata	4.7	7.0
	" simpsoni	.3	.4
	" luteocephala	1.3	2.0
	" africana	.8	1.2
	" vittata sugens	.8	1.2
	" apicoargentea	.3	.4
	Eretmopodites chrysogaster	4.0	6.0
	Aedes irritans	.8	1.2
	Aedes punctothoracis	.3	.4
	Aedes unidentified	.5	.8
	Megharrhinus africanus	.3	.4
	Unidentified	2.2	3.3
	Total for all species ...	66.6	

Ratio of Culicine to Anopheline:- $\frac{646}{327}$ i.e. 2 to 1.

- -

The above table is based on the results of 293 searches in which 989 breeding grounds were recorded; the searches were made from June 1934 to May 1935 inclusive.

Table No. 1 shows that 8 species of Anophelini and over 20 species of Culicini were found breeding in the area. The commonest anopheline found was A. costalis; A.mauritianus and A. squamosus were next most commonly found, while the five remaining species of anophelines were rare. Among the Culicines culex annulioris var consimilis was most common followed by C. decens, C. decens var invidiosus, Stegomyia fasciata and Eretmopodites chrysogaster in that order. While the amount of culicine breeding was double that of anopheline species the most common mosquito found was A. costalis. Potential yellow fever vectors formed 17.1% of the total number of mosquitoes breeding in the area.

B. The following table shows the sites and their relative proportions of the breeding grounds of Anopheline and Culicine mosquitoes found.

TABLE NO. 2.

TYPES OF BREEDING GROUNDS.

	PERCENTAGE OF TOTAL WITHIN SWAMP LIMITS			PERCENTAGE OF TOTAL OUTSIDE SWAMP LIMITS.			PERCENTAGE OF TOTAL GROUNDS INSIDE SWAMP LIMITS. Percentage of total Breeding Grounds.	PERCENTAGE OF TOTAL GROUNDS OUTSIDE SWAMP LIMITS. Percentage of total Breeding Grounds.
	CENTRAL SWAMP POOLS. Percentage of total Breeding Grounds.	PERIPHERAL SWAMP POOLS Percentage of total Breeding Grounds.	SMALL STREAMS. Percentage of total Breeding Grounds.	LARGE STREAMS & RIVERS. Percentage of total Breeding Grounds.	POOLS OUTSIDE SWAMP, BORROW PITS, ROCK HOLES, DOMESTIC UTENSILS. Percentage of total Breeding Grounds.	TREE HOLES. Percentage of total Breeding Grounds.		
Anopheline	42	25	21	6	5	1	88	12
Culicine	40	26	14.5	2.5	15.5	1.5	80.5	19.5

Table No. 2 demonstrates clearly that the swamp area of the locality supports a large proportion of both the Anopheline and Culicine breeding.

C. The types of breeding grounds in which the most important mosquitoes were found:-

A. costalis was found to show a definitely marked preference for clear stagnant water exposed to sunshine. It was never found breeding in water with a distinct flow. In the dry season it was occasionally found to be present in the backwaters of the larger streams especially where vegetation was present. In the rainy season occasional larvae were found in tree holes; although culicine larvae were found from time to time during the rains to breed in water in the numerous solution holes in the iron ore outcrops, A. costalis was never found in these sites. The reason for this is uncertain: possibly the temperature of the water in these small rock pools was too high. Throughout the year the largest incidence of A. costalis breeding was in the swamp area: during the rains extension from there to water collections in borrow pits, depressions in the ground and much more infrequently, domestic water containers was noted. In the latter one third of the rainy season while breeding continued in the swamp area, pupae were seldom found there; it seemed certain that while oviposition continued in swamp pools at that time, the torrential rains washed out the larvae before they reached maturity.

A. funestus seemed to prefer water with a slight flow and water which was definitely shaded at least for part of the day. It was found also in quite stagnant pools which were usually shaded to some extent. The dry season showed the maximum breeding, the sluggish flow in small streams appearing to suit the mosquito best.

A. mauritianus was found in pools and in stream backwaters. Shade or sunlight did not appear to have any particular influence.

A. obscurus showed a somewhat similar range of grounds.

The main culicine incidence fell in swamp area. There was a catholicity of taste in each species and water of all kinds, clear or muddy, sufficed so long as the water was stagnant. Shade appeared to have little influence. Running water appeared abhorrent and even water with a sluggish flow was not greatly favoured. Those in Group 1 Table No. 1 were found constantly throughout the year. Those in Group 2 Table No. 1 became much more numerous in the rainy season. Those in Group 2 all seemed to prefer water near human habitations no matter what the physical characters of the water were. While their range extended into swamp pools particularly near houses, their choice was definitely small collections of water in calabashes, broken bottles, tins, rotting tree stumps etc., in close proximity to dwellings.

D. Variation from month to month was found in the location and number of breeding sites. Since it will be later shown to be the principal vector of malaria in the locality, it is of interest to consider the monthly variations in the location of A. costalis breeding sites.

This is shown diagrammatically in CHART No. 1. The impossibility of discovering every breeding ground all the year round and the difficulty of being certain in which grounds larvae would reach maturity, negative making a chart on/

on breeding ground observations alone. It will be later shown that the average life of A. costalis is possibly considerably under one month, therefore it is reasonable to take the monthly density of A. costalis as a measure of the amount of breeding occurring during that month. In constructing CHART No. 1 the average density, as established by room searches, of imagines of A. costalis in the Servant's Quarters, Magbenkiti and Mafawki villages was worked out, and to each month there was allocated on the chart an area proportional to this density. The area on the chart for each month was then divided into sections, whose relative proportions were those in which larvae of A. costalis were found in the various types of breeding grounds contiguous to these three places during that month. That is, the various types of breeding grounds are plotted each month as observed proportions of the total result of all breeding in the month as measured by the adult density. Though CHART No. 1 is therefore to some extent artificial in the methods used in its construction, it corresponds fairly well to one based on actual larval findings, (particularly if allowance is made, based on the presence or absence of pupae, for the failure of larvae to reach maturity in certain situations) and I think, reflects reasonably accurately the course of events.

CHART No. 1 shows that during the rainy season, there is a large extension of breeding in pools in swamp, in which situation breeding occurs throughout the year. During the dry season the majority of breeding is occurring in small streams, the amount increasing with the progress of the dry season. Breeding in borrow pits etc., outside swamp limits is found only during the rains as might be expected. The cause of this variation will be discussed more fully later in Part 5. CHART No. 1 is of value in directing control measures, showing in which place concentration of effort is likely to yield the best results at any time, and in allowing control measures to be planned and instituted in advance.

E. It is of interest to consider the results of such other investigations as are available into mosquito breeding grounds in the Protectorate.

Wood (1914) found swampy areas to be the most important breeding grounds. His short article gives very little detail referring directly to breeding grounds, but contains details of spleen examinations in numerous villages in the Koinadugu district. He has noted against many of the villages examined their situation relative to swamps and rivers. Analysing his data one obtains the following figures for those villages whose relation to swamp or river is described:-

Table No. 3.

Percentage of inhabitants examined who showed enlargement of the spleen:-	Wet Season	Dry Season.
In villages situated over 400 yards from nearest swamp or river.	33%	14%
In villages situated under 400 yards from nearest swamp or river.	48%	31%

These/

These figures at once suggest that proximity to a swamp or river (very few of the villages examined were near any river) increases the malarial incidence in the inhabitants of the village. The reason seems most likely to have been ~~that~~ the proximity to favourable breeding grounds for vectors of malaria, which attained a greater density and caused a higher incidence of malaria. The increase in the incidence of Splenic enlargement in the wet season is also noteworthy. Basing his opinion on the examination of the spleen in 1149 children under 14 years of age in the dry season, and 557 children in the wet season Wood concludes that the incidence of malaria during the wet season is double that of the dry season.

In March and April 1931 surveys of two main railway construction camps of the Sierra Leone Development Company, at Sahr Marank and Pepel, were made by the staff of the Sir Alfred Jones Laboratory, Freetown. (Gordon and Davey, 1931). In March at Sahr Marank, which lies in the Fresh Water Belt of the Tidal Fringe the vast majority of Anopheline breeding was found in contiguous swampy areas. The survey was made at the end of the dry season and breeding was found limited to the sluggish and tortuous streams traversing the swamps. From larvae collected from swamp breeding grounds. A. costalis, A. funestus, A. marshalli var hargreavesi, A. rhodesiensis, A. squamosus, A. obscurus, A. mauritianus var paludis, and A. mauritianus var Ziemanni were bred out. Personal observation for over a year following this confirmed the finding that the bulk of auopheline breeding at Sahr Marank occurred in the swamp areas, and the following amplification can be made. The breeding continued throughout the year, following the same course as indicated in C and D to occur at Marampa. Geologically the formation of the swamps at both places was identical; the only difference between the swamps of the two areas was that the main swamps at Sahr Marank drained into the Port Loko creek which was tidal and their lower reaches were flooded at high tide. In that area of the swamp daily flooded no breeding occurred, except towards the periphery, where the influence of the tide was negligible. That area of the swamp immediately above the limit to which the high tide flooding reached appeared to support more breeding then reaches of the swamp higher up, probably due to greater water stagnation in that area from interference with efficient drainage by the tidal rise.

In April 1931 the survey at Pepel showed a complete absence of Anopheline breeding. There are no springs or streams on the island of Pepel which lies in the Saline Belt of the Tidal Fringe. Large swamps of sand and clay overlaid with alluvial mud are present; these are low-lying and covered, except in some of their upper parts, by the tide daily. The water in those parts of the swamp above high tide level is very salt. It is recorded that Anopheline larvae placed in water in shallow pools made in the upper swamp reaches died in a few hours, the water being too saline. While no Anopheline breeding was found in April, culicines were found breeding freely in water in crab holes on the outskirts of the swamps. The following species were recorded:-

Aedes (Aedimorphus) nigricephalus; Aedes (A) irritans; Aedes (A) sp. probably tarsalis; Culex rima; Culex philipi; Culex sp? perfidiosus or decens var invidiosus; Uranotaenia annulata. Some crab holes contained larvae, others did not. The governing factor appeared to be the salt content of the water; crab holes in which the water contained over 1.9 per cent of/

of Sodium Chloride did not contain larvae. The investigators expressed the opinion that dilution by rain of the salt water in the swamps would render the swamp areas above high tide level capable of supporting an Anopheline population. In August, 1931 they made a further survey during the height of the rains. A. costalis was then found breeding in numbers in those swamp areas, the saline content of 2.9 per cent of the dry season being reduced by dilution to o.18 per cent. Personal observations from 1931 to 1935 corroborate the annual recurrence of this phenomenon. With the advance of the rains, A. costalis and other Anophelines establish themselves in the diluted water in these areas of the swamps above high tide level; in pools from seepage etc. along the landward edge of these tidal swamps; and in borrow pits etc. outside swamp limits. No Anopheline breeding has ever been found by me in crab holes or in those areas of the swamp flooded by the tidal rise.

Barber and Olinger (1931) and Evans (1931) describe the occurence in Nigeria of a race of A. costalis capable of breeding in water of a high degree of salinity. No evidence of the existence of a similar race of A. costalis, either adults or larvae, has been found at Pepel at any time. Larvae of A. costalis from various breeding places at Pepel have invariably died on being placed in water of a high saline content equalling that in which complete development of the melanic coastal race described from Nigeria was possible. In surveys in the Saline Fringe of the Tidal Belt the possible occurrence of such a race of A. costalis should be borne in mind, as the presence of such a race would materially alter the plans for control of breeding.

F. Observations in the Inland Plateaux region have shown that Culicidae, and particularly Anophelini are considerably fewer in number than in the Coastal Belt. Possibly several factors are operative in causing this reduction, but while the lower temperatures at certain seasons of the year and the scantier population of the country have some effect, the comparative paucity of Anophelini is without doubt mainly due to the rarity of suitable natural breeding grounds, in particular the absence of the extensive swampy areas common in the Coastal Belt. Camps situated in areas where no swamp is present have remained free from Anopheline mosquitoes (and malaria) except during the rainy season when a scanty anopheline population may exist, breeding in rain filled holes. Camps situated in areas where swamp is present or near have shown the presence of Anopheline mosquitoes even during the dry season, when the only possible source from which the mosquitoes could come was from breeding in the swamp. It has been noticeable, however, that throughout the year, the incidence of all Culicidae in the Inland Plateaux region has been very considerably under that common in the Coastal Belt region.

SUMMARY OF PART 4.

(1) The various species of culicidae found breeding in a district in the NON-TIDAL FRESH WATER AREA are recorded. The most common anopheline found was A. costalis, which was present in 20 per cent of the breeding sites discovered. Culicine breeding was found to be twice as common as anopheline, and potential yellow fever vectors occurred in 17 per cent of the total sites discovered.

(2) 88 per cent and 80.5 per cent of anopheline and culicine breeding respectively was found to occur in swamps.

(3) The types of breeding grounds favoured by the more important mosquitoes are detailed.

(4) Variation in the location throughout the year of the breeding places of A. costalis was found, and a chart, CHART No. 1, has been constructed to show diagrammatically these variations monthly.

(5) Such other information as is available re breeding of anophelines in the Non-tidal Fresh Water Area of the Protectorate indicates that swamps are the main breeding places.

(6) Observations on anopheline breeding in an area in the FRESH WATER BELT of the TIDAL FRINGE of the PROTECTORATE are cited. Swamp is again seen to support the largest proportion of breeding, but certain differences from the previous area discussed are observable in the distribution of the breeding grounds within the swamps, due to the flooding by the tidal rise.

(7) Observations on anopheline and culicine breeding in an area in the SALINE BELT of the TIDAL FRINGE are cited. While swamp again supports the bulk of the anopheline breeding, breeding only occurs in those areas of swamp above high tide level, and there only when rain has sufficiently diluted the salt water in those areas to permit breeding. No evidence has been found that a melanic, coastal race of A. costalis capable of breeding in waters of high salinity exists in the area.

(8) Diagrams of the seasonal variations in the location of the breeding grounds of Anopheline mosquitoes in the several areas of the Protectorate are appended.

(9) The incidence of culicidae in the Inland Plateaux region of the Protectorate has been noticed to be considerably less than that common in the other areas of Sierre Leone. The main reason for this it is suggested is that the topography of the country is such that suitable breeding grounds are scanty.

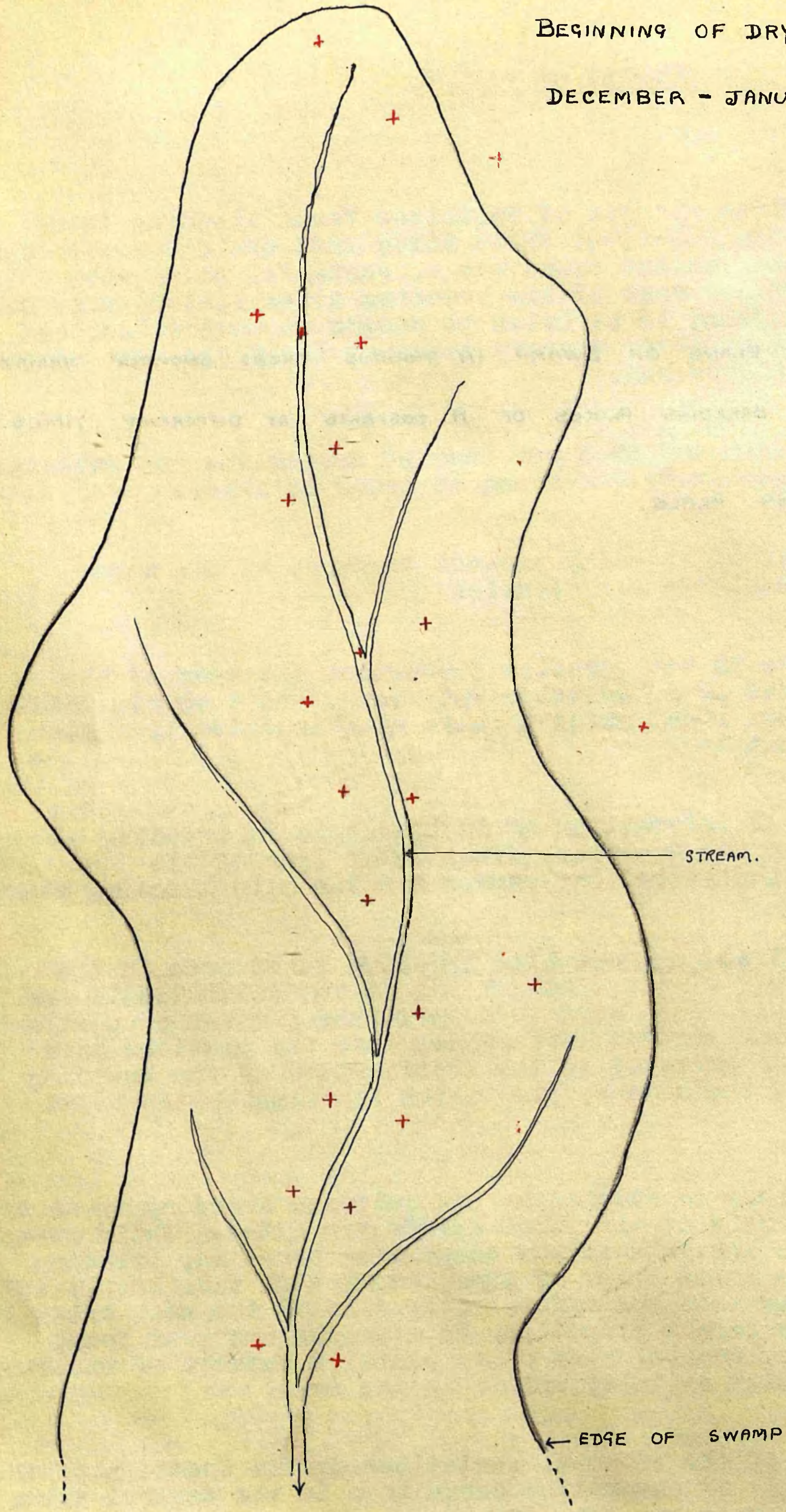
DIAGRAMMATIC PLANS OF SWAMP IN VARIOUS AREAS SHOWING VARIATION IN LOCATION OF BREEDING PLACES OF *A. COSTALIS* AT DIFFERENT TIMES.

+ = BREEDING PLACE.

COASTAL BELT NON-TIDAL FRESH WATER AREA.

BEGINNING OF DRY SEASON,

DECEMBER - JANUARY.

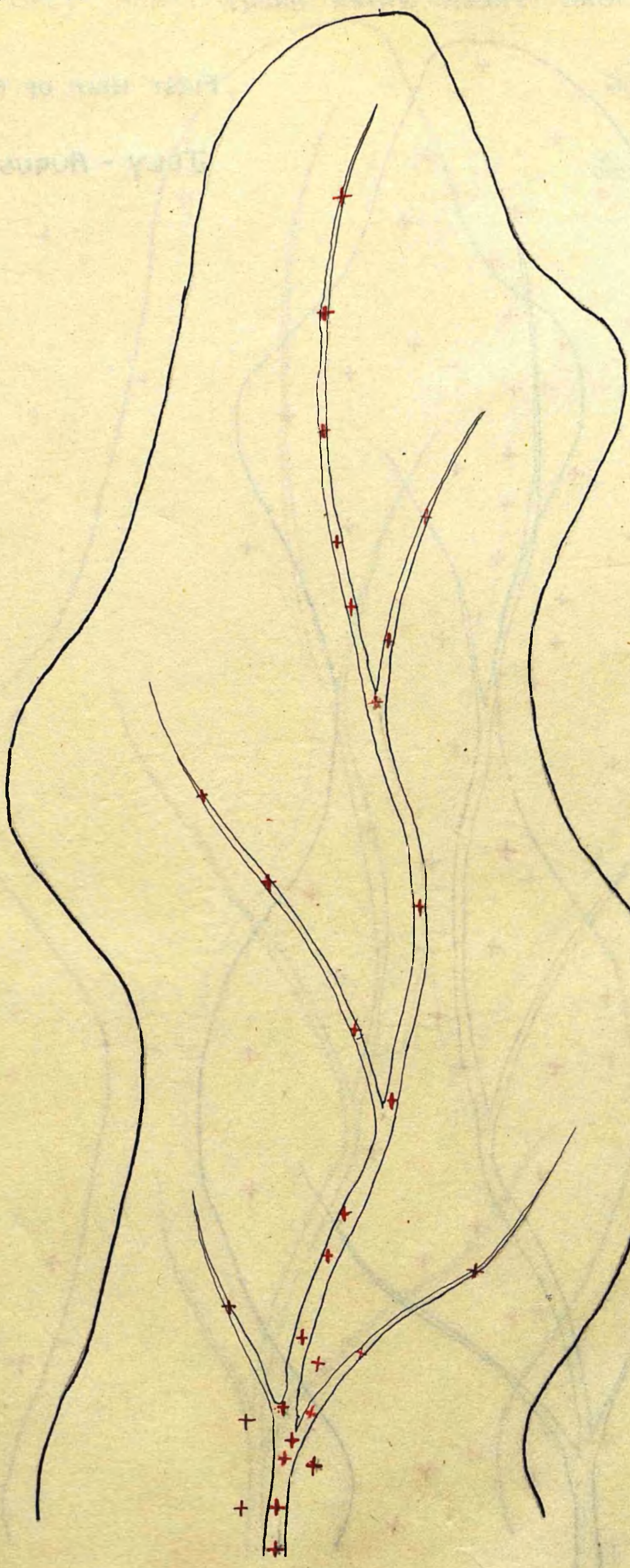


BREEDING MAINLY IN CENTRAL SWAMP POOLS, A LITTLE IN SMALL STREAMS.

COASTAL BELT NON-TIDAL FRESH WATER AREA.

END OF DRY SEASON,

MARCH - APRIL.

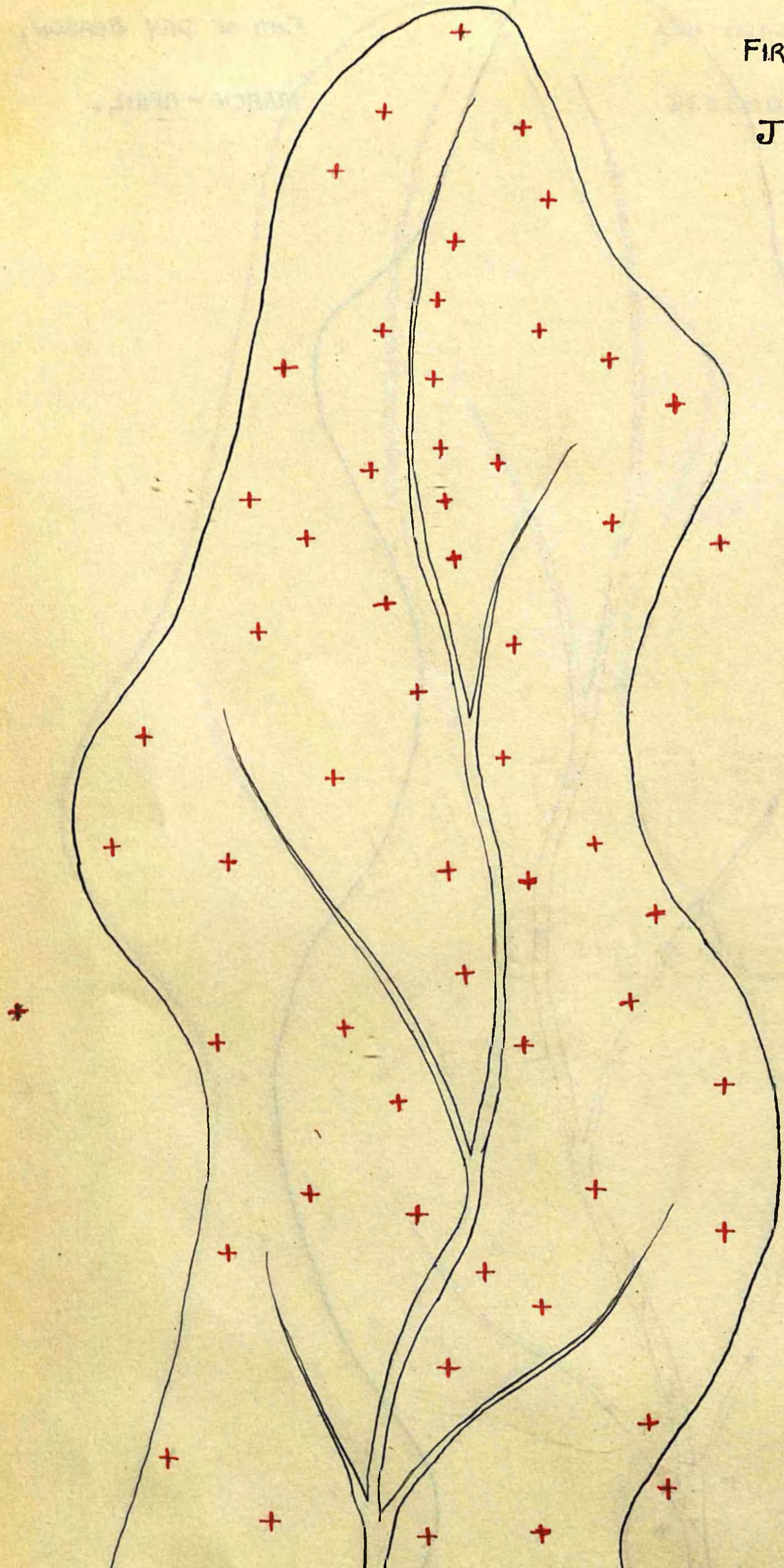


BREEDING ALMOST ENTIRELY LIMITED TO SMALL AND LARGE STREAMS.

COASTAL BELT NON-TIDAL FRESH WATER AREA.

FIRST HALF OF RAINY SEASON,

JULY - AUGUST.

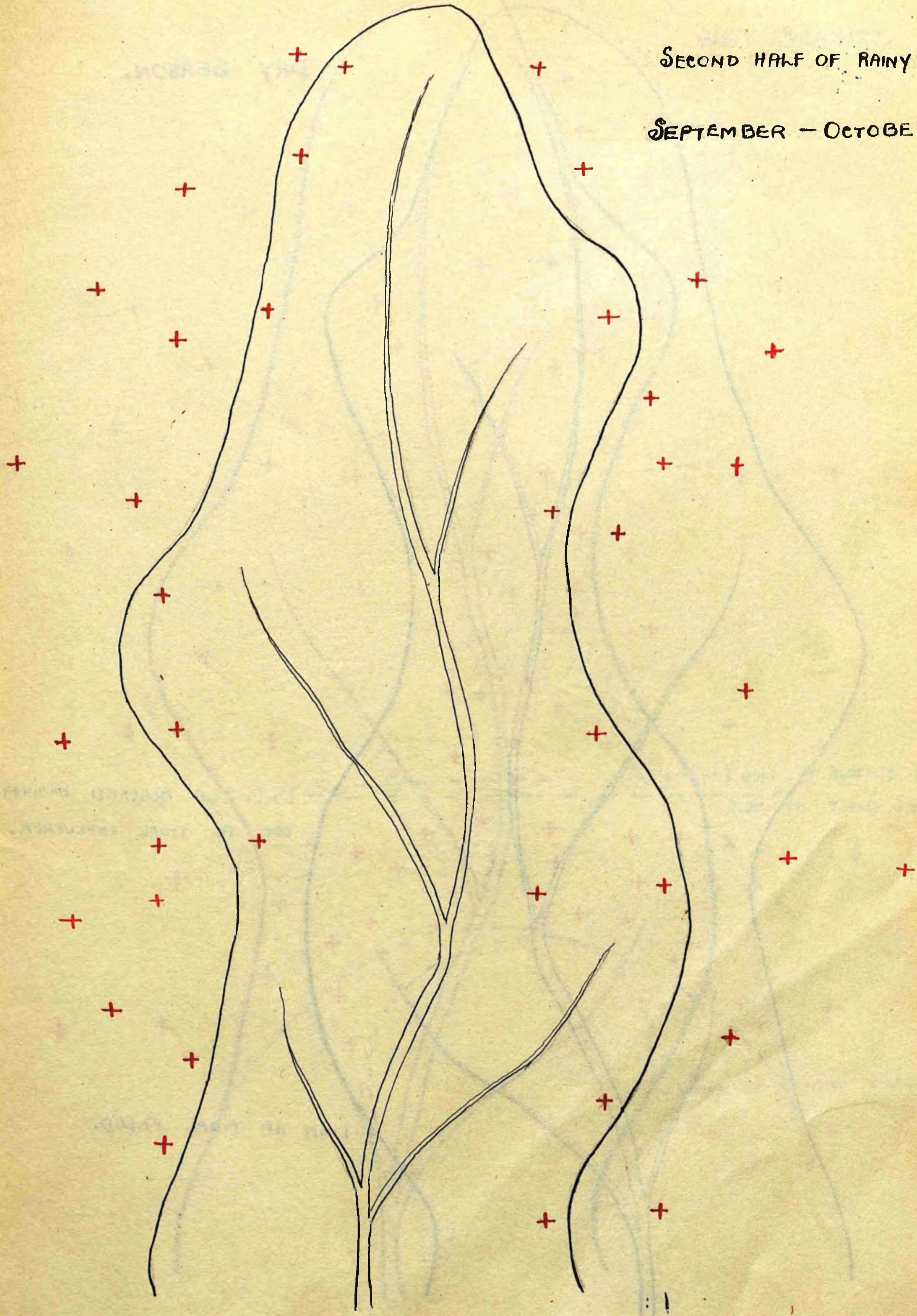


BREEDING ABSENT IN ALL STREAMS BUT EXTENSIVE IN CENTRAL AND PERIPHERAL SWAMP POOLS; A FEW SITES OUTSIDE SWAMP.

COASTAL BELT NON-TIDAL FRESH WATER AREA.

SECOND HALF OF RAINY SEASON,

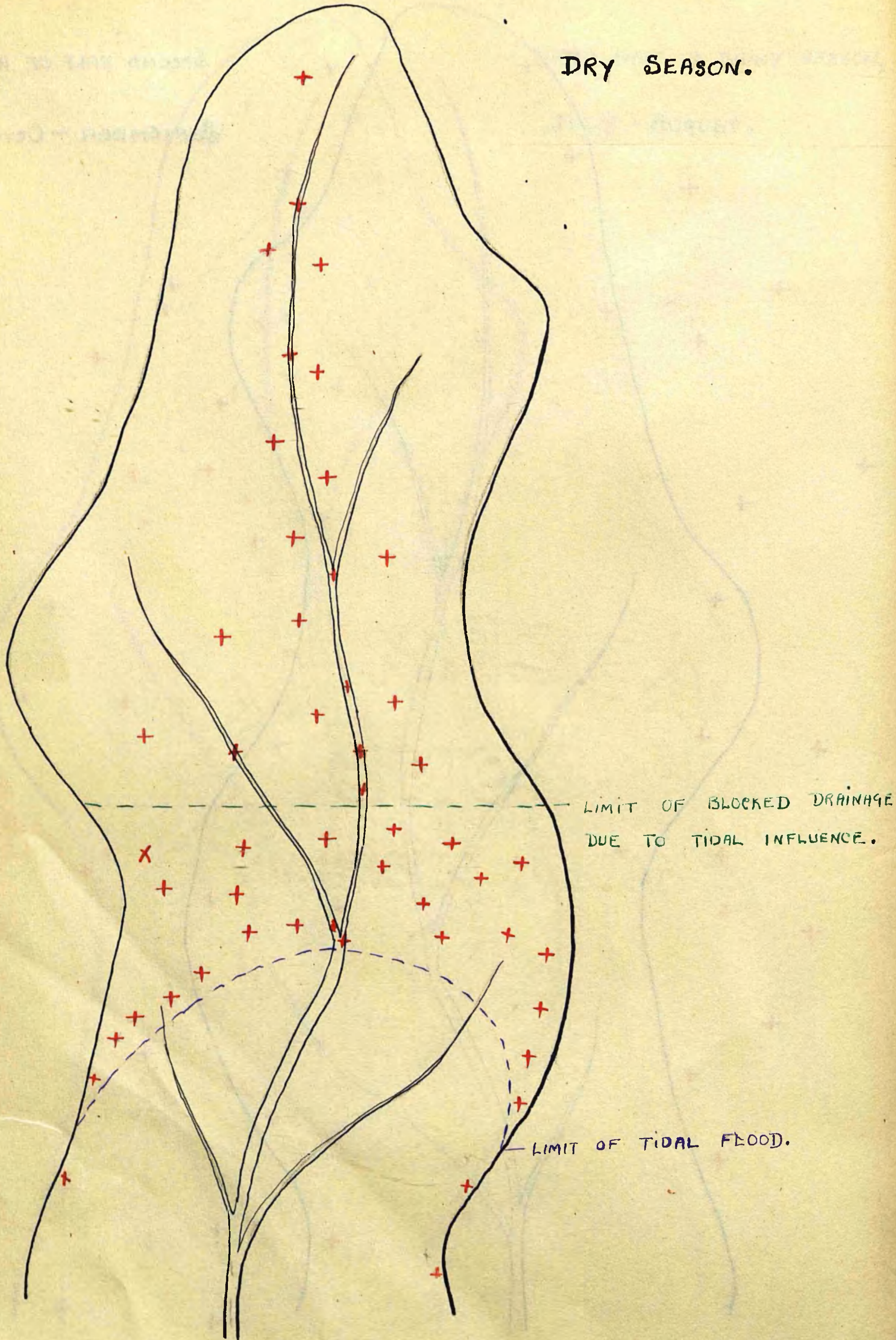
SEPTEMBER – OCTOBER.



CENTRAL POOLS WASHED OUT; BREEDING MAINLY IN EXTRA-SWAMP SITES AND PERIPHERAL POOLS.

COASTAL BELT TIDAL FRINGE FRESH WATER BELT.

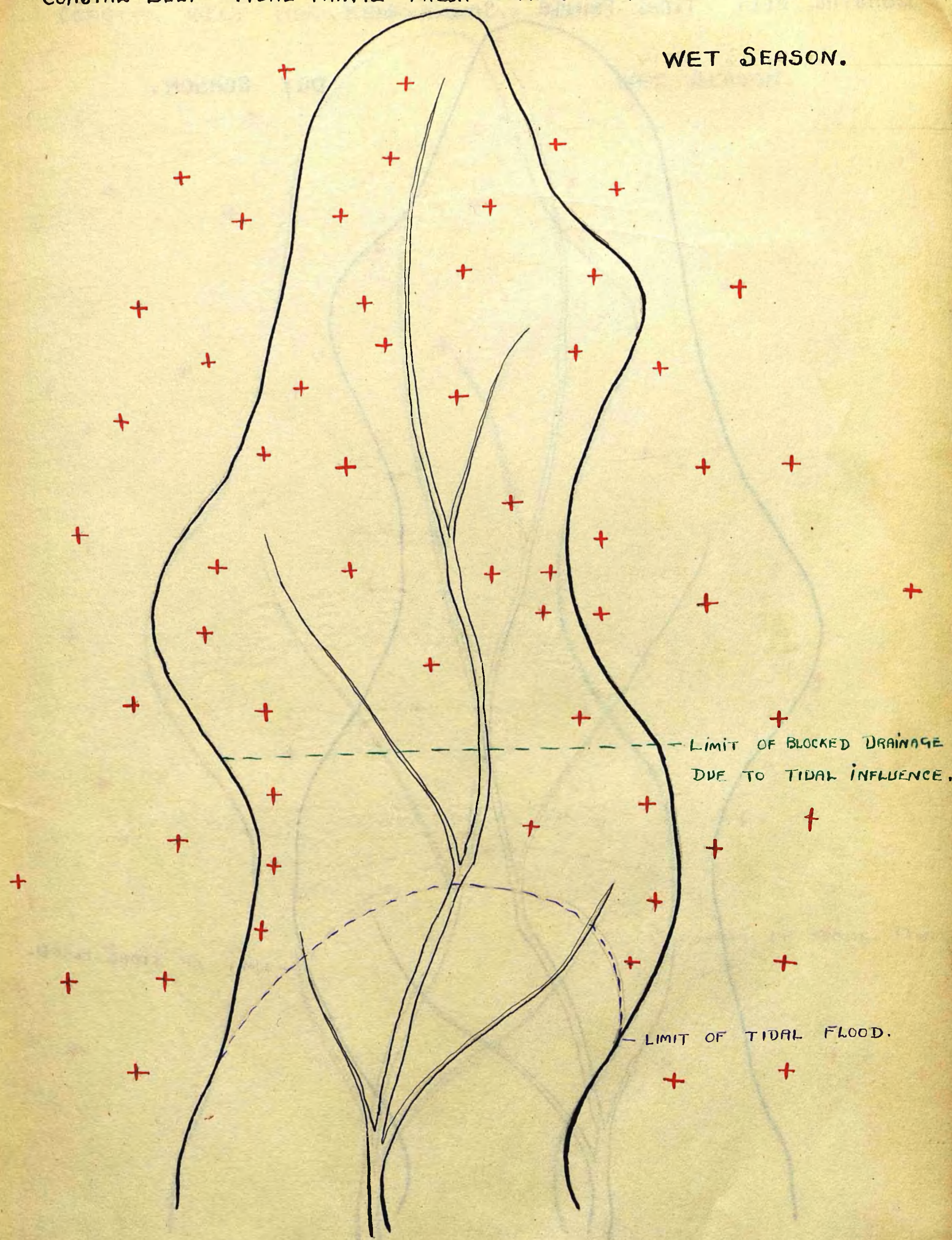
DRY SEASON.



BREEDING IN STREAMS AND CENTRAL SWAMP POOLS, PARTICULARLY IN THAT AREA WHERE SWAMP DRAINAGE IS BLOCKED BY TIDAL INFLUENCE. NO BREEDING IN AREA FLOODED BY TIDE EXCEPT NEAR SWAMP EDGE.

COASTAL BELT TIDAL FRINGE FRESH WATER BELT.

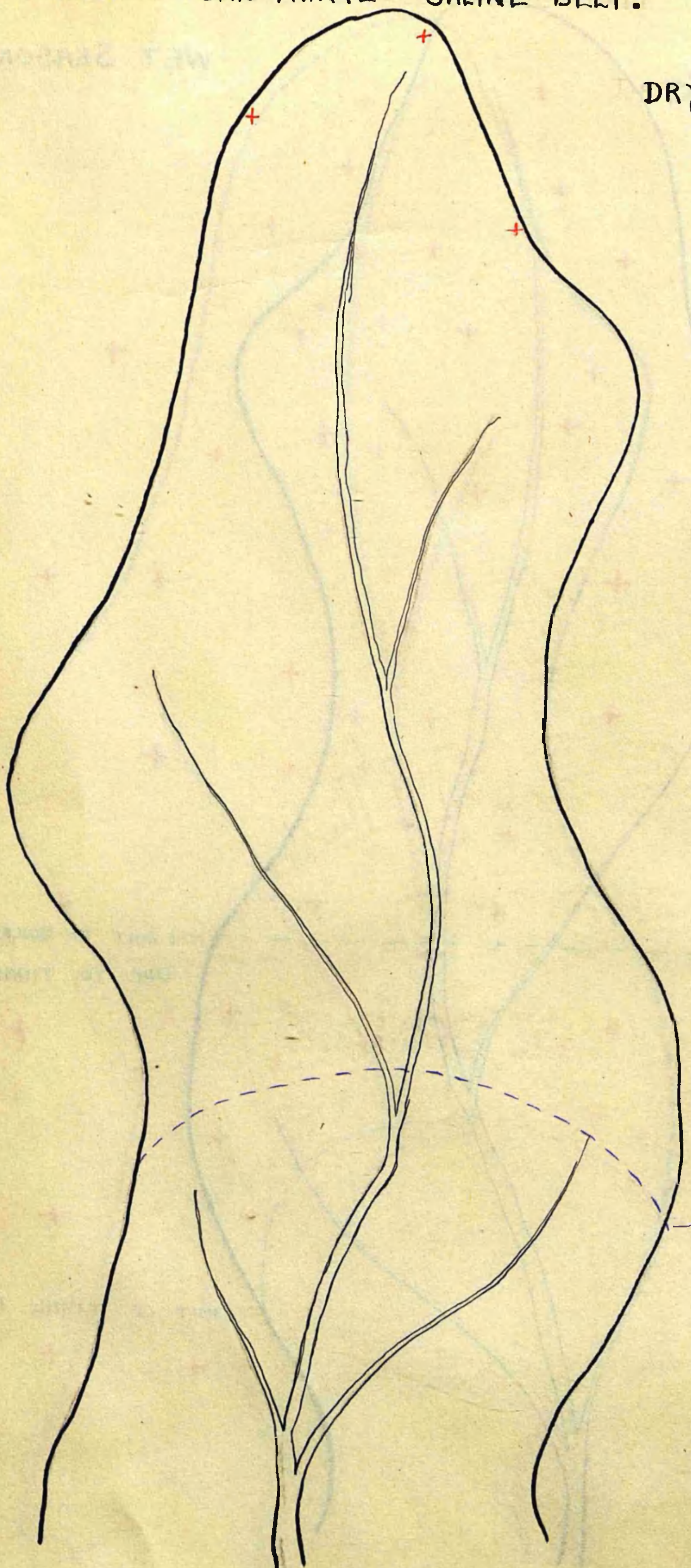
WET SEASON.



BREEDING IN CENTRAL, PERIPHERAL AND EXTRA SWAMP POOLS. NO STREAM BREEDING. RAPID DEVELOPMENT OF FLUSHING ACTION IN AREA OF BLOCKED DRAINAGE ENDS BREEDING THERE.

COASTAL BELT TIDAL FRINGE SALINE BELT.

DRY SEASON.

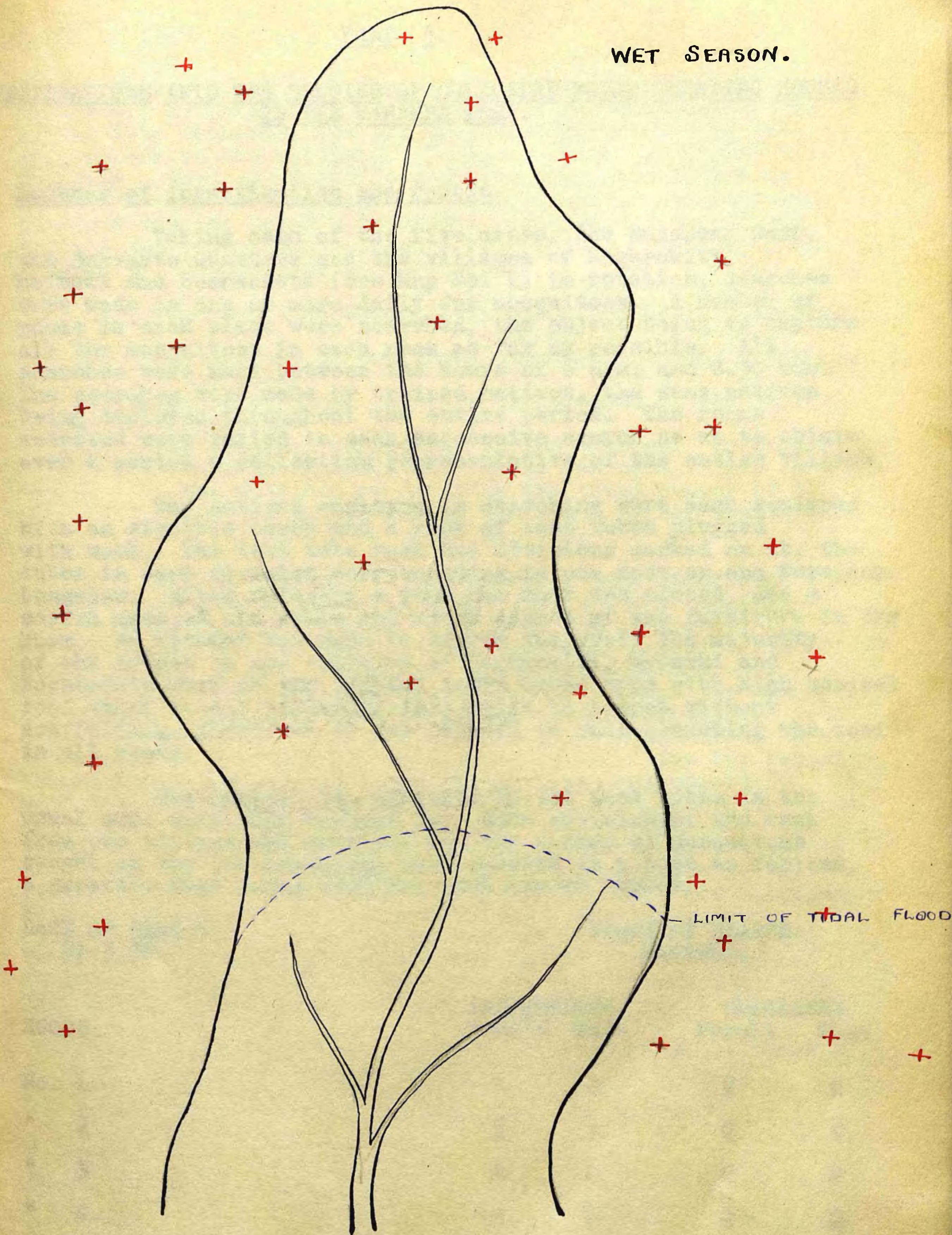


BREEDING ONLY WHERE FRESH WATER SEEPAGE DILUTES SALINITY OF SWAMP WATER.

TIDAL RISE OF SALT WATER AND SALINITY OF ALL WATER IN SWAMP PREVENTS BREEDING.

COASTAL BELT TIDAL FRINGE SALINE BELT.

WET SEASON.



BREEDING IN POOLS ABOVE TIDAL INFLUENCE, RAIN HAVING SUFFICIENTLY DILUTED HIGH SALINITY. BREEDING IN SITES OUTSIDE SWAMP LIMITS.

PART 5.

INVESTIGATIONS INTO THE SPECIES OF CULICIDAE FOUND HAUNTING HOUSES, IN THE MARAMPA AREA.

Methods of investigation and record.

Taking each of the five areas, The European Camp, the Servants Quarters and the villages of Magbenkiti, Mafawki and Rochendata (See Map No. 2) in rotation, searches were made in one or more daily for mosquitoes. A number of rooms in each place were searched, the object being to capture all the mosquitoes in each room as far as possible. All searches were made between the hours of 6 a.m. and 8.30 a.m. The searches were made by trained natives, the same natives being employed throughout the entire period. The rooms searched were varied in each successive search so as to obtain over a period a collection representative of the entire village.

The natives employed in searching were each equipped with an electric torch and a rack of test tubes plugged with wool. The test tube rack had divisions marked on it, the tubes in each division corresponding to one room or one European bungalow. After entering a room the door was closed, and a search made of the walls and every aspect of the furniture in the room. No attempt was made to search the roof: the majority of the houses in the villages of Magbenkiti, Mafawki and Rochendata were of the typical round house type with high conical roof which it was virtually impossible to search without scaffolding, therefore it was decided to omit searching the roof in all cases.

The mosquitoes, captured in the test tubes in the usual way, were then brought in. Each division of the rack from one village was examined and the number of mosquitoes caught in the corresponding room entered in a book as follows, a separate page being used for each search record.

DATE OF SEARCH: 29.3.34 | PLACE OF SEARCH: Mafawki.

ROOMS.	ANOPHELINES Female	ANOPHELINES Male	CULICINES Female	CULICINES Male
No. 1	1	0	0	0
" 2	3	1	0	0
" 3	0	0	0	0
" 4	2	0	0	0
etc.				
TOTAL ROOMS 12 TOTAL MOSQUITOES	11	1	0	0

The examination of the captured mosquitoes was for some time made by myself, and the anopheline and culicine species recorded. The extreme paucity of culicines in the catches, and the vast preponderance of Anopheles costalis found led to the abandoning of this practice since the time occupied could be ill afforded. Thereafter the record of the catches was made as above by the head boy of the mosquito gang/

gang. It was found that, using a hand lens, he could accurately differentiate anopheline and culicine mosquitoes by the wing markings, and the male from the female by the differences in the antennae. Periodic checks confirmed his accuracy. When any culicine mosquito was noted by him in the catch he reported the fact to me, when the mosquito was examined and the species recorded. The proportions of the various species of Anophelines were obtained from the records of those coming to dissection.

From the data recorded it was possible to estimate:

(1) The species of culicidae commonly haunting houses in the area.

(2) The numbers and relative proportions of the various species.

(3) The seasonal variations in the species. To establish this the Monthly Room Index was used. This index was obtained by dividing the total number of the species caught during the month in one area by the total number of rooms searched.

In the searches in the European Camp Bungalows, each bungalow was searched entirely, and the number of mosquitoes recorded against the bungalow searched. In estimating the Monthly Room Index of the European Camp each bungalow was regarded as 5 roomed, except one which was regarded as 6 roomed. The five roomed bungalows each contained two bedrooms 16' x 16', a dining room 16' x 16', a front verandah 10' x 48' a back verandah 5' x 36', two bathrooms approximately 6' x 8' each, and two latrines approximately 4' x 5'. The six roomed bungalow had similar bedrooms, dining rooms and verandahs, with one bathroom 8' x 15' one latrine 6' x 4', one store-room 10' x 10' and two end verandahs 10' x 26'. Compared to the sizes of the native rooms searched, (In the Servants Quarters each room was 12' x 10'; in the native villages the average size was, if anything, less) the number of rooms per European bungalow was therefore underestimated. This was done intentionally to make allowance for the better lighting and ventilation of these bungalows compared to the other houses searched. It is likely, however, that the estimated Monthly Room Index for the European Camp is greater than it should be.

(4) If any agreement or dissimilarity was to be found in the mosquito populations of the five places investigated.

Results of investigations.

Section 1.

In Table No. 4 are set out the species of culicidae found in rooms in the five places investigated at Marampa, and the numbers in which they were found to occur.

TABLE NO. 4.

SHOWING THE SPECIES FOUND AND THEIR NUMBERS AMONG 10,937 MOSQUITOES COLLECTED IN THE FOLLOWING PLACES:-

PLACE	TIME	NUMBER OF ROOMS SEARCHED.	NUMBER OF MOSQUITOES FOUND.
European Camp Marampa.	July 1933 to May, 1935	16,298	3,370
Servants' Quarters Marampa.	Aug. 1933 to May, 1935	1,817	2,814
Magbenkiki Village.	Sept. 1933 to May, 1935.	2,777	2,077
Mafawki Village	July 1934 to May, 1935.	1,211	1,319
Rochendata Village.	July 1934 to May, 1935.	1,166	1,357
		23,269	10,937

SPECIES	CULICINI			SPECIES	ANOPHELINI			
	MALES	FE-MALES	TOTAL		MALES	FE-MALES	TOTAL	
O S. fasciata		12	12	A. costalis	669	9741	10410	= 95.2% of total and 96.5% of Total Anops.
x S. vittata sugens		2	2	A. funestus	25	334	359	
x S. Africana	1	6	7	A. mauritianus	2	3	5	
x S. luteocephala		2	2	A. squamosus		5	5	
x C. thalassius	1	3	4	A. obscurus	1	3	4	
x E. chrysogaster	2	7	9					
x Aedes puncto-thoracis		3	3					
L. tigripes var fusca	1	3	4					
C. decens	2	12	14					
C. " var invidiosus	2	20	22					
C. duttoni	5	12	17					
C. annulioris var consimilis.		2	2					
C. cinereus	2	21	23					
C. nebulosus	2	15	17					
O Megharrhinus Africanus.	3	5	8					
Unidentified	7	1	8					
TOTAL	27	127	154		697	1008	10783	

x Caught during the rainy season.

@ 11 in rainy season; 1 in dry season.

0 Caught during the rainy season. 3 found in morning searches; other 5 caught on entering a European bungalow during the day.

Remainder of culicines were found throughout the year, being more prevalent during the rains than in the dry season.

Ratio of Culicine to Anopheline 1:70

The species of house-haunting culicidae recorded agrees with that recorded by observers in Nigeria, Gold Coast and Sierra Leone. From the table it is at once evident that A.costalis was found to be by far the most predominant mosquito found in houses, 95.2% of all the mosquitoes caught belonging to this species. A funestus formed 3.3% of the total; other species of anophelines were negligible in amount, and all species of culicini together formed only 1.4% of the catch.

Comparing these results with the results of the survey of breeding grounds described in Part 4, the complete disparity between the relative amount of culicine breeding and the relative numbers of adult culicini found in houses is striking. Larval Surveys do not give any indication whatever of what mosquitoes will be found haunting houses in the vicinity of the breeding grounds, a fact commented upon by several observers in West Africa.

Section 2.

The ratio of culicines to anophelines found in houses is small. The following table shows that this is a common finding in West Africa.

TABLE NO. 5.

COLONY	DISTRICT	AUTHORITY AND DATE	TOTAL NUMBER OF CULICINI FOUND.	TOTAL NUMBER OF ANOPHELINI FOUND.	RATIO OF CULICINI TO ANOPHELINI.
Gold Coast	Takoradi	Pomeroy (1931)	357	2195	1 : 6
	Accra	Macfie (1922)	276	10	28 : 1 (1)
Nigeria	Lagos & Ikoyi	Connal (1930)	350	295	1 : 1
"	Kaduna	Johnson (1919)	902	4541	1 : 5
"	Katagum	" "	15	3995	1 : 266
"	Zungeru	" "	382	1679	1 : 4
"	Gadau	Taylor (1930)	74	2134	1 : 29
"	Lagos	Beeuwkes	6297	221	28 : 1 (2)
"	Ibadan	et alia (1933)	5725	2685	2 : 1
"	Kano	"	1395	3386	1 : 2½
"	Zaria	"	1492	4335	1 : 3
"	Wallidazene	"	522	4280	1 : 8
Uganda	Kampala	Gibbins 1932.	21%	22,463	1 : 4
Sa.Leone	Freetown	Gordon et al (1932)	82	1223	1 : 15
"	Kissy	"	46	3763	1 : 82
"	Marampa	MacKelvie (1935)	154	10783	1 : 70

(1) Macfie points out that this figure is misleading, 80% of the total culicines having been taken in a single house during the same month by the same collector.

(2) Beeuwkes et alia state "The high incidence of the various mosquitoes of this genus (Culex) in Lagos is explained by the large numbers of Catch pits, drains, and medicine pots which exist there and which serve as breeding places for great numbers of the different species of the genus ... . In Ikoyi, Yaba and other environs of Lagos the numbers of anophelines were greatly in excess of the numbers of anophelines in the city proper."

Section 3.

Apart from stating that the culicine concentration was about equal in the four native areas and considerably less comparatively in the European Camp, the small number of culicines caught renders it useless to discuss this group of mosquitoes further, except to relate the ratio of potential yellow fever vectors to other culicines found to the ratios found elsewhere in West Africa. This is done in the following table.

TABLE NO. 6.

COLONY	DISTRICT	AUTHORITY & DATE.	TOTAL NUMBER OF POTENTIAL YELLOW FEVER VECTORS	TOTAL NUMBER OF OTHER CULICINES FOUND	RATIO OF VECTORS TO OTHER CULICINI.
Gold Coast	Takoradi	Pomeroy (1931)	185	181	1 : 1
"	Accra	Macfie (1921)	23	253	1 : 11
Nigeria	Lagos & Ikoyi	Connal (1930)	18	332	1 : 18
"	Kaduna	Johnson (1919)	15	887	1 : 59
"	Katagum	"	2	13	1 : 6
"	Zunguru	"	5	377	1 : 75
"	Lagos	Beeuwkes et alia (1933)	474	5823	1 : 12 (1)
"	Ibadan	"	4387	1338	3 : 1 (1)
"	Kano	"	1192	203	6 : 1 (1)
"	Zaria	"	1286	206	6 : 1 (1)
"	Walli-dazene	"	513	4802	1 : 9 (1)
Sierra Leone	Freetown	Gordon et alia (1932)	4	76	1 : 19
"	Kissy	"	5	51	1 : 10
"	Marampa	MacKelvie (1935)	39	115	1 : 3 (2)

(1) Refers only to Stegomyia fasciata and T. (Mansonioides) africanus.

(2) Includes first seven species in Table No. 4.

Potential yellow fever vectors at Marampa therefore form a larger proportion of the house-haunting culicini than in the majority of other areas recorded but their proportions do not reach that found in endemic yellow fever zones in West Africa. When one compares the density of potential yellow fever vectors at Marampa per 1,000 rooms with the similar figures for Lagos, Ibadan, etc., a marked difference is at once apparent.

TABLE NO. 7.

COLONY	DISTRICT	AUTHORITY & DATE	NUMBER OF POTENTIAL YELLOW FEVER VECTORS PER 1,000 ROOMS.
Nigeria	Lagos	Beeuwkes et al (1933)	169
"	Ibadan	"	1,655
"	Kano	"	624
"	Zaria	"	610
"	Wallidazene	"	2,565
Sierra Leone	Freetown	Gordon et al (1932)	1.3
"	Kissy	"	8.6
"	Marampa	MacKelvie (1935)	1.7

Despite the extraordinary difference between the Freetown figures and the Nigerian results quoted, yellow fever was recorded in Freetown in 1935. If the room index of potential yellow fever vectors is any guide it would seem that the occurrence of yellow fever at Marampa is a possibility, despite the low room index compared with Nigerian areas.

Section 4.

In considering the findings relative to anophelines in the catches it is of interest to compare the density found with that recorded in other West African areas. This is done in Table No. 8. From this table it is apparent that there is a lower anopheline density in the dry season than in the rains in all the five places observed in the Marampa area. This is the general finding in West Africa. Table No. 8 also shows that with the exception of Beeuwkes' Lagos figures the concentration in the Marampa European Camp is one of the lowest recorded. (It should be remembered that the Marampa figures relate to a more limited search of the rooms than in Freetown and Kissy respectively, where the entire room, walls, furniture and ceilings were searched.)

Section 5.

A. funestus occurred in too small numbers to permit of any extended discussion. Its incidence during the rains was negligible, and while found throughout the year, the maximum incidence was during the dry season, reaching a peak in January.

A. costalis was found to be present throughout the year. The concentration varied from month to month. In Chart No. 2 are depicted the numbers of A. costalis per

TABLE NO. 8.

COLONY.	DISTRICT.	AUTHORITY & DATE.	SEASON	NUMBER OF ROOMS EXAMINED	TOTAL ANOPHELINES FOUND.	NUMBER OF ANOPHELINES PER ROOM.
NIGERIA	Lagos and suburbs.	Barber and Olinger (1931)	Wet Dry	2,321 2,629	14,608 10,748	6.3 4.1
	Lagos	Beeuwkes et alia (1933)	Wet Dry	480 2,320	83 138	0.17 0.06
	Ibadan	Barber and Olinger(1931)	Wet Dry	997 401	852 752	0.9 1.9
	Ibadan	Beeuwkes et alia(1933)	Wet Dry	487 2,164	1,245 1,440	2.5 0.67
	Kano	"	Wet Dry	426 1,484	1,156 2,230	2.7 1.5
	Zaria	"	Wet Dry	485 1,623	1,513 2,822	3.1 1.7
	Wallidazene.	"	Wet Dry	100 100	4,215 65	42.2 .65
SIERRA LEONE	Freetown	Gordon et al (1932)	Wet Dry	3,005 60	1,223 6	0.4 .1
	Kissy	"	Wet Dry	358 224	3,763 244	10.5 1.1
	European Camp Marampa	MacKelvie (1935)	Wet Dry	6,789 9,509	1,983 1,343	0.29 0.14
	Servants Quarters	"	Wet Dry	722 1,095	1,214 1,550	1.7 1.4
	Magbenkiti Village	"	Wet Dry	787 1,990	778 1,279	1.0 0.6
	Mafawki Village	"	Wet Dry	355 856	580 719	1.6 0.8
	Rochendata Village	"	Wet Dry	361 805	733 604	2.0 0.8

room monthly for each of the five areas investigated, together with the monthly rainfall. This chart shows that while there is a definite connection between rainfall and the numbers of A. costalis the relationship is not a direct correspondence. With the onset of the rains there is at first no great alteration in numbers but as the rainy season advances a steep rise occurs. A very marked peak is reached in August, followed by an immediate fall until in October or November a very low level is reached despite the considerable rain falling in these two months. Following the close of the rains the numbers found remain low and fairly constant with a tendency for a gradual rise to occur as the dry season progresses. Early rains in March have no tendency to cause an earlier rise in mosquito numbers: an abnormally dry dry season, such as in 1935, favours a rise towards the end of the dry season.

The explanation of these monthly variations is to be found in the monthly variation of the amount of water suitable for breeding. The cycle of events is somewhat as follows:- (See Chart No. 1).

Towards the end of the dry season in March or April A. costalis is found breeding in stagnant water courses, in pools in the lesser streams which have almost dried up, and in backwaters of such streams as continue to flow sluggishly. The swamps are for the most part completely dried up except, perhaps, an occasional pool which is in a hole reaching below the subsoil water table level. A little rain begins to fall but has at first no effect, as it is insufficient to cause a marked flow in the streams or cause pools in the low lying swamp. More rain falls and with the increasing flow in the streams and water courses suitable breeding grounds become fewer, the stagnant pools being washed out. Mosquito concentration thereupon becomes less. With further increase in rain in June breeding rapidly diminishes in water courses but the subsoil water table rises and the formation of pools in the lowest parts of the swamps offer suitable breeding areas for costalis. Breeding also commences in pools outside swamps in such sites as borrow pits, etc., and tree holes. Heavy rain in July, causing a rapid rise in the subsoil water table, leads to a rapid increase in the number of swamp pools, the lowest areas of swamp becoming first affected. Breeding in water courses ceases entirely, water running freely in all channels. Breeding in pools outside swamp limits increases as the heavier rainfall fills up more pools. Heavy rain in August raises the subsoil water table again until pools form all over the swampy areas, the majority of breeding occurring in the pools towards the periphery of the swamps, some of the more central pools beginning to be washed out. Breeding in sites outside the swamps again increases and mosquito concentration reaches its peak. With further rain in September and October all the swampy ground lies below the general sub-soil water table and practically all the swamp pools are washed clear of larvae by the steady heavy rains. This leads to the rapid fall in the number of mosquitoes, the population being supported almost entirely by breeding in borrow pits, etc. As the rains slack off in November swamp breeding again increases while pools outside the swamp fall off in importance. Rapid drying of the swamps following the cessation of the rains begins with December and the onset of the harmattan. Breeding begins to reassert itself in the lesser streams. With the progress of the dry season and the increasing drying up of the swamps an increasing proportion of the breeding occurs in first small streams, then as these dry up, the larger streams, until swamp pool breeding practically disappears in April. Such in general is the course of events over that area of Sierra Leone called/

called the Coastal Belt. Local circumstances will cause local variation but as a general rule the above cycle is widely applicable. The basic factors of low lying country, large swampy areas, an impermeable stratum near the surface and a marked rainy season with a heavy precipitation causing a rapid rise in the subsoil water table are practically omnipresent in the area.

The correspondence between the graphs for the four native areas is striking. The graph for the European Camp shows a much lower anopheline concentration with much less marked seasonal variations: it seems probable that these differences are due to anti-mosquito measures around the European Camp area.

From Chart No. 2 it would seem likely that the average life span of A. costalis is something less than one month. Were it more than one month one would not expect the marked peak in August to be followed by the immediate large drop to the September level: a much smoother curve would be presented due to the survival well into September or October of adults born in August.

<u>SUMMARY OF PART 5</u>.

1. The species of Culicidae found haunting houses in the Marampa area of Sierra Leone are enumerated; and the proportions in which each species occurred is recorded.

2. No relationship was found between the proportions in which the various species were discovered in houses and the proportions in which they were found to be breeding in the area.

3. Culicine species were found to be scanty in numbers. Potential yellow fever vectors were present among them, but although the proportion of potential vectors to other culicines was found to be higher than usually noted in West Africa, their total numbers were few.

4. A. costalis was by far the commonest mosquito found. It occurs continuously throughout the year. The numbers present rise rapidly in the first half of the wet season to a marked peak in August from which maximum they rapidly fall. An abnormally dry dry season tends to increase the numbers present towards the end of that season.

5. The variation in the monthly concentration of A. costalis adults is related to the monthly variation in breeding grounds. The factor of importance is not the amount of rain falling in the month but the amount of water stagnant in pools, pits, streams, etc., in any one month.

6. The nature of the graphs in Chart No. 2 suggests that the average life span of A. costalis is something less than one month.

PART 6.

MALARIAL, FILARIAL AND OTHER INFECTIONS FOUND IN ANOPHELINE MOSQUITOES, TOGETHER WITH OBSERVATIONS ON THE AGES OF GROUPS OF ANOPHELES COSTALIS, AND THE DENSITY OF INFECTIVE ANOPHELINES.

Methods of investigation and record.

The entire daily catch of female anophelines from each area was caged, a separate cage being used for each village, and for each European Bungalow. The cages used were similar to those described by Barraud (1929). The cages were labelled with the name of the place where the catch was made and the date on which the catch was made.

The cages containing mosquitoes were placed on shelves in a large box in the bottom of which was kept a large container constantly full of water. On the top of the gauze of each cage a large pad of cotton wool was placed; this wool was soaked in water, the water being renewed twice daily. To ensure survival during the dry season each cage was placed in a shallow bowl of water; the gauze, dipping into the water at one end acted as a wick, soaking up water as required and maintaining an adequate humidity within the cage. After a minimum period of 48 hours the mosquitoes were removed from the cages for dissection. Owing to the necessity for travelling to the other camps at times and the pressure of other work, it was not always possible to dissect the mosquitoes exactly 48 hours after catching. The majority were dealt with at the end of 48 hours, a lesser proportion were dissected at 72 hours, and a very small proportion at varying longer intervals.

As each cage was dealt with the date of catch and the date of dissection were recorded in the dissection record sheets against each batch dissected.

A native assistant removed the mosquitoes singly in test tubes from the cage being dealt with. Each mosquito was then killed by chloroform vapour or by concussion and examined in the tube by me. The species and wing grade were noted and recorded. Thereafter the tube was returned to the assistant, who removed the mosquito, took off the wings and legs, and placed the body on a 3" x 1" glass micro slide along which he had previously placed three drops of saline at equidistant intervals.

The slide was then placed on the stage of the dissecting microscope, and using triangular bladed dissecting needles the mosquito was dissected as follows by me:-

(1) The head was cut off and left in the first drop of saline, the body being moved into the second drop.

(2) With the left hand needle gentle pressure was made on the thorax; this caused the salivary glands and usually a very little of the periglandular tissues to extrude through the opening in the cut neck. The glands, with or without the small quantity of periglandular tissue, were then cut off with the right hand needle, and, leaving these behind in the drop of saline, the body was transferred to the third drop of saline.

(3) A nick was made in either side of the penultimate abdominal segment and the stomach and ovaries were drawn out. The remainder of the mosquito was then drawn out of the drop of saline and placed on the corner of the slide. The stomach was separated from the ovaries and, if the latter were in Stage 5 or 5+, a fact which could be observed easily under the dissecting microscope, they were placed alongside the remnants of the mosquito on the corner of the slide. If the ovaries were in an earlier stage they were separated from the stomach/

stomach but left in the drop of saline. The drop of saline containing the glands and that containing the stomach alone, or stomach and ovaries, were each covered by a separate cover glass, care being taken that the ovaries, if present, lay quite definitely apart from the stomach under their cover glass.

(4) The slide was then transferred to the compound microscope. Using a 1/3rd objective and a x 10 eye piece the ovaries were examined and the appropriate age category recorded. The stomach was then examined and the presence or absence of any oocysts recorded, particulars being taken of the number of cysts, their size and contents. Any suspicious appearance was investigated with a 1/6th objective and x 10 eye piece, these being used also for investigating the details of any cysts present. It was not found possible to classify the cysts according to the species of plasmodium responsible for their production.

(5) The glands were then examined under the 1/6th inch objective with a x 10 piece, and the presence or absence of sporozoites recorded. The glands were then crushed by gently lowering the objective on to the cover slip and then re-examined. Sporozoites could be readily identified with this magnification, but if any doubt existed or any appearance noted requiring further magnification the 1/12th inch oil immersion with x 6 or x 10 piece was used.

<u>FILARIA</u>: It should be clearly understood that no complete dissection to show the presence or absence of filaria was performed. The head and proboscis were not examined at all. When as frequently happened filarial larvae were extruded from the thorax with the extruded glands and periglandular tissues or when, as more rarely occurred, filarial larvae were noted protruding from the head end of the cut neck or were brought out when the stomach and ovaries were withdrawn, these larvae were examined and their presence recorded. Thus the data recorded with reference to filaria cannot be considered complete. They certainly underestimate the frequency with which filarial infection is present. However they do give some information, and since the technique of dissection was kept unchanged throughout, it is thought that the data over a large number of dissections should show any seasonal variation in the filatial infection rates, since the percentage of positive findings should be reasonably constant.

A specimen dissection record sheet is shown overleaf.

From the data recorded it was possible to obtain -

(1) The malarial oocyst and sporozoite infection rates in the species of anophelines dissected.

(2) The proportions of mosquitoes in each Wing Grade and each Ovarian Grade.

(3) The malarial infection rate in each Wing and Ovarian Grade.

(4) Information similar to the above but of more limited value in regard to filarial infection of mosquitoes.

(5) Information re agreement or otherwise in these data recorded from each of the five places.

MOSQUITO DISSECTION RECORD SHEET.

MAGBENKITI VILLAGE.

NUMBER	DATE CAUGHT	DATE DISSECTED	SPECIES	WING GRADE	OVARIAN GRADE	STOMACH	GLANDS	FILARIA	REMARKS.
7	10.12.34	12.12.34	A.cost	1	2				
8	"	"	"	2	5				
9	"	"	"	1	2				
0	"	"	"	1	5				
1	"	"	"	2	5				
2	"	"	"	2	5				
3	"	"	"	2	5				
4	12:12:34	14.12.34	"	1	5	2 cysts			Large, nearly full matured.
5	"	"	"	2	2	2 cysts			Very small, scanty fine pigment.
6	"	"	"	1	2				
7	"	"	"	2	5		+	+	Long fully developed filaria in thorax.
8	"	"	"	3	5				
9	"	"	"	1	5				
0	"	"	"	1	5				
1	"	"	A.fun.	1	5				
2	"	"	A.cost.	1	5				
3	"	"	"	1	5	2 cysts			Cysts full of sporozoites.
4	"	"	"	3	5				
5	15.12.34	17.12.34	"	1	5				
6	"	"	"	2	5	2 cysts	+	+	Cysts small. Developing filaria in thorax.
7	"	"	"	1	2x				xOvaries diseased
8	"	"	"	1	5				
9	"	"	"	1	5				
0	"	"	"	2	5+				
1	"	"	"	2	5				
2	"	"	"	2	5				

Results of dissection.

Section 1.

"In all parts of West Africa from which figures are available A. costalis and A. funestus show a higher rate of infection with malaria and filaria than any other species". (Gordon et al 1932). Both have been proved capable of experimental infection with P. falciparum and W. bancrofti. Both bite man freely, they preponderate in numbers over all other anopheline species found in association with man in West Africa, they show high rates of infection in nature and to them must be ascribed a very large proportion indeed of the transmission of malaria in West Africa. These facts are now so generally accepted that further discussion is unnecessary.

How far the above facts apply to malaria in the Protectorate of Sierra Leone has now to be shown. In Table No. 9 I have collected all the available data I can find with reference to house haunting species, their density and their natural infection rates. The available material is small, but it substantiates the statements made above with reference to A. costalis and A. funestus.

TABLE NO. 9.

PLACE	DATE	AUTHORITY	NUMBER OF ROOMS	NUMBER OF A.COSTALIS	NUMBER OF A.FUNESTUS	NUMBER OF A. RHODESIENSIS	NUMBER OF A.UMBROSUS	NUMBER OF A.PITCHFORDI	NUMBER AND SPECIES OF CULICINE MOSQUITOES CAUGHT.
European and native quarters, goal, barracks & town, Kaballa.	September October November December 1914	Woods	Not stated	14 males 141 females 155	2 males 130 females 132	106 males 75 females 181 x	3 females 3	7 females 7	75 females
European houses Sahr Marank	March 1931	Gordon and Davey.	32	96	1	0	0	0	None recorded
Native labour lines do.	"		76	14	0	0	0	0	"
Village of Robere near Sahr Marank camp.	"		13 Houses	58	0	0	0	0	"
European houses Pepel.	April 1931		All houses and servants quarters.	0	0	0	0	0	0
Native labour lines Pepel +			100	1	0	0	0	0	0
Native village Pepel			16 Houses	0	0	0	0	0	3
European houses Pepel	August 1931		Approx. 10 rooms.	15 males 71 females					1 female.

x Majority caught in Wood's own bungalow in which he suspected these A. rhodesiensis were breeding.

\+ Re-examined in August 1931, Anophelines were found present in enormous numbers.

PLACE	DATE	AUTHORITY	NUMBER & SPECIES dissected	PERCENTAGE infected in gut.	PERCENTAGE INFECTED IN GLANDS.	PERCENTAGE OF TOTAL INFECTIONS WITH MALARIA.	PERCENTAGE INFECTED WITH FILARIA.
Sahr Marank	March 1931	Gordon & Davey	249 A. costalis	1.2%	14.5%	15.7%	17%
Pepel + European Houses.	July 1931	"	55 A. costalis.	5.5%	5.5%	11.0%	16.3%
"	August 1931	"	57 A. costalis			13.5%	22.5%
Pepel, Native lines	"	"	52 A.costalis			13.5%	11.5%
Koinadugu	1914	Wood	91 A. costalis	7.3%	8.8%	15%	
			100 A. funestus	11.9%	10%	21.9%	
			37 A. rhodesiensis			2.7%	
			1 A. umbrosus			0	
			3 A. pitchfordi			0	

+ Sample collected by me and sent to Professor Gordon who typed the species and performed the dissections.

Table No. 10 summarises the results obtained in the Marampa area.

TABLE NO. 10.

TIME	SPECIES	NUMBER DISSECTED	OOCYST INFECTIONS		SPOROZOITE INFECTIONS		FILARIAL INFECTIONS	
			NUMBER	%	NUMBER	%	NUMBER	%
August 1933 to Jany. 1934	A.costalis	1,006	116	11.5	131	13.0	35	3.5
	A.funestus.	27	3	11.1	3	11.1	2	7.4
APRIL 1934 to May 1935	A.costalis	4,454	341	7.7	353	7.9	126	2.8
	A.funestus.	158	8	5.1	8	5.1	3	1.9
	A.squamosus	3	0		0		0	
	A.mauritianus	3	0		0		0	

Total Dissections 5,651

It is again demonstrated that A.costalis and A. funestus show considerable natural infection rates with malaria and filaria. The higher rate shown by A. costalis and the preponderating proportion in which it occurs in houses make it certain that to this species must be attributed practically the entire transmission of malaria in the Marampa area. The filarial infection must certainly have been higher than the figures quoted owing to the limited nature of the dissection of filaria.

The possibility that any considerable proportion of the malarial or filarial infections observed in the mosquitoes dissected were derived from an animal source, as opposed to a human source, is very greatly discounted by the results of Davis & Philip (1931) who found that A. costalis blood meals were invariably of human origin. Monkeys do occur around the Marampa area and the possibility of malarial infection of mosquitoes from these animals has been shown by Green (1932); the small numbers of monkeys in the Marampa area, the marked preference of A. costalis for houses in search of its blood meals, and its known androphilism render it unlikely in the extreme that infection of A.costalis from non-human sources occurred to any appreciable degree.

Section 2.

It is of interest at this stage to discuss the relative ages of groups of A. costalis. Perry (1912) described a method of grouping anophelines into four age groups according to the stage/

stage of deterioration of their wing scales. His method will be discussed more fully later. Christophers (1911) described a method of grouping into five age groups based on the stage of development of the ovaries.

Gordon et alia (1932) kept records by both classifications. In their paper they state "of Perry's method of classifying the anophelines in wing grades gives a correct estimate of the relative ages of those found in houses, then over an adequate period one would expect to find a smaller proportion in each successive age grade. In our series of 3,253 anophelines examined, 50 per cent. were in Grade 1, 36 per cent. in Grade 11, 12 per cent. in Grade 111, and 2 per cent. in Grade 1V. These figures appear to support Perry's theory." The proportions in which 4,173 Anopheles costalis were found divided amongst the four wing grades at Marampa were as follows:- Grade 1, 46 per cent.; Grade 11, 39 per cent.; Grade 111, 13 per cent.; Grade 1V, 2 per cent. While these Marampa figures corroborate the statement quoted above I do not think the diminishing proportions found in successive age groups can be taken to mean that the successive groups represent successively older mosquitoes. Suppose the human population of a town or country was examined at fortnightly intervals over a period of 1000 years and the inhabitants grouped into 4 age groups; Group 1, 0 - 6 months old; Group 11, 6 months to 50 years old; Group 111, 50 to 60 years old; Group 1V, 60 to 100 years old. By far the largest proportion of the total would be found in Group 11. If Group 11 were taken as from 6 to 7 months old, and Group 111 as from 7 months to 70 years, Group 111 would form the largest group. I think it would be more accurate to say that the proportions in which the age groups occur are only a measure of the proportions of the total population surviving in that age group. No inference is possible from the relative proportions of the groups as to the relative ages of the groups.

Christophers's ovarian classification has the disadvantage that, following ripening of the eggs (Ovarian Stage 5) and oviposition, the ovaries return to Ovarian Stage 2. Since ovulation occurs several times during the life of an anopheline the stage of ovarian development is no guide to the actual age of a mosquito: a mosquito in Ovarian Stage 2 may be just commencing its first cycle of ovarian development or it may be commencing its third or fourth cycle. Perry (1912) however writes "It was found that the deterioration of the wing is probably closely related to the number of times that eggs have been deposited. Christophers has made the very important observation that occasionally an anopheles omits to lay one or two eggs of a batch, and such retained eggs are found amongst the succeeding batch of eggs. Amongst the 3757 A. culicifacies this phenomenon was observed 21 times. Amongst 1410 specimens of Wing Grade 1 it was never seen at all. Amongst 1797 of Grade 11 it occurred 12 times, (·67%); amongst 471 of Grade 111 it occurred 5 times, (1·06%); and amongst 79 of Grade 1V it occurred 4 times (5·06%)." Whatever the exact cause of retention of one or more eggs may be it seems reasonable to assume that the greater the number of times the ovarian cycle is gone through the greater will be the chances of the phenomenon occurring. Perry regards the increasing percentage of mosquitoes showing retained eggs in successive wing grades as evidence that his wing grades represent successively older groups of mosquitoes. The figures for 4173 A. costalis at Marampa are.

Wing Grade.	Percentage showing retained eggs (Grade 5 +)
1.	1·03
11.	1·88
111.	4·39
1V.	5·20

These/

These figures then corroborate Perry's argument.

The most conclusive proof that the successive groups represent successively older mosquitoes is furnished by Gordon et alia (1932). They reason that, since an anopheline once infected in the glands by malarial sporozoites probably remains so throughout its life, it is to be expected that an increasing proportion of anophelines should be found infected in the glands in each successive grade, if the grades represent successively older mosquitoes. In Table No. 11 I quote their figures which substantially prove their statement.

TABLE NO. 11.

(Gordon et alia 1932).

WING GRADE	TOTAL ANOPHELINES	NUMBER INFECTED IN GLANDS.	PERCENTAGE INFECTED	PERCENTAGE OF TOTAL INFECTION.
I	1,637	77	4.7	29.7
II	1,181	114	9.6	43.0
III	391	56	14.3	21.6
lV	52	13	25.0	5.0
	3,261			

Table No. 12 which follows show the figures for Marampa area for A. costalis only for one year (May 1st 1934 to April 30th 1935) including the data relative to oocyst infections.

TABLE NO. 12

WING GRADE	TOTAL A. COSTALIS	NUMBER INFECTED IN GLANDS.	PERCENTAGE INFECTED IN GLANDS.	PERCENTAGE OF TOTAL INFECTIONS	NUMBER INFECTED IN GUT	PERCENTAGE INFECTED IN GUT.
I	1,935	66	3.41	19.3	88	4.55
II	1,637	178	10.87	52.0	175	10.69
III	524	78	14.88	22.8	57	10.88
IV	77	20	25.97	5.9	8	10.39
	4,173					

Perrys very reasonable presumption "that progressive deterioration of the wings is a very useful indication of the relative age of mosquitoes" can I think be held proved by the foregoing data.

Section/

Section 3.

There was found to be a considerable seasonal variation in the rates of malarial infection in A. costalis. To demonstrate this CHART NO. 3 has been constructed from the combined figures for the Servants Quarters, Magbenkete and Mafawki villages. The individual charts for all five places follow very similar courses as is shown by CHART NO. 4 but, to ensure adequate monthly figures, these three places which are closely connected have been combined. From CHART NO. 3 it is seen that malarial infection of A. costalis is occurring throughout the year, as is shown by the persistence of positive oocyst findings. Throughout the year there is a marked correspondence between the oocyst and sporozoite graphs. A rise in the oocyst rate is followed very rapidly by a rise in the sporozoite rate; a fall in the oocyst leading to a fall in the sporozoite. This suggests again that the life of A. costalis cannot be long, as were it a period of months for instance, a high oocyst rate in any one month should give rise to a high sporozoite rate for some months subsequently. The close correspondence then between the graphs for oocyst and sporozoite rates indicates that the average life span of A. costalis is not over a month.

The most striking features of CHART NO. 3 are the rapid ascension of the oocyst and sporozoite rates to a high peak in September and October: this is followed by a rapid decline to a low limit early in the dry season; from then onwards there is a rise until the beginning of the rainy season when the rapid leap to the September peak is preluded by a definite drop in June, July and August.

The explanation of that variations is to be found in the relative proportions of young and old anophelines present during each month. In CHART NO. 3 the monthly percentage of old anophelines (Grades 11,111, & 1V) in the total anopheline population is shown.

It is at once evident that when the percentage of old anophelines is low the infection rates are low; when old anophelines predominate high infection rates occur. The percentage of old anophelines present in any one month is governed by the number of young anophelines resulting from breeding. When breeding is occurring freely and the total numbers of anophelines are increasing due to influx of young imagines, a decrease in the percentage malarial infection rates occurs. This is seen in June, July and August. With the quick fall after August in the total numbers of anophelines due to interruption of breeding, a quick rise in the infection rates occurs due to the increased proportion of old anophelines to young anophelines in the total population.

With the onset of the dry season when breeding occurs continuously at a slowly increasing rate young anophelines do not predominate and the increasing proportion of old anophelines present gives rise to an increasing monthly infection rate. Towards the end of an abnormally dry season, such as 1935, when breeding can occur more freely in residual stream pools the disproportionate rise in young anophelines causes a drop in the infection rates. In the usual dry season, such as in 1934, when enough rain falls in March and April to prevent excessive breeding in stream pools, the infection rate remains high until the onset of the rainy season proper leads to the rapid rise in mosquito numbers, with a high proportion of young imagines and a fall in the infection rates.

While many factors are known to influence the infection of mosquitoes with malaria, and while some of them such as the influence of temperature and humidity may operate to some extent in the Marampa area, I think the monthly variation found in the percentage malarial infection rates of A. costalis in that area are due in great degree to the variation in the proportions of old to young/

young imagines occurring each month.

Fluctuation in the rates of malarial infection has been commented on by other observers. Taylor (1930) writing of A. costalis and A. funestus says "The fluctuations in the infection rates during the rains are similar in both species and evidently are caused by the proportion in the catches of newly-emerged flies which have not had time to acquire infections. This proportion depends directly on the rate of breeding which itself depends on the rainfall." Gibbons (1932) on the other hand attempts to correlate the variations in the infection rates with fluctuations in temperature and humidity, the latter being the most important factor in his opinion. His graphs are not entirely convincing, though most interesting. Neither temperature nor humidity appear to have any appreciable influence on the variations found at Marampa.

Section 4.

In this section will be discussed methods of ascertaining the actual ages of groups of A. costalis.

Let us first consider the course of events when a mosquito is becoming infected with malaria. In infections with P. falciparum and P. vivax under tropical conditions, oocysts develop and become microscopically visible on the stomach of the mosquito from 48 hours to 72 hours after the infective meal. Development of the oocysts proceeds until, on or about the tenth day, the ripe oocyst bursts and sporozoites are liberated which find their way to the salivary glands. While sporozoites remain visible in the glands throughout the life of the mosquito, no trace of the oocysts remains after they have ruptured.

In the case of infection with P. malariae the same cycle occurs, but the period of development is apparently somewhat longer. Mer (1933) found that the period from infective meal to the infection of the salivary glands by sporozoites to be 28 days, oocysts being visible 11 days after the meal. Under the conditions of his experiments he found the period from infective meal to sporozoites in the salivary glands in the cases of P. vivax and P. falciparum to be within 17-18 days. De Buck (1935) found that under tropical conditions, sporozoites appeared in the salivary glands in 15 days, and oocysts could be detected 6 days after the infective meal. Under the same conditions P. vivax showed sporozoites in 10 days, oocysts being visible after 3-4 days.

Now, if one takes from one locality over a long period a large number of mosquitoes of the same species which have been subjected to possible infection with malaria, the infection of these mosquitoes must have occurred at a rate which can be mathematically averaged. Let X per cent. per day equal this unknown average daily infection rate. Next let us presume that, instead of having been born at different times over a long period, all the mosquitoes were born on the same day, and as they became older are being infected with malaria at the rate of X per cent. per day. In the case of infection with P. falciparum and P. vivax under tropical conditions, the course of events will be as follows. The oocyst rate will mount at the rate of X per cent. per day, from zero at birth to 1X per cent at the end of the first day of life, 2X per cent at the end of the second day, and so on until at the end of the tenth day it will reach 10X per cent. The oocysts resulting from the first day's infection are now mature and proceed to rupture and disappear, giving rise to sporozoites. Thus at the end of the eleventh day, instead of having 11X per cent. of oocyst infections, there are 10X per cent. of oocyst infections plus 1X per cent of sporozoite infections. As oocysts are now maturing and disappearing at a rate equal to that at which fresh infections/

infections are arising the oocyst rate having reached 10X per cent. remains constant at that level, no matter the age to which the mosquitoes live. Since, however, sporozoites persist throughout the life of the mosquitoes, the sporozoite rate, from 1X per cent at the eleventh day, continues to increase at the rate of 1X per cent and would eventually reach 100 per cent did the mosquitoes survive long enough. This sequence of events is depicted graphically in Chart No. 7.

Since there is no evidence that infection with malaria affects the longevity of mosquitoes, the influence of mortality on the above sequence of events is offset by taking X as a percentage figure, the relation between the number of infected mosquitoes to the number of non-infected mosquitoes remaining unaffected no matter the mortality.

In the case of infection with P. malariae the same sequence of events occurs, except that the date after which the oocyst rate becomes stabilised is different. Let us presume that in Sierra Leone, occysts of P. malariae reach maturity on the fifteenth day after the infective meal. The oocyst rate will then stabilise at 15X per cent.

Unless X is very large or the length of life of the mosquitoes very long, the effect of repeated infections of the same mosquitoes is negligible.

When one comes to consider the above as applied to the results of dissection of mosquitoes, it is obvious that if the mosquitoes have been subject to infection with P. falciparum or P. vivax only, we are justified in presuming that, if successively older groups of mosquitoes show the same percentage rate of infection with oocysts, while showing relatively increasing sporozoite rates, the common percentage oocyst rate represents 10X per cent. Where only infection with P. malariae is possible, the common oocyst rate will represent 15X per cent. Where the possibility of the mosquitoes becoming infected with either P. falciparum, P. vivax, or P. malariae is present, the common oocyst rate will represent 10X x Y plus 15X x Z where Y represents the percentage of infection with P. falciparum and P. vivax in the total malarial infections of the population on which the anophelines are feeding, and Z equals the percentage of infections in the population with P. malariae.

To take the concrete case of Marampa area, Table No. 11 shows the figures for 4,173 A. costalis examined during the period May 1st, 1934 to April 30th 1935. It is at once evident that, while the sporozoite rate increases steadily in Groups 11,111 and 1V, the oocyst rate remains at a constant figure. The average rate for the three groups is 10.72 per cent.

In the area in which these mosquitoes were captured examination of the blood of children showed that infections with P. falciparum formed 84 per cent of the total malarial infections, infections with P. malariae formed 16 per cent, while no cases of infection with P. vivax were found.

Suppose that these mosquitoes had been subject to infection only with P. falciparum, this figure of 10.72 would not represent 10X. Since oocysts only become microscopically visible in the case of P. falciparum after 48 to 72 hours, the observed figure of 10.72 represents only the visible oocyst rate. Taking as a standard figure that oocysts become microscopically visible after 72 hours, 10.72 would represent (10-3) X per cent, i.e. 7X per cent. Similarly in the case where infection with P. malariae only was possible oocysts of P. malariae becoming visible only after 6 days, 10.72 would represent (15 - 6) X per cent, i.e. 9X per cent.

We/

We can now say that 10.72 = $7X \times \frac{84}{100}$ plus $9X \times \frac{16}{100}$

X therefore is equal to 1.46.

Having ascertained a value for X it is now possible to calculate the ages of the groups of mosquitoes. Since sporozoite infections are occurring at the rate of 1.46 per cent per day the average age of any group of mosquitoes is the sporozoite rate per cent, divided by 1.46, plus the number of days it takes on an average for oocysts to mature. In the case of P. falciparum this is 10 days, in the case of P. malariae it is 15 days, therefore in this case where there are 84 per cent of P. falciparum infections and 16 per cent of infections with P. malariae, the average period is $\frac{10 \times 84}{100}$ plus $\frac{15 \times 16}{100}$, i.e. 10.8 days.

The average ages of Groups 11, 111 and 1V then are

Group 11. $\frac{10.87}{1.46}$ plus 10.8 = 18.2 days.

Group 111. $\frac{14.88}{1.46}$ plus 10.8 = 21.0 days.

Group 1V. $\frac{25.97}{1.46}$ plus 10.8 = 28, 6 days.

The average age of the entire group of 4,173 mosquitoes is found to be 16.4 days, since the average sporozoite rate of the entire group is 8.2 per cent.

From the foregoing it is possible to construct a formula for calculating the ages of groups of mosquitoes in any area in which the mosquitoes are being infected with malaria. Using the following symbols.

A = the observed percentage sporozoite rate in the species of mosquitoes in the area.
B = the observed percentage figure at which the oocyst rate becomes stabilised.
C = the number of days for oocysts of P. falciparum to mature in the area.
D = " " " " " " " P. vivax " " "
E = " " " " " " " P. malariae " " "

F = " " " " " " " P. falciparum to become visible

G = " " " " " " " P. vivax " " "

H = " " " " " " " P. malariae " " "

J = the number of cases of P. falciparum per 100 cases of total cases of malaria in the population in the locality under investigation.

K = the number of cases of P. vivax per 100 cases of total cases of malaria in the population in the locality under investigation.

L = the number of cases of P. malariae per 100 cases of malaria in the population in the locality under investigation.

X = the average daily rate per cent at which mosquitoes are becoming infected with malaria in the locality.

X = is found to be equal to

$\frac{B}{C - F}$/

$$\frac{B}{C - F} \times \frac{J}{100} \text{ plus } \frac{B}{D - G} \times \frac{K}{100} \text{ plus } \frac{B}{E - H} \times \frac{L}{100}$$

and the age of any group of mosquitoes is equal to $\frac{A}{X}$ plus

$$\frac{C \times J}{100} \text{ plus } \frac{D \times K}{100} \text{ plus } \frac{E \times L}{100}$$

X, the only unknown in the formula is obtained from factors which are capable of exact evaluation in any country where malaria occurs.

To discover experimentally the daily rate of infection of mosquitoes with malaria is virtually impossible. Such variable factors for instance as

(1) The volume of blood ingested.
(2) The number of opportunities the insect has for infective meals.
(3) The ratio of sexes among the gametocytes ingested,
(4) The possible effect of the gut contents of the mosquito,
(5) The number and phagocytic power of the leucocytes ingested,
(6) The diet subsequent to the infective meal,
(7) The meteorological conditions,

are impossible to assess or control experimentally. A possible method of ascertaining a value for the unknown average daily infection rate which suggests itself is by following the decrease in the oocyst rate in captured mosquitoes. Suppose a very large number of mosquitoes, which had had an opportunity for infective meals on the population of an area were captured and kept in captivity. Daily samples were then dissected for a number of successive days until oocysts were no longer found. The average daily rate at which the oocysts disappeared would be equal to the average daily rate of infection. For instance, if 1000 mosquitoes were captured and 100 dissected per day from the 3rd to the 12th day inclusive after capture, and during that time 150 mosquitoes were found to show oocysts, no oocysts being seen after the 10th day, in an area where infection was by P. falciparum only, the daily infection rate would be equal to 1.5 per cent per day. If adequate numbers were taken it would be possible to ascertain the unknown figure by dissection on two days, for instance the fifth and the eighth days after capture, the difference in the oocyst rates divided by three giving the average daily infection rate value. In this manner the rate of infection throughout the year could be investigated and any variation in it observed.

Group I with 4.55 per cent of occyst infections and 3.41 per cent of sporozoite infections does not agree with the above theoretical method of calculating ages, since before any sporozoite infections arise in a group the oocyst rate should attain the stabilised maximum figure, in this case 10.72 per cent. One cause of this discrepancy is possibly certain mosquitoes in the group were over the average age and showed therefore the presence of sporozoites. The main cause of the discrepancy in my opinion, however, is that there has been an error in grouping, some mosquitoes which should have been placed in Group II having been assigned to Group I. Perry describes his classification into groups as follows:- "In Grade I were placed specimens with the wing well marked and with the wing fringe practically complete. In Grade II were placed specimens with the wing fairly well marked but with the wing fringe somewhat worn. In Grade III were placed specimens with the wing decidedly shabby and the wing fringe very much worn. In Grade lV were placed specimens with the wing actually threadbare. Although such grading is largely a matter of judgment it is found in practice that Grades III and lV are usually quite easily picked out".

Following/

Following this classification difficulty was frequently encountered in deciding between Group 1 and Group II mosquitoes. Perry tacitly admits this difficulty. Terms such as 'fairly well marked', 'somewhat worn', 'practically complete', 'decidedly shabby' are too indefinite for strict classification purposes. While agreeing that in practice Grades III and lV are usually quite easily picked out, the difficulty in deciding between Group 1 and II very probably accounts for the anomalous malarial infection rate findings of Group I.

The main purpose of the classification being to obtain data on the length of life of mosquitoes several alternative improvements in Perry's classification suggest themselves. First, since the actual age in malarial countries is calculable by the method I have outlined, the classes could be simplified into two, one representing Perry's Group IV - the only completely defined class - and the other the remainder of the mosquitoes at present represented by Groups I, II and III. From the oocyst rate of Group IV the value for X could be obtained; from the sporozoite rate of Group IV the maximum average life could be obtained; from the average sporozoite rate of all the mosquitoes the average life of the species in the locality could be determined. The percentage of Group IV mosquitoes being so small, large numbers of mosquitoes would require to be examined to obtain adequate figures for Group IV. To avoid the necessity for this a more detailed classification is indicated. Two alternatives are practically possible:- first define Perry's Group I as "Wing perfect", leaving his definitions of Groups, II, III and IV as presently stated. This would remove the difficulty of decision between Groups I and II, but leaves some possibility of error between Groups II and III. The second possibility is to re-define Groups I, II and III. In practice it has been observed that there is a distinct tendency for the wing fringe wear to begin at the distal end of the wing and spread proximally. This is what one might expect, since, in flight, the distal portion of the wing must make a larger travel than the proximal. The groups could be defined more clearly as follows:-

Group	I	...	Wing perfect: no visible wear.
"	II	...	Wing well marked: wear on fringe limited to distal third of wing.
"	III	...	Wing decidedly shabby: wear on fringe extending along the entire fringe.
"	IV	..	Wing and fringe completely threadbare

This classification was tried in practice in parallel with Perry's: it was found easier to work than Perry's because of the more decided definitions. In 300 mosquitoes grouped by this new method the only differences in results obtained were in an alteration of the proportion of Groups I and II, Groups III and IV remaining substantially unchanged. The numbers dealt with are too small to base an opinion on them but it is notable that oocyst and sporozoite infections in Grade I are cut out.

TABLE /

TABLE No.13.

PERRY'S GROUP.	PER-CENTAGE IN GROUP	PER-CENTAGE OOCYST RATE.	PER-CENTAGE SPOROZ-OITE RATE.	SUGGEST-ED GROUP	PER-CENTAGE IN GROUP	PER-CENTAGE OOCYST RATE	PER-CENTAGE SPOROZ-OITE.RATE
1	49	2.0	1.4	I	32	0	0
II	36	8.3	7.4	II	54	7.4	6.2
III	13	10.3	12.8	III	12	11.1	13.9
IV	2	0	33.3	IV	2	0	33.3

If, as has been suggested, the average age of A. costalis is just over a fortnight, it follows that the population must be being renewed entirely about fortnightly intervals. Thus, in the examination of the population at monthly intervale, the proportion of young to old (Grade I to Grades II, III and IV) mosquitoes should remain reasonably constant throughout the year, despite the variations in total numbers of the population. That this is so is shown by CHARTS Nos. 5 and 6. CHART No. 5 shows that the percentage of Grade I mosquitoes in the total population monthly is, if anything, higher during the dry season than during the rains, although the total numbers of the anopheline population are less then, suggesting that the population during the dry season is replaced at a greater rate. On the whole however there appears to be little difference. CHART No. 6 shows that there is a fairly constant ratio between young and old anophelines in the population monthly, no matter the total numbers of the monthly population.

Section 5.

Table No. 10 shows that both A. costalis and A. funestus show considerable filarial infection. It should be remembered that the rates quoted refer only to the limited dissection performed and do not represent all the filarial infections which were possibly present in the mosquitoes dissected.

Variation in the rate of infection monthly was found and CHART No. 9 has been constructed to show this, together with such factors as might be influencing the variation. The filaria infection rates are seen to be lowest during the wettest months of the year. Little correlation is evident between the variation in the infection rate and either rainfall, humidity or the proportion of old anophelines in each month. The limited dissection performed renders it impossible to draw any definite conclusions, except that A. costalis and A. funestus show considerable infection rates with filaria in nature and must certainly act as vectors.

Section 6.

Davey and Gordon (1933) show that 'the estimation of the density of infective anophelines is a matter of importance to any community in which malaria exists'. They propose a formula for calculating this as follows:-

$$\frac{\text{Total number of female anophelines captured in room searches, plus 'X'.}}{\text{Total number of rooms examined.}} \times \frac{\text{Total number of sporozoite infected anophelines.}}{\text{Total number of female anophelines dissected.}}$$

'X'/

'X' is an unknown factor, and represents that number of female anophelines which had been in the searched rooms during the previous night but which had left before the search was made in the morning. They point out that, in comparing the infective densities of different places 'the modifying term 'X' does not require to be taken into consideration, as it is a factor common to both the infective densities, so long as the anophelines, whether of one or more species, behave similarly as regards the period of time they remain in the house after their blood meal'.

At Marampa some attempt was made to estimate 'X', as follows. At various hours between 10 p.m. and 2 a.m. a European bungalow into which mosquitoes had been coming was completely closed up. The anophelines in the bungalow were captured in the morning before the bungalow was opened up. The results were compared with the room index for that bungalow for the previous two and the succeeding two days, the room index being established in the usual manner by morning searches, the bungalow having been left open all night as usual. This was done on 12 occasions. It was found that the number of anophelines found when the bungalow was closed up late at night were always greater than when it was left open all night. Numbers up to 4 times those found on the previous two and succeeding two days were caught on one occasion. The number of observations was too few to permit any definite value for 'X' being obtained, but further observations seem indicated. It should be noted that the bungalow in which these observations were made was well lighted and that in the normal way there were ample avenues for the escape of anophelines in the morning.

CHART No. 8 has been constructed to show the seasonal variation in the infective density in the various places at Marampa and to show the effects of measures of sanitation in reducing the malaria inoculation risk for inhabitants of the European Camp.

It is clear from the Chart that in the unsanitated villages the risk of contracting malaria is at its greatest during the rainy season as might be expected, since anophelines are most numerous then. There is however another marked rise in the infective density towards the end of the dry season in March when a peak is reached little short of that attained in August during the month of maximum anopheline density. It is obvious that transmission of malaria must be occurring throughout the year.

This chart also shows that the risk of contracting malaria is very considerably less in the European Camp than in the neighbouring native villages. This indicates that the methods of drainage and mosquito control in practice there are beneficial. The complete anti-mosquito programme at Marampa was not in operation until late in 1933. The difference in the wet season months in that year from subsequent years is marked.

CHART No. 10 has been constructed to see if any relation existed between the infective density in the European Camp and the incidence of malaria in Europeans living there. No correlation is evident. The reason for this is probably that the number of Europeans was too small to give accurate figures, that they used mosquito nets, and took quinine daily. The months of maximum incidence of malaria are seen to be July and December. Records of Malarial incidence in our staff since 1930 show a tendency for the beginning of the rainy season and the beginning of the dry season to show the maximum malarial incidence.

A consideration of Chart No. 10 suggests that for the abolition of malaria among Europeans in the Marampa Camp the infective density would require to be very low. No doubt academically/

academically the figure would require to be zero; for practical purposes an index constantly under, .001 would probably suffice.

Section 7.

The only infections other than those with malaria and filaria noted during dissection were as follow.

(1) Three mosquitoes (2 A. costalis, 1 A. squamosus) showed mermythids free in the abdominal haemocoele.

(2) In about one half per cent of mosquitoes dissected the ovaries were found to be invaded by thick walled, yellowish, numerous bodies some 20 to 30 microns in length. These appear to be similar to the bodies described by Schwetz (1929), who describes them thus:- 'Nematode ova. - The infection in question was visible even to the naked eye, the ovaries in these cases being of a yellowish tint instead of their customary white colour. On microscopical examination the substance of the ovaries is seen to be completely invaded by numerous egg-like, ovoid bodies. These varied in length from 20 to 30 microns. Each had a thick wall within which was a cytoplasmic mass completely filling the interior except at one side where a roughly spherical small homogeneous body occurred.........The fact that nematodes with fully formed intestine were sometimes found in this species of mosquito suggested the possibility of these bodies being eggs of this worm. Structurally they appear to differ to some extent from eggs so they may be spores of some unidentified parasite.' The incidence of these bodies found by Schwetz was at a similar rate to that found at Marampa.

(2) Occasionally in the salivary glands and the thorax there were found spirochaetes and flagellated organisms.

(4) Cysts, non-malarial but whose exact nature was unknown were found on 5 occasions on the stomachs of A. costalis. No case showing Ross's black spores was encountered.

SUMMARY OF PART 6.

1. Anopheles costalis and Anopheles funestus are shown to have a high rate of infection with malaria and filaria in the Protectorate of Sierra Leone. To these two species must be attributed all but a negligible proportion of the transmission of malaria in the country.

2. The rate of infection of A. costalis with malaria is subject to considerable monthly variation. It is suggested that the main factor causing this variation is the variation in the proportion of young to old anophelines each month.

3. Arguments that Perry's method of classifying anophelines into four age groups by the amount of wing wear is correct are set out. Improvements on Perry's methods of classification are suggested.

4. A method of calculating the actual ages of groups of anophelines infected with malaria in nature is given. The average age of A. costalis in Sierra Leone is found by this method to be 16.4 days, and the average age of mosquitoes in the oldest wing grade is found to be 28.6 days

5. Observations on the density of infective anophelines are set down. Malaria is shown to occur in the European inhabitants of a camp where the infective density of A. costalis varies between .001 and .023, and it is suggested that for the abolition of malaria in practice a density of constantly under.001 is required.

6. Such other infections as were noted during the course of dissection of mosquitoes are recorded.

PART 7.

INVESTIGATIONS INTO OUTDOOR BITING OF CULICIDAE, TOGETHER WITH THE EFFECT OF WIND ON THE DISPERSION OF ANOPHELINES.

Methods of investigation and record.

Outdoor biting experiments were carried out in Lunsahr, the Labour Camp and the Clerk's Camp, as well as in the five other places, European Camp, Servant's Quarters, Magbenkiti, Mafawki and Rochendata. In rotation in each place two boys exposed themselves between 6 and 8 p.m. to bites from mosquitoes. Any mosquitoes attempting to bite them were captured on alighting on the boy with a test tube. They were identified next day by me and a record kept.

Section 1.

Between 14.1.35 and 3.6.35 223 mosquitoes were captured attempting to bite during a period of exposure of 430 hours. The mosquitoes were in all cases female and their numbers and species were:-

Anopheles costalis,	173,	77.55%	of the total catch.
Anopheles funestus	35,	15.70%	" " " "
Anopheles mauritianus	2,	.9%	" " " "
Anopheles theileri	2,	.9%	" " " "
Anopheles squamosus	1,	.45%	" " " "
Culex nubulosus	4,	1.8%	" " " "
Culex decens	3,	1.35%	" " " "
Culex decens var invidiosus	1,	.45%	" " " "
Culex horridus	1,	.45%	" " " "
Culex annuloiris var consimilis	1,	.45%	" " " "

Anophelines formed 95.5% of the total, culicines 4.5%. The majority of the A. funestus came from the area of the Labour Lines and Clerk's Quarters, from where also came the specimens of A. theileri. The average catch per hour was lowest in the European Camp as might be expected.

These results are at variance with the findings of similar experiments by Gordon et alia (1932), who found a low percentage of A. costalis and A. funestus in outdoor catches in Freetown and Kissy village, and a high percentage of potential yellow fever vectors among their catches. It has been frequently noticed at Marampa that mosquitoes of the Aedes group bite freely out of doors in the late afternoons between 4 and 6 p.m., and that they tend to enter houses in the European Camp between these hours, leaving them however soon after darkness.

While the concentration of anophelines biting out of doors was lower than that found in the morning searches of the houses in all cases, the numbers found biting on the average per hour tended to vary in much the same manner as the mosquito room index monthly, increasing as the room index increased.

It would seem from this small series of observations that A. costalis and A. funestus bite out of doors fairly freely in the early hours of the evening, and that there must therefore be a definite danger of the transmission of malaria by these mosquitoes at these times.

The discrepancy between these results and the results obtained by Gordon et alia (loc cit) and by Barber and Olinger (1931) together with the marked tendency for biting outdoors of members of the Aedes group observed suggest that much more extensive outdoor biting observations are indicated.

Section 2.

Gordon et alia (loc cit.) show clearly by staining experiments that the anopheline population in houses is constantly changing. 'Every twenty-four hours there is, with the exception of a small residue not exceeding 4 per cent., a complete change over of the anopheline population in each house in the village' they state. Of the ninety six per cent. which leave the houses their opinion is that 'A minority probably seek some breeding place, but the majority enter some other house to obtain the further blood meals that are essential to complete the development of their ovaries'.

It is of interest to consider how frequently oviposition possibly occurs. From the date of hatching of the adult to the time when the first batch of eggs is fully ripened probably at least six days elapse. After this batch of eggs is laid the second ovarian follicle is in a stage representing about forty eight hours development; thus the second batch of eggs may be expected to be fully matured in a further four days. Christophers (1911) suggests that even less time may suffice. Thus oviposition may be expected to occur on or about the seventh, eleventh, fifteenth etc. days of the life of the adult mosquito. That is oviposition probably occurs on an average about every fifth day of the life of the mosquito. It follows therefore, that, on the average some twenty per cent of the total population of anophelines oviposit daily.

If, as has been estimated, the average life span of A. castalis is some 16 days, it is necessary if the anopheline population is to be maintained at a constant level that a daily influx of newly born anophelines equal to the average death rate should occur. This rate is 6% approximately. Allowing for mortality one can estimate that during each 24 hours, about three quarters of the anopheline population is to be found in houses, the remaining quarter at the breeding grounds. In considering dispersion then one may assume that three quarters of the anopheline population are in or near houses, while one quarter are at or near the local breeding grounds, and that from these centres dispersion will occur.

On MAP No.2 are shown the results of searches for anopheline breeding grounds from 16th June to 12th November, 1934, each breeding place found being shown by a cross. Since there were no malarial gametocyte carriers among the residents in the European Camp, and since the Servant's Quarters and the villages of Magbenkiti and Mafawki were the only possible sources from which the mosquitoes of the area could be infected, (with the exception of the village of Rochendata, whose distance it is thought would neutralise any marked effect.) one might expect that, when the wind was blowing from the East to the West there would be a higher percentage of infected mosquitoes at the European Camp than when the wind was blowing from the West to the East, if the wind had any effect on the dispersion of anophelines from Magbenkiti, Mafawki, the Servant's Quarters and the breeding grounds contiguous to these places.

Similarly at Magbenkiti winds blowing from the South, South East or East would tend to higher rates of infection there than winds from the West or North West. At the Servant's Quarters the same direction of winds that predisposed to high infection rates in the European Camp would affect this area in a like manner.

The results of dissection of mosquitoes during the period 16th June to 12th November have been tabulated according to the direction of the wind at 6 p.m. on the evening before the mosquito/

mosquito catches were made. The results are as follows:-

TABLE NO. 14.

	Wind theoretically in favour of a high rate of infection.			Winds theoretically in favour of a low rate of infection.		
PLACE.	Winds blowing to	Oocyst rate %	Sporozoite rate %	Winds blowing to	Oocyst rate %	Sporozoite rate%
European Quarters.	West, North West, South West.	8.2	6.6	East North East South East	5.7	2.9
Magben-kiti Village	North, North West, West.	6.8	7.9	East or South East	4.7	3.1
Servant's Quarters	West, North West, South West.	3.0	7.7	East or North East	4.6	2.3

Adequate figures for Mafawki were not obtained during the period.

The above figures show that, with the one exception of the oocyst rate at the Servant's Quarters, the infection rates are higher in every case when the wind blows to any one place from an area from which the dissemination of infected mosquitoes might be expected to occur, than when it blows in the opposite direction. The results also suggest strongly that it was from the region around Mafawki, Magbenkiti and the Servant's Quarters with the breeding grounds between them that infected mosquitoes were reaching the European Camp.

More extended observations confirmed these findings. It was noticed during the times when tornadoes were frequent that there was a distinct tendency for the infection rates at all the places, under observation to approximate, indicating a more even distribution of anophelines.

It can be concluded therefore that the direction of the wind controls to a marked extent the direction in which mosquitoes disseminate from any centre. The importance of these findings with relation to the siting of camps relative to either native habitations or anopheline breeding grounds needs no emphasis.

SUMMARY OF PART 7.

1. A small series of outdoor biting experiments indicated that A. costalis and A. funestus bite out of doors freely, in the early evening hours. More extended observations, particularly in the hours between 4 p.m. and 7 p.m. are suggested to investigate the outdoor biting of potential yellow fever vectors.

2. The direction of dispersion of anophelines from any centre appears to be influenced by the direction of the wind. In choosing a site for a camp it is advisable to consider the direction of the prevailing wind in relation to dispersion of anopheline mosquitoes from centres of potentially infected mosquitoes in native villages or breeding grounds contiguous to them.

PART 8.

CONTROL MEASURES.

In this part will be discussed those measures which, in my experience, have proved of value in the prevention of disease in the Protectorate.

A. MEASURES DIRECTED TOWARDS REDUCING THE PREVALENCE OF CULICIDAE.

1. CLEARING:- It is well recognised that the clearing of bush or jungle around a housing site helps to reduce the prevalence of culicidae in that area. It has always been the practice in our camps to clear all bush around them. The extent cleared varies with the size of the camp, and is sometimes also influenced by local ground features. In the main camps during the period of the Railway Construction, and in all permanent camps, the area cleared extended to a minimum of 100 yards from the nearest house all rpund. This extent was found to be satisfactory in practice. In addition to assisting in the diminution of culicidae clearing has the following advantages:-

(a) Mosquito breeding grounds, actual or potential, and sometimes unexpected, are disclosed and can be dealt with.

(b) Disease vectors other than mosquitoes are diminished, among which may be cited Glossina palpalis and species of Chrysops.

Clearing was found to be very efficacious in reducing the incidence of Glossina Palpalis. This fly was found to be numerous in the camps at Pepel and Sahr-Marank when these were first established. Extensive clearing in these camps led in both places to the virtual disappearance of the fly from the camp area while it remained highly prevalent in the immediately contiguous uncleared areas. G. palpalis was very troublesome to staff working on the bridge over Port Loko creek at Sahr-Marank. Clearing both banks of the creek to 150 yards from the bridge and to a depth of 50 yards from the stream edge abolished the fly almost completely from the bridge site.

(c) The latrine of the Protectorate native is oftener than not the bush. If a clearing is made and proper latrines made inside the clearing, the disinclination to use a proper latrine is overcome by the disinclination to walk further to the more distant uncleared bush. Fly breeding in an uncleared area in which defaecation will occur and the consequent potential spread of disease to a closely adjacent camp are thus avoided.

(d) Clearing improves the ventilation of a camp. Uncleared bush close to a camp taints the air with a heavy smell of decaying tropical vegetation and damp ground. There is a much pleasanter atmosphere in a clearing.

(e) There is in my opinion a definite psychological benefit. It is much better to live inside a well kept clearing than to have your house shut in by dense bush.

Methods of Clearing:- The work of clearing is divisible into two stages, the first initial clearing and then the subsequent maintenance of that clearing.

Regard should be paid to the probable length of life of a camp when an initial clearing is to be made. If the camp is not intended to be used for a period of over two years clearing need not include stumping. When however a site for a more permanent camp is being cleared it will be found to be an economy to remove the roots of any small bush and trees in the area as future maintenance costs are thereby reduced.

The/

The cost of the initial clearing will vary with the type of growth on the site, and whether or not stumping is decided upon. From the costs aspect three distinct types of bush occur:- primitive forest growth, encountered mostly in the hilly plateaux region; open country covered with elephant grass is net with in the same region; by far the most common type of growth met with is the small dense growth resulting from repeated clearing and farming of the ground. This 'tertiary' bush includes 'orchard bush' - country covered with long grass in which small trees grow in an open manner reminiscent of trees in an orchard - which covers large areas. Initial clearing is meant to include the first cutting down of all growth, disposing by burning or otherwise of the cut material, and stumping if necessary. The cost per acre for initial clearing of open elephant grass land is low; it should not exceed 10/- per acre. The cost per acre for the common tertiary bush is from 35/- to 45/-; stumping in addition adds from £2 to £2:10/- per acre. I have no experience of clearing primitive forest growth but the cost per acre must needs be very high. Not only is the cutting down of the trees expensive, the disposal of them after they have been cut would be as expensive again. The cost would not probably be under £10 per acre at a very low estimate. The figures given above are based on labour employed at the rate of 1/- per day.

Having established the initial clearing to the desired limits there remains the work of permanently maintaining it. I have found by far the simplest method to be to mark out the clearing into squares - 200 feet sided squares, equalling approximately 1 acre are suitable - the corners being marked by numbered concrete pegs or similar suitable means, the squares being marked on a map of the camp. The repeated clearing of the area can then be done either by day labour or by contract labour, the latter being the method I adopted in all cases. The contractor supplies his own tools, cuts down all growth in his given area, heaps up the cut material and burns it off, the rate of pay per 200 feet sided square being 2/6. The whole clearing requires to be cut not less than 4 times and not more than 5 times per year, so that the cost of maintenance of a clearing by this method is from 10/- to 12/6 per acre per year.

MAP No.3 shows the area of clearing at the permanent camp at Marampa, with the squared system applied. The area inside the red hatched line was maintained by the permanent sanitary gang: The area inside the green line was maintained by contractors at regular intervals.

2. Treatment of mosquito breeding grounds:- Since, as has been shown, the greatest amount of breeding of culicidae occurs in swamps the most helpful method of controlling mosquito incidence is to be found in treating swamps. Neither A. costalis nor A. funestus will breed in freely running water; both are essentially pool breeders. The control of anopheline swamp breeding therefore resolves itself into preventing the formation of pools and securing a free flow in the water channels. Similar measures will also decrease culicine breeding.

The method of treatment of swamps varies with the locality in which the swamps are situated, and is based on the geology of the swamps. (See Part 2, Section 2.) In the Non Tidal Fresh Water Area of the Coastal Belt the following has been found to be the best method of dealing with the swamps found there.

(1) CLEARING. All swamps in the flat coastal belt are covered with a profuse growth of a type of palm, interspersed with which/

which are various smaller vegetations. It is impossible to survey the swamp or treat it in any way until it has been cleared of all such high growth. The removal of this vegetation is also definitely beneficial, as, allowing the sun and air free access to the surface of the swamp, it promotes evaporation and drying. The roots of the palms should be removed to cheapen future maintenance costs and the cavities left filled in. Holes and depressions disclosed by clearing which are potential pool basins should be filled in, likewise any pools present. Fallen trees and other similar impediments to the water drainage should be removed from the swamp surface.

2. <u>DRAINAGE</u>. The expense of tile or cement open drains or any form of subsoil drainage over such large areas is such as to preclude their use, at least except in very special circumstances. One is forced then to adopt the use of open earth drains. These are subject to disadvantages of which the main are erosion during the rainy season, an irregular bottom which tends to promote stagnant pools when the water run is scanty during the dry season, and the necessity for constant maintenance owing to the erosion of the sides and bottom. A further disadvantage is that the layer of sericite and kaolin down to which it is neccessary to put certain of the drains, is when exposed, easily washed away, causing undermining of the sides of the drains with a consequent tendency for the sides to cave in.

A very rapid flow in the drains while admirable from the point of view of preventing breeding of A. costalis and A. funestus leads to rapid erosion of the drains which increases the maintenance difficulties. It is therefore necessary to have the water flowing at the slowest rate which will for certain prevent breeding, thus reducing to the minimum the difficulties incident on too rapid a flow. The gradient of the drain and to a certain extent, the amount of water flowing in the drain govern the rate of flow and the presence or absence of breeding. Experience and experiment have shown that a gradient of 1 in 125 at the most is the optimum for large drains in which there is a good flow of water all the year round, while a maximum of 1 in 80 is best for smaller drains which show a tendency to dry up during the dry season. For main central channels of fairly extensive swamps a gradient of 1 in 150 is permissible.

One has then to devise the best method of drainage of these swamps with open earth drains of the above gradients. The first step is to clear the main natural water channels (there is usually only one) of all obstruction such as fallen trees, fish traps, vegetation etc. This channel should be cleared to at least half a mile beyond the limit of the swamp to be dealt with. Starting from this point the channel should then be dug out to a gradient of 1 in 150 throughout its length. It should be carefully noted here that when doing this the earth etc. dug out should not be piled on the sides of the channel. If this is done a ridge is formed which during the rains acts as a small dam preventing water from the swamp surface running off into the channel. The fall across the average swamp is so small that a ridge 6 inches high leads to quite extensive pool formation during the rains. The spoil from the channel can be used in filling up pools in the swamp, or scattered widely across the swamp. While grading this channel it should be straightened out as much as conveniently possible. These channels are usually very tortuous; better drainage can be secured by remedying this, but the short circuited parts of the channel must be filled in. It will usually be found that as a result of these measures that a fall in the water level of/

of from 2 feet at the bottom end of the channel to 3, 4 or 5 feet at the upper end can be obtained.

It now remains to drain the swamp. It should be remembered that the cycle of events in the typical swamp is as follows: Water is present in them all the year round, even at the end of the dry season. At that time the water is derived from seepage from the contiguous high ground, the water travelling along above the impervious layer of sericite and kaolin previously described. With the onset of the rains direct precipitation on the swamps and run off from the higher ground increase the amount of water in them. The water table rises until the thin layer of soil above the impervious layer becomes completely waterlogged. Pools then form in the swamps. The area of pool bearing ground increases as the rainy season advances, its boundaries steadily marching towards the periphery of the swamps. Central pools now begin to be washed out; peripheral pools soon follow suit. As the rains diminish the process is reversed, until in the dry season few pools centrally situated remain; water in channels obstructed for various reasons tends to stagnate; the water table descends and the swamps return again to being fed solely by seepage.

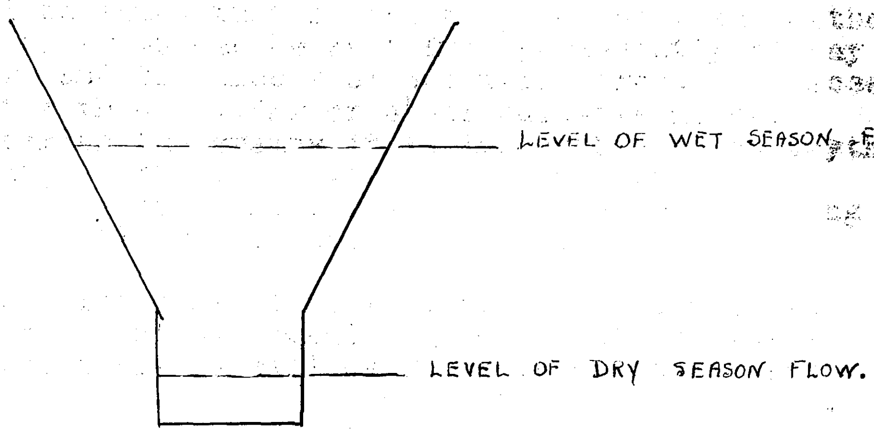
In the Coastal Belt the country is so flat that adequate fall for drainage is difficult to secure. The typical swamp in my experience shows an average gradient from top to bottom of around 1 in 75 to 1 in 100. The swamp surface from side to side is very much more level, a much smaller gradient than 1 in 100 being usual.

The soundest method of drainage appears to be to prevent water getting into the swamp as much as possible. Run off from the high ground and seepage from the same source can be prevented by a drain completely encircling the periphery of the swamp. To cut off seepage it is necessary to put this drain down to the impermeable layer. It should be placed sufficiently far out at the edge of the swamp to run along the line where seepage will occur when the water table is at its highest. Discretion is necessary in laying out this drain, asm if it is sited too far out on the rising ground at the swamp periphery it will have to be deeper there to reach the impermeable stratum, and so more costly both to construct and to maintain; if it is placed too near the centre of the swamp it will leave outside it a large belt of undrained swamp. This drain should be made with a gradient of between 1 in 100 and 1 in 125, as throughout the year it will have a fair amount of water flowing in it. In constructing it the earth removed should all be placed on the side of the drain nearest the centre of the swamp. There the spoil will not obstruct the run off water, and will form a useful dump of material for filling up holes in the swamp.

While the peripheral drain serves to take the majority of water entering the swamp it will be found that further drains within the swamp are necessary. These drains should be laid out up and down the swamp, not across it as the fall across the swamp is usually too small to give the required gradient of 1 in 75 at which these drains should be made. It is advisable to use as few of these small drains as possible. They tend to dry up during the dry season, and the poor flow in them then is apt to permit breeding in small pools in the drains.

In constructing all drains it is well to provide for the lessened flow in the dry season. This can be done by making the/

the drain of the shape shown in section below.



Drains up to 2 feet deep can be made with vertical sides. Drains over this depth are best made with sloping sides, a slope of 35 to 40 degrees from the vertical being suitable to prevent the sides caving in. The large peripheral drains should be 2 feet wide at the bottom with a 1 foot wide central dry season channel. The smaller drains in the swamp should be 1 foot 6 inches wide with a 6 inch wide central channel.

The cost of the drains varies with the width and depth but can be estimated at the following rates:-
Up to 2 feet deep at a rate of 2½d per cubic yard of excavation.
Up to 4 feet deep at a rate of 3½d per cubic yard of excavation.
Over 4 feet deep at a rate of 4d per cubic yard of excavation.

In the Fresh Water Belt of the Tidal Fringe similar measures for treating swamps can be adopted, with the addition that no drainage of the swamp in that area affected by the daily tidal rise is required. The swamp should be cleared to allow the tide free flow over its surface, and in that area affected by the tide the peripheral drain should be placed along the line to which the high tide reaches.

In the Saline Belt of the Tidal Fringe those swamps affected by the tide should be cleared (they are usually covered by a dense growth of mangove) to allow the tide free flow over their surface. In the absence of a melanic coastal race of A. costalis capable of developing in salt water, the daily wash of salt tidal water is efficient in preventing anopheline breeding in these swamps. Where high ground abuts on these swamps, leading to breeding in the fresh seepage water around the periphery of the swamps, it is best to put down a drain around the foot of the high ground to catch this seepage or run off water, and deliver it into the sea.

In this area occur swamps which while not covered by the tide daily have water of a considerable saline content. During the dry season this water is too saline to permit anopheline breeding. Dilution by rain water in the wet season lowers the salinity sufficiently to permit breeding. Amelioration of this condition can be obtained by draining the swamp, and in addition/

addition constructing round the periphery of the swamp a continuous drain to cut off seepage and catch run off. This helps to keep up the salinity of the swamp longer during the rainy season and shortens the time during which the swamp is suitable for anopheline breeding.

It will be found that by the adoption of these methods that large areas of swamp can be kept free permanently of any mosquito breeding, and the amount of potential breeding places left can be dealt with by oiling or other suitable means. Without first clearing the swamps it is impossible to do anything to control breeding in them. Inexpensive open earth drains laid out as above very materially reduce the area of breeding grounds and very greatly reduce the cost of oiling.

3. In addition to the treatment of swamp areas it is necessary to treat actual or potential breeding grounds outside these areas. Most of these places will be found to be easily and permanently eradicated, such as borrow pits, tree holes etc. Small holes in lateritic rock require no treatment since anopheline breeding has never been found to occur therein; very large pools in rock can be readily filled or drained. The treatment of large streams is the most troublesome among the areas requiring attention outside swamp limits. Efficient canalisation is required. The great difference between the dry and the wet season flow, erosion, and the considerable debris brought down in these streams in the wet season explain the difficulty of canalisation. The methods are too well known to require recapitulation here. Usually the question is not of the method to adopt but is whether the cost of the undertaking is justified by the probable benefit. It is obviously best to abort the question by not placing a camp where the necessity for dealing with a large stream will arise.

B. <u>MEASURES DIRECTED TO PREVENTING THE INCIDENCE OF DISEASE.</u>

In this section will be discussed these measures which proved most valuable in preventing Europeans from contracting malaria in the Protectorate.

1. <u>Segregation</u>. I have no doubt that segregation is by far the most valuable method for the prevention of malaria among Europeans in the Protectorate. The indigenous natives are so heavily infected with malaria, they form such an enormous reservoir for the infection of the omnipresent anophelines, the vectors are so numerous and widespread, their breeding grounds are so extensive and both difficult and costly to treat efficiently, that only by segregation is it possible to hope for really good results in preventing Europeans from contracting malaria. The question is what forms efficient segregation.

Since a low density of A. costalis or A. funestus appears to be adequate to keep up a high malaria rate, it is of prime importance to know what are the limits of dispersion ~~(1931)~~ of these anophelines. Barber and Olinger (1931) state that A. costalis will disperse at least half a mile from a large breeding place and probably much farther. I have previously shown that the prevailing wind assists in the dispersion of anophelines. From observation of the relation of many camps to the nearest breeding ground and the nearest source of infection for the mosquitoes, i.e. the nearest native habitation, I am/

am of opinion that to ensure freedom from malaria several factors must be taken into account in the siting of a camp:-

(a) The actual or potential breeding grounds in the vicinity. Observation has shown that where there ia a breeding ground anywhere within a quarter of a mile of a camp, anophelines were numerous in that camp. Where breeding grounds were within half a mile but over a quarter of a mile, scarcely any difference in the density of anophelines could be noticed. Where the nearest breeding ground was over a mile distant the density of anophelines was markedly diminished, particularly if the prevailing wind blew to that side of the camp towards which the breeding ground lay. Camps in which the nearest breeding ground was over a mile and a half distant were free from anophelines for all practical purposes. These statements presuppose that the intervening ground between the camp and the breeding ground was completely free from dwelling house, native or otherwise. From these observations I am of opinion that the safe limits of distance from breeding grounds to ensure freedom from malaria should be a minimum of 1½ miles on that side of the camp to which the prevailing wind blows, and 1 mile on the opposite side. If circumstances permit it is distinctly advisable to increase these distances by a further half mile.

(b) The situation of native habitations in the vicinity in relation to the camp. A native village appears to act much in the same way as a breeding ground, in forming a reservoir from which anophelines disperse. The presence of native made breeding grounds (borrow pits etc.) within the village, and the invariable habit of siting their villages close to water explain the invariable presence of anophelines in the villages. The absence of any hospice return instinct in the mosquitoes as has been shown by Gordon et alia indicates that mosquitoes will as readily disperse from these villages as from breeding grounds. The necessity to leave the place from which they obtained their blood meal to oviposit also indicates that dispersion from villages is to be expected. The same rules for distance hold good in the case of villages as in the case of breeding grounds.

(c) The relation of a combination of native habitations and breeding grounds in the vicinity. The presence of native habitations in close proximity to a breeding ground increases the potential danger of the breeding ground, since a convenient source of a blood meal being present, more intense breeding is likely to take place in the available breeding area. When the combination of native habitation with contiguous breeding ground is present it is wise to site the camp at a place at least 1½ miles distant on that side of the combination to which the prevailing wind will blow from the camp to the combination, and 2 miles on the other side.

In the Flat Coastal plain it is very difficult to fulfil these conditions owing to the frequency of swamps and villages. It is almost impossible to find an area 3 miles in diameter in which neither a village nor a swamp occurs. It is therefore necessary in almost all camps in this area to use some method of mosquito control to obtain any freedom from malaria. In the inland Plateaux region however, where the population is less dense and swamps are infrequent it is fairly easy to fulfil these conditions of segregation. It is of interest to compare the results obtained in the two areas in the prevention of malaria in Europeans. In the Tonkolili area where the Sierra Leone Development Company started operations on gold in 1933, no anti-mosquito work has been done at all in any of/

of the camps except the usual clearing of the camp site and observation of general cleanliness in the camp compounds. The camps there have all been sited away from swamp, an absolute minimum of ½ a mile with, in practically all cases, at least double this distance being the rule. The camps are in all cases also situated a mile from the nearest native houses. In the camps in the flat plain region between Marampa and Pepel it has not been possible to achieve this degree of separation of camps from breeding grounds or native habitations. In all of these camps however anti-mosquito measures have been in force in the neighbouring swamp breeding grounds, a minimum radius of ¼ mile with in most cases at least ½ a mile radius being adequately dealt with by anti-larval measures. The results in the two European Staffs are summarised below.

Number of days lost through malaria per 100 residents per year in the Marampa and Pepel Staffs, i.e. staffs working in the flat Coastal Plain with anti-larval measures in force but with limited segregation. Average from November, 1930 to December, 1934.

358 days per year per 100 residents.

Number of days lost by Tonkolili staffs, i.e. staffs working in the Inland Plateaux region with no anti-larval measures in force, but with marked segregation. Year 1934.

72 days per year per 100 residents.

It was noteworthy that the majority of the malaria in this latter figure was due to malaria contracted by men on railway survey work, who contracted their malaria when they left the plateaux region and began working in the flat plain region. Practically no malaria at all was experienced by the staff whose work limited them to the Plateaux region. Practically all, if not entirely all the malaria except one case, occurring in the Plateaux region, could be traced to one camp. It was impossible in this camp to obtain the degree of segregation experienced in other camps. The gold workings were in a swamp in the course of a stream. The swamp had the same geological formation as those typically found in the plains, and in addition there were living on the banks of the swamps a large number of native labourers with their families. The European camp was about half a mile distant from these two contiguous places, and the Europeans living in that camp were the only sufferers from malaria in the staff in the Plateaux region. The exceptional case occurred in another camp where it was found that unauthorised natives were living in a house within half a mile of the European house where the inmate contracted malaria.

It seems clear from the above that in the Plateaux region at least, a very considerable diminution in the degree of malarial incidence can be achieved at no cost whatever, simply by adequate separation of the European from potential breeding grounds of mosquitoes and from native habitations.

2. Mosquito Nets and Clothing. The use of mosquito nets and mosquito boots etc., is too well known to require labouring. It may be pointed out, however that the makers of camp beds and nets for tropical use have somewhat hazy ideas on what constitutes an efficient camp bed mosquito net. The average camp bed is of such a size that when the net is hung on the net/

net poles, it is certain that some part of the body will come in contact with the net, allowing a mosquito to bite the part of the body in contact with the net. Unless the hanging of the net can be improved by a different shape of net pole, it is essential that a double linen valance be put on the net, reaching up to such a height when the net is slung that an arm or leg coming in contact with the side of the net will be protected by the double valance, and so rendered inaccessible to mosquito bites.

The use of mosquito boots and sensible clothing in the evening should also be stressed. Insufficient attention is paid to these details. Careful note was taken during one year of all cases of malaria occurring in the European staff and it was found that 80% of cases occurred in those men who did not wear mosquito boots and frequently lounged around in the evenings with inadequate clothing.

(d) Quinine. No one believes that quinine in regular doses acts as a prophylactic against the incidence of malaria. It was the practice of all the staff under my care to take 5 grains of quinine daily. While this did not prevent the onset of malaria, I am quite convinced that it lessened the severity of the attacks and their frequency. The taking of 5 grains of quinine daily is, I think, a most valuable precaution, in diminishing the number of days lost through malaria. Formerly it was the practice to have men going on leave stop taking their daily quinine about 3 weeks before they were due to sail from Africa. Blood films were then taken at intervals before sailing to attempt to find out the presence of malaria. Onnone occasion out of 6 men due to go on leave, 5 went off duty with malaria within a week of having stopped taking their daily quinine. All had been working and quite fit before stopping their quinine. Such an instance proves both the value and the danger of 'prophylactic' quinine. If it is clearly realised that latent infection is common when regular daily quinine is being taken, and steps are taken on the slightest suspicionto discover and treat this latent infection, I can see no reason for not taking regular daily quinine. The Choice seems to lie between no quinine and certain severe malaria, or quinine and a very much less severe attack plus the possibility of a latent infection. It is worth recording that in none of the cases of malaria I encountered in men taking regular quinine was there ever any suspicion of the approach of blackwater fever.

C. EXPERIMENTS IN CONTROL OF MALARIA BY TREATMENT OF GAMETOCYTE CARRIERS WITH PLASMOQUINE.

The expense of other methods of reducing the incidence of malaria at the main camp at Marampa led to the attempt to improve matters by treating the gametocyte carriers with plasmoquine.

Reference to Map No.2 shows that the only possible source from which local mosquitoes could become infected was the inhabitants of the Servant's Quarters, and the villages of Magbenkiti, Mafawki and Rochendata. It was considered unlikely that mosquitoes from Rochendata village dispersed in any great number to the European Bungalows, the prevailing wind being against spread in this direction. The absence of marked breeding occurring in the Squares D 13 and 14 seemed also to/

to indicate that mosquitoes did not tend to drift between Rochendata and the European Camp. The nature of the ground was unfavourable to spread between these two places, a high ridge existing with its centre in Square C.14. The free breeding found around Magbenkiti and Mafawki, the intermediate position occupied by the Servant's Quarters, and the prevailing breeze being from these three places towards the European Camp all indicated that it was from that quarter that the bulk of the mosquitoes were coming to the European Bungalows. It was decided therefore to try the effect of treating the carriers in the villages of Magbenkiti and Mafawki and those of the Servant's Quarters with plasmoquine, keeping Rochendata village untreated as a control.

Experiment was made in 1933, by treating the carriers in the Servant's Quarters with plasmoquine and quinine for a month, followed by treating the carriers in Magbenkiti village for a similar period. The results were as follows:-

Infection rates of mosquitoes before any quinine and plasmoquine administered:-

	European Camp.		Servant's Quarters.		Magbenkiti Village.	
	Oocyst rate	Sporozoite rate	Oocyst rate	Sporozoite rate	Oocyst rate	Sporozoite rate
August 1933	3.7%	3.9%	4.3%	12.3%	-	
September, 1933	15.9%	25.3%	20%	25.2%		

After administration of quinine and plasmoquine to carriers living in the Servant's Quarters: beginning on 28th September:-

October, 1933.	9.0%	9.0%	16.2%	21.5%	22.6%	17.2%

After administration of quinine and plasmoquine to carriers living in the village of Magbenkiti, beginning on 29th October:-

November, 1933.	10.0%	5%	9.6%	6.7%	12.8%	20.5%

From the above it was considered that, while a drop in the infection rates of the European Camp occurred after all the carriers in the Servant's Quarters had been treated, the rates in the Servant's Quarters remained unchanged to any great extent until the carriers in Magbenkiti were treated. It seemed that infected mosquitoes from the Servant's Quarters tended to disseminate to the European Camp, while infected mosquitoes from the village of Magbenkiti disseminated to the Servant's Quarters, and from there probably also to the European Camp. It seemed likely also that mosquitoes were disseminating from Mafawki to all three other places. It was known that following the flooding out of mosquito larvae in the middle of the rainy season with the subsequent drop in the room indices, there is a rise in the infection rates of mosquitoes followed by a fall in October, but the fall was considered to be too great to be accounted for by this cause alone, and some of the drop was considered/

considered due to the administration of the quinine and plasmoquine. In view of these results it was considered that it would be worth while attempting control of malaria in the European Camp by plasmoquine treatment of local gametocyte carriers in 1934.

Barber and Olinger (loc cit.) have shown that in Nigeria heavy crescent carriers are the ones most likely to transmit subterian malaria to mosquitoes. They also show that the index of heavy crescent carriers (those having one or more crescents per 100 leucocytes) is high among infants and young children, low at 4 years, then rapidly falls to nil! This is in accordance with the generally accepted view in West Africa.

That plasmoquine in small doses has the effect of rendering the gametocytes incapable of developing in mosquitoes appears clearly proved. (Barber, Komp and Newman; S.N. Sur, H.P. Sarkar and K.M. Banerji; Jerace und Giovannola; Manson-Bahr and Walters.) Numerous publications show that, while in some cases the regular administration of plasmoquine to populations leads to an improvement in the incidence of malaria by diminishing or abolishing the infection in anopheles, this result is not obtained in all cases. The main factor causing this variation in results appears to be the possibility or otherwise of treating <u>every</u> carrier of gametocytes with <u>regular</u> doses of plasmoquine.

Since then it is clear that plasmoquine is effective in preventing gametocytes infecting mosquitoes, it remained only to see if, under actual working conditions, any diminution in the infection rates of mosquitoes or any diminution in the incidence of malaria in the European Camp followed the treatment of gametocyte carriers with plasmoquine.

The following steps were taken:-

(1) Blood and spleen examinations were made of 72 children from the Servant's Quarters, Magbenkiti, and Mafawki. Blood was taken on numbered slides, a thin film on one slide, and three thick preparations on a second slide. The spleen was examined by palpation with the subject standing. On a record sheet were entered the name, sex, and estimated age of the subject, the number of the slides, and the result of the spleen examination, enlargement being recorded in finger breadths. The thick blood films were examined by the method described by Green (1932) and examined. If Malaria parasites were present and the species could be identified the record was completed. If parasites were present but the species could not be identified, the corresponding thin film was stained by Leishman's method and a further attempt made to identify the species. If the thick film was negative, no examination was made of the thin film.

The ages of the children ranged from 2 months to 10 years the average age being 3 years. The results were as follows. All the children showed some degree of splenic enlargement. It is unnecessary to go into details of degree and age distribution. The blood films showed:-

Showing infection with Subtertian malaria	80.5%
Showing Subterian gametocytes	75%
Showing infection with Quartan Malaria	6.9%
Showing Quartan Gametocytes	6.9%
Showing mixed Subtertian and Quartan malaria	6.9%
Total showing gametocytes	82%
Percentage of quartan in total malarian infections	16%

The/

The relative number of gametocytes to leucocytes was not taken, but it was noted that no heavy gametocyte infections were found in subjects over 4 years of age.

(2) Blood films were examined from 20 adults in these places 10% were found to show slight infection with subtertian malaria, but in no case were gametocytes found.

It was considered likely that the findings of Barber and Olinger (loc cit.) in Nigeria, based on very much more extensive examinations, held true in Sierra Leone, and that the only carriers of gametocytes, in numbers sufficient to infect anophelines, were to be found among the early age groups. Treatment of all children up to 12 years of age was it was thought, adequate to secure treatment of all gametocyte carriers likely to be infecting mosquitoes.

(3) Inhabitants of the European Bungalows whom it was thought might by any possibility be gametocyte carriers had their blood examined. No carriers were found.

(4) A register of the inhabitants of the Servant's Quarters, Magbenkiti and Mafawki was compiled by a house to house search. From this register, sheets showing all those inhabitants up to 12 years of age were constructed. These sheets showed the name and age of the children, the dose of medicine to be given, the dates on which the medicine was to be given, and a space was left under each date wherein the actual taking of the medicine was indicated by a symbol after the medicine had been actually swallowed. A blank under any date against any name indicated that no medicine had been given to that child for some reason or other.

(5) Beginning on 23-4-34 regular dissection of anophelines captured in the European Camp, Servant's Quarters, Magbenkiti and Mafawki was carried out. From 22-6-34 similar regular dissection of mosquitoes from Rochendata were dissected as controls.

(6) Throughout the entire period of the plasmoquine administration anti-larval measures were continued unchanged.

(7) Periodic checks were made throughout the period of plasmoquine issue on the population of the various places, so that any new inhabitants could be placed on the register, and any within the defined age limit receive treatment. The headmen of the villages were instructed to report the arrival in their village of any new inhabitants immediately.

(8) Quinine was given in liquid form; plasmoquine was given in tablet form. The administration was done by natives, the same natives being employed throughout. The issue of medicines was made in the morning between 6 and 7.30 a.m. This hour was chosen so that the issue could be made before the villagers left for their farms. The administration was personally supervised to begin with, later it was left to the natives employed. Their efficiency was tested by various means, and I am certain that the medicines were given to them correctly as shown on the records kept.

(9) <u>Details of Treatment Given</u>:-

Period A. From 10-6-34 to 12-6-34 inclusive, quinine and plasmoquine given daily at the Servant's Quarters, Magbenkiti, and Mafawki in the following doses:-

Age/

Age.	Dose of Quinine.	Dose of Plasmoquine.
0-1 year	2½ grains daily	.005 gm. daily.
1-5 years	5 " "	.01 " "
5-12 years	7½ " "	.015 " "

All children up to 12 years of age treated.

Period B. From 13-6-34 to 22-6-34 inclusive, quinine given daily in the foregoing dosage to the same group of children. From 24-6-34 to 30-6-34 quinine given on alternate days only.
From 13-6-34 to 30-6-34 inclusive plasmoquine given to the same group of children in the same dosage as Period A, but on alternate days only.

Period C. From 2-7-34 to 1-8-34 inclusive plasmoquine alone given to all children up to 12 years of age as follows:

Age.	Dose of Plasmoquine.
0-5 years	.01 gm. on alternate days.
5-12 years	.02 gm. " " "

From 3-8-34 to 9-8-34 inclusive plasmoquine stopped and quinine given as follows to the same group of children:-

Age.	Dose of Quinine.
0-5 years	3½ grains on alternate days
5-12 years	7 " " "

Plasmoquine recommenced on 10-8-34, and from 10-8-34 to 17-8-34 inclusive plasmoquine given as follows:-

Age.	Dose of Plasmoquine.
0-5 years	.01 gm. on alternate days.
5-12 years	.02 gm. " " "

Period D. From 18-9-34 to 13-11-34 plasmoquine, after having been stopped on 17-8-34, recommenced at the Servant's Quarters only in the following dosage:-

All inhabitants under 20 years of age given .02 gm. on alternate days.

Period E. From 1-10-34 to 13-11-34 plasmoquine given to all inhabitants of Mafawki village under 20 years of age in a doze of .02 gm. on alternate days.

Period F. From 13-10-34 to 13-11-34 plasmoquine given to all inhabitants of Magbenkiti village under 20 years of age in a dose of .02 gm. on alternate days.

RESULTS. These are shown on the OOCYST and SPOROZOITE CHARTS.

The continuous horizontal lines on the charts indicate the level of percentage oocyst and sporozoite rates found by dissection. The broken undulating lines indicate the percentage of those in the age groups under treatment who, it was estimated, were possibly infective to mosquitoes, owing either to having had no treatment or insufficient treatment. The calculation was made as a percentage of the total number in the age group known to be living in the various places on the successive days. Where no medicine was taken the individual was considered to be infective. Where some medicine was taken, the individual was not considered to be infective to mosquitoes until 4 clear days had elapsed after the last dose of medicine had been taken, provided that at least three doses of medicine had been taken.

If/

If the exhibition of plasmoquine was going to have the effect of decreasing the infection rate of mosquitoes with malaria, the effect would become first apparent in a diminution of the oocyst rates. Theoretically, if plasmoquine was completely effective, the oocyst rate due to P. falciparum and P. vivax should diminish steadily and vanish 10 days after the beginning of treatment. It is of interest to follow the oocyst rates for each place in turn.

From the 13th day after commencing treatment to the 28th day, (22-6-34 to 7-7-34) the oocyst rate at the European camp runs at a lower level than that prior to this period. From then onwards there is a progressive rise in the rate until the 74th day (23-8-34) despite the continuance of treatment. Following the cessation of plasmoquine treatment there is a further rise until 25-9-34 when the effect of plasmoquine which had been recommenced at the Servant's Quarters on 18-9-34 should be appearing. Instead of a fall, as one might have expected from treatment of the gametocyte carriers living nearest to the European camp, there is a rise in the oocyst rate between 25-9-34 and 20-10-34. There is then a fall in the rate until 13-11-34, all the gametocyte carriers in the locality having been under treatment since 13-10-34. The continual rise in the oocyst rate from 7-7-34 to 23-8-34 despite continuous plasmoquine administration at that time indicates that little effect is being exercised by the treatment on the infection of local mosquitoes.

At the Servant's Quarters the oocyst rate shows a distinct rise from the 13th day after treatment has commenced until the 38th day (17-7-34); after this there is a fall to a level very slightly lower than that before treatment was commenced, This fall continuing until 23-8-34. Following this there is a continued progressive rise in the rate, plasmoquine having been stopped from 18-8-34. This rising tendency is not checked by the issue of plasmoquine at the Servant's Quarters from 18-9-34 and at Mafawki from 1-10-34, the rise continuing until 20-10-34. A fall occurs after this but to a level which is still relatively high, this despite the issue of plasmoquine to Magbenkiti from 13-10-34 in addition to its issue at the Servant's Quarters and Mafawki. The rise in the oocyst rate from 22-6-34 to 17-7-34, and the very small fall from 17-7-34 to 23-8-34 despite continuous plasmoquine treatment during these periods suggest strongly that plasmoquine is having little if any effect on the infection of mosquitoes.

The oocyst level for Magbenkiti village becomes slightly higher from 22-6-34 to 7-7-34, when, if plasmoquine was showing any effect the level should have dropped. A drop occurs from 7-7-34 and an almost constant level is maintained thereafter until 23-8-34. Thereafter there is a rise continuing until 8.10.34 after which successive fall occurs until 13-11-34. It would seem therefore that, as in the previous case, plasmoquine is having little effect on the oocyst rate.

Mafawki shows a drop from 22-6-34 to 17-7-34. Thereafter, in spite of the continuance of the treatment, there is a rise in the rate until 23-8-34. A further rise occurs on the cessation of plasmoquine until 25-9-34. There is then a fall between 25-9-34 and 8-10-34. This is succeeded by a marked rise between 8-10-34 and 20-10-34 although the issue of plasmoquine was commenced at the Servant's Quarters on 18-9-34 and at Mafawki on 1-10-34. From 20-10-34 to 13-11-34 there is a marked fall. The rise between 17-7-34 and 23-8-34 and again between 8-10-34 and 20-10-34 indicate that the treatment is having no marked effect on the oocyst rates.

From/

From the above considerations it is extremely doubtful if the administration of plasmoquine and the variations in the various oocyst rates can be correlated. When it is seen from the OOCYST CHART that the oocyst rates at Rochendata where no plasmoquine was administered vary in a very similar manner to those of the other four places under discussion, it seems certain that the issue of plasmoquine has been without effect on the oocyst rates at these four places.

From the practical point of view of the abolition of infection in mosquitoes and the control of malaria thereby the continued persistence of oocyst infections in mosquitoes throughout the entire period means that no beneficial result has accrued from the treatment. The sporozoite rates as shown in the SPOROZOITE CHART remain at quite considerable levels, indicating that the transmission of malaria throughout the period of the experiment continued to a marked degree. No diminution in the incidence of malaria in the European Camp was observed during the periods when plasmoquine was being administered.

At first sight it would seem that the administration of plasmoquine had had some effect on the malarial infection of mosquitoes, but the variations which occur in the rates are better explained as the usual seasonal variations which normally occur during that period of the year. (See PART 6, Section 3).

The reason for the failure to diminish the infection of mosquitoes with malaria remains to be sought. The dosage of plasmoquine given should be adequate. Barber, Komp and Newman (1929) found that .005 gm. plasmoquine sufficient in the majority of cases to prevent crescents from developing into oocysts in the stomachs of mosquitoes. Jerace and Giovannola (1933) show that .02 gm. plasmoquine given in a single dose deprives the gametocytes of their power of propagation for a week after the dose. Sur, Sarkar and Banerji (1932) found that a daily dose of .02 gm plasmoquine daily for three days prevented infection of mosquitoes from gametocyte carriers. Barber, Rice and Brown (1932) found that marked diminution of malaria rates in mosquitoes could be effected by .01 gm. plasmoquine twice a week. All the doses quoted above are those for adults.

That the cause of failure is to be found in the fact that only individuals up to 12 years of age were treated, and that the mosquitoes were becoming infected from gametocyte carriers over that age, is not tenable. All the evidence of examination of blood films of different age groups in West tropical Africa show that gametocytes are rarely found in age groups over 10. The fact that the age limit was increased to 20 in the latter part of the experiment without the results being in any way improved tends to show that the explanation of failure does not lie in too limited an age selection.

The only explanation of failure tenable is that carriers in the lower age groups were missed. The estimated percentage of known missed potential carriers is shown on the oocyst chart. Except in the case of Mafawki the percentage is not high, but even these few potential carriers seem capable of sustaining a high rate of infection in mosquitoes. This is in accordance with the findings of Barber, Rice and Brown (1932). The difficulties of securing that every native child in a locality receives a regular dose of plasmoquine are very great. There is no need to detail the numerous obstacles which crop up to invalidate any scheme such as this. It seems clear however that until something approaching a strict military discipline could be applied to native villages that the control of malaria by regular exhibition of plasmoquine is impossible. Even the small/

small percentage of potential carriers which are shown to have been missed, appears adequate to keep up considerable infection.

The fact that the variations in the malarial infection rates in mosquitoes at first sight suggests that plasmoquine had some effect in causing these variations, but that the variations are better explained as the result of variation in the relative proportion of old to young anophelines suggests that in future work in similar areas note should be taken of the age grades of the mosquitoes examined, so that variations in the infection rates due to varying proportions of age groups be not ascribed to variations caused by plasmoquine.

SUMMARY OF PART 8.

(1) Methods and costs of clearing camp sites and draining swamps are described in detail. These measures result in marked diminution of culicidae, and of other vectors of disease.

(2) Segregation of Europeans from Africans is considered the most valuable method of obtaining a low malaria incidence in Europeans. The distances at which European camps should be placed from mosquito breeding grounds and from native habitations are discussed. It is recommended that very much larger distances than commonly advised are necessary.

(3) Some observations are made on mosquito nets, mosquito boots and clothing, and the use of daily doses of quinine.

(4) Experiments were made in the control of malaria in a European camp by treating the gametocyte carriers in its vicinity with plasmoquine. It was found that no improvement could be effected. The cause of failure is ascribed to the impossibility of securing that every potential carrier received regular doses of plasmoquine.

PART 9.

OBSERVATIONS ON THE HEALTH OF EUROPEANS AND NATIVES IN INDUSTRIAL UNDERTAKINGS IN THE PROTECTORATE, AND THE FACTORS INFLUENCING IT, INCLUDING SANITATION, HOUSING AND HEALTH LEGISLATION.

If the Protectorate of Sierra Leone is ever to be developed and the general standard of living of the native thereby improved, European staffs will be required in the country. It is important, therefore, that measures to safeguard them from contracting diseases indigenous to the country and dangerous to their health should be taken. It is proposed now to record the results obtained in the European staff of the Sierra Leona Development Company, to point out the factors tending to good health, those tending to bad results, and to indicate how bad results may be improved. Observations on the health of the natives grouped in industrial undertakings will then be made, showing what has been done to improve their health and in what manner improvement could be effected. These considerations will necessitate a review of the legislative measures at present in force in the Protectorate.

The following tables show the records of sickness etc. among the European staff of the Sierra Leone Development Company since November, 1930 to December, 1934; and for comparison the average of 5 years of similar statistics for European Government Officials in Sierra Leone. It should be remembered that the majority of the Government Officials live in Freetown, where conditions are very much better than those prevailing in the Protectorate.

	November 1930 to July 1931	[illegible]
Total number of staff resident.	44	5
Average number resident.	30.5	[illegible]
Total number on sick list.	59%	[illegible]
[illegible] on sick list.	272	[illegible]
[illegible] sick list.	2.5%	[illegible]
[illegible]	3.67	[illegible]
[illegible] on sick list.	10.46	[illegible]
[illegible]	8.92	[illegible]
[illegible]	2	1
[illegible] total	4.55	[illegible]
[illegible]	5.55	[illegible]

TABLE No. 15.

	November 1930 to July 1931.	August 1931 to July, 1932.	august 1932 to July 1933.	August to December 1933	January December 1934.	Figures for European Government Officials, average of 5 years from 1929 to 1933 inclusive, compared to average figures for Sierra Leone Development Company European Staff. Government.	S.L.D. Co.
Total number of staff resident.	44	65	49	36	47		
Average number resident.	30.5	40.4	28	24.5	30.4		
Total number on sick list.	59%	69%	47%	39%	53%	59%	53%
Total number of days on sick list.	272	359	210	87	268		
Average daily number on sick list.	2.5%	1.5%	1.2%	1.6%	1.6%	1.66%	1.68%
Percentage of daily sick to average number resident.	3.67	2.43	2.07	2.33	2.4	2.18	2.98
Average number of days on sick list to each patient.	10.46	7.98	9.13	6.21	10.7	10.26	8.90
Average sick time to each resident.	8.92	8.89	7.85	8.47	8.81	7.99	8.99
Total number invalided.	2	1.	1.	1.	1.		
Percentage of invalidings to total residents.	4.55	1.54	2.04	2.77	2.13	2.64	2.61
Percentage of invalidings to average number resident.	6.56	2.22	3.57	4.08	3.29	3.59	3.94
Total number of deaths.	0	0	0	0	0		
Percentage of deaths to total residents.	0	0	0	0	0	.23	
Percentage of deaths to average number resident.	0	0	0	0	0	.32	

Of the cases invalided only one was due to tropical disease.

TABLE NO. 16.

	November 1930 to July 1931.	August 1931 to July, 1932.	August 1932 to July 1933.	August to December 1933.	January to December, 1934.	Figures for Government European Officials, average of 5 years from 1929 to 1933 inclusive for comparison with the average figures for the Sierra Leone Development Company's European staff. Government Officials.	S.L.D. Co.
Average number resident.	30.5	40.4	28.0	24.5	30.4		
Total sick days.	272	359	210	87	268		
Total days on sick list for malaria.	130	166	110	13	94		
Total days on sick list for other causes.	142	193	100	74	174		
Percentage of malaria days to total sick days.	47.80	46.24	52.38	14.94	35.07	24.66	39.29
Number of days lost through malaria per year per 100 residents.	426	411	393	126	309	195	333
Number of days lost through non-malarial causes per year per 100 residents.	466	478	357	720	572	607	519

The above table shows that malaria is clearly the greatest single cause of sickness among the European staff.

From these figures it is possible to say that the measures taken for preserving the health of the Company's staff have resulted in maintaining a health level very similar to that shown by the Government figures. With the exception that malaria shows a greater incidence in the staff working in the Protectorate, this despite the operation of considerable and expensive anti-malarial programmes.

The factors of importance relative to health in European staffs are sanitation, housing and food, and length of tour.

The main items in sanitation are a safe piped water supply, an efficient latrine and refuse disposal system, and a programme of vector control. This latter has already been dealt with in detail.

The source of water supply for a permanent camp will vary with the locality. Having regard to the source decided upon the same rules for prevention of the pollution of the gathering grounds apply in Sierra Leone as elsewhere, and need not be detailed. By their insanitary habits native water carriers will almost invariably pollute either a water supply or its gathering grounds. If there is a choice of two water supply areas they will invariably go to the nearer, whether or not that is the safe one. For these reasons no water supply to a permanent camp which is not piped can be regarded as safe. In installing a piped supply special care should be taken to examine the water for the presence of dissolved iron. The large areas of the country covered with lateritic soil lead to many water supplies containing soluble ferrous hydroxide, which on contact with the air is oxygenated and precipitated as insoluble ferric hydroxide. This phenomenon was found to occur in all our water supplies between Marampa and Pepel. The large amount of precipitate necessitates the use of filters specially designed for the removal of dissolved iron, such as the Candy Polarite type of filter, which has proved efficient in use.

The pail system, with fly proof latrine seat, weak disinfectant in the pail and disposal of the contents into fly-trapped Otway pits is in general use in Sierra Leone for latrines. Properly supervised it is efficient. Particular attention is required to ensure that the disposal pits are well made and maintained in good repair. Intense culicine breeding has been occasionally found in a pit into which culicine mosquitoes had access. Although it is not widely adopted in the country a water carriage system with disposal into a septic tank is occasionally used. In a permanent camp with a long expectation of life its installation ought to be seriously considered. The higher first cost would be to a great extent offset by the cheaper maintenance costs; besides being pleasanter in use the system is probably safer than the pail system.

Refuse is best disposed by incineration, either in a mud beehive type of incinerator which functions well, or in a more complicated destructor, the product from the incineration being disposed of by burying in pits.

Between November, 1930 and June, 1935 the absence of any epidemic of dysentery or other water carried disease in our staff indicates that such measures of sanitation as outlined above are adequate. During this period only two cases of amoebic dysentery occurred. One case contracted the infection in an outcamp on survey work where conditions were not ideal; the second case occurred in a main camp, and the source of infection seemed likely to have been from water obtained by a water carrier at a site which was forbidden, but which was more convenient to him than the recognised site at a greater distance.

The/

The question of housing and food are dealt with together as they are interconnected. Good fresh food is difficult to obtain in the Protectorate. The native does not grow vegetables to which the European is accustomed. Meat, mutton and fresh fish are difficult to obtain in most inland areas. This throws one back on the necessity for living largely on tinned foods and emphasises the great advantage of the provision for a large staff of a cold storage plant, so that meats and fish can be obtained from cold storage companies in Freetown. A large variety of vegetables grow well, and the provision of a vegetable garden for securing a supply of these is very desirable. It can be appreciated that the cost of living in the Protectorate, if a normal European diet is to be obtained is of necessity high. A much greater difficulty than actually procuring supplies of suitable food is to get such supplies well, cleanly and safely cooked. There is not to be found in Sierra Leone the intelligent, well trained native servant class that is common in other Colonies, particularly in the East. From the point of view of decently cooked, well served food life in Sierra Leone might almost be described as one unending struggle with the cook. One might then sum up the food question by saying that it is difficult and expensive to obtain good fresh food and more difficult to get it well cooked.

The physical attributes of housing to strive after are dryness, coolness, good ventilation and lighting. For dryness in the wet season, the most suitable houses I have encountered in Sierra Leone were those made of concrete or brick. Houses of mud blocks, pise, or similar material are damp in the humidity of the wet season. The provision of these essentials in good concrete houses in our permanent camps at Marampa and Pepel has very markedly increased the comfort of the staff, reflecting on their physical well being and their capacity for work.

It is of interest to consider alternative methods of housing permanent staffs in Sierra Leone. One method is to build separate houses, in which the staff live, each member with his own domestic native staff forming a self contained unit. This means that in addition to doing the work he is engaged for, each member of the staff must run his own house. My experience of this method in Sierra Leone is that the large majority of men run their houses extremely badly, and, for the expense of living do not get an adequate return in good food, cleanliness or comfort. A large part of the difficulty of tropical life is psychological; lack of comfort and poor food added to the constant nuisance of incompetent domestic servants considerably aggravatee the difficulty, and is reflected inevitably in the capacity for work of the individual.

An alternative housing method is to centralise all housing in one building and run that building something on the lines of an hotel with a European in charge of it. The difficulty over food and servants would be solved for each member of the staff by this method.

Examining this question further, let us take the hypothetical case of a company faced with housing a staff of 25, consisting of 4 first class officials and 21 second class officials, making provision for married quarters for all the first class staff and for one third of the second class staff, and, as is customary in Sierra Leone, making provision for visitors.

It is first of all necessary to examine the minimum requirements to house a man comfortably. In my opinion these are, a bedroom, a dining room, a bathroom, a latrine, a store-room, a kitchen. For a staff of the above size housed on the one man one house principle, the camp would consist of 4 houses suitable for first class officials and 21 houses suitable for second class officials, totalling say:-

8/

8 plus 21 bedrooms = 29 bedrooms.
25 dining rooms.
25 bathrooms.
25 latrines.
25 store-rooms.
25 kitchens.
Provision for three visitors, at least two further houses.

On the centralised system, by alloting to the first class staff one bedroom, one sitting room, one latrine and one bathroom each, to the unmarried second class staff one large bedroom and verandah, to the married second class staff one bedroom, one sitting room, one bathroom, and latrine, for visitors, 3 bedrooms, 1 sitting room, 3 bathrooms and 3 latrines, adding one man to the staff as cook and 'hotel' keeper, the total comes to

29 bedrooms
12 sitting rooms.
22 bathrooms, one between each two of the second class unmarried staff.
20 latrines.
1 large common dining room.
1 common baggage room.
1 large kitchen.
1 laundry.

This shows an economy in building costs of

2 bedrooms.
15 dining rooms.
5 bathrooms.
7 latrines.
27 store-rooms.
27 kitchens.
minus the cost of
1 common dining room.
1 large kitchen
1 laundry.
1 baggage room
1 food store room.

This saving represents roughly the equivalent of at least 5 houses over the one man one house camp, i.e. a saving of some 20%. The desirability of using concrete or brick, the necessity to substitute metal for wood because of white ants both indicate that any housing scheme would prove expensive, and it would seem that the possibility of a 20% saving is worth exploring. In addition to a direct saving in building costs there would be a further saving in electric light and water service lines prime cost and maintenance cost. There would be a saving in sanitary costs since a much smaller area would require to be sanitated than in the case of a one man one house camp. The installation of a water carriage latrine system would be facilitated, further cheapening sanitary costs. The social amenities of the camp would be improved without interfering with the privacy of each member of the staff, and without requiring resort to the building of a club. A large well run vegetable garden would be a possibility easily attained. Good food, well cooked and served, cleanliness and comfort would be ensured at a reasonable cost. The individual members of the staff would be relieved of the tedium of supervising their individual domestic staffs. The cost of the extra member of the staff could be easily borne by the remainder of the staff; £2 a month per head would amply cover this. The entertainment of visitors would be greatly facilitated. Where circumstances allow of it it is suggested that a commercial undertaking faced with the need to house a number of men to the best advantage for the men and/

and at the least cost to the company would be advised to examine such a centralised system in detail.

<u>Length of tour</u>. The customary tour for Government officials is eighteen months. Many commercial undertakings have similar tours, many have longer tours. Recently an increase of the tour for Government officials to two years has been recommended by A Committee on Leave and Passage Conditions for the Colonial Service, 1934.

It has been the practice of the Sierra Leone Development Company to have short tours. The question of the length of tour is dependent on the nature of the work engaged upon, the length of leave out of the country, the provision of local leave during the tour, as well as the climate of the country and the average of sickness in the district. In our experience the strenuous work incident on such industrial occupations as railway construction and mining in such a country as Sierra Leone leads to a marked falling off in efficiency in a man after 9 or 10 months. The presentpaucity of suitable places for local leave render it difficult to obtain a full return to efficiency by this expedient. It has been found, therefore, better to make the tour from 12 to 15 months in length. While not actually ill at the end of this period the climatic effects and the prevalence of indigenous disease, particularly malaria, in the Protectorate have marked effect on the efficiency of a man after this period in the country. Rather than then by an increase of local leave, temporarily increase the efficiency of staff to something below 100% and prolong the tour further, it has been considered wiser to give home leave. Since the chief purpose of leave out of the country is to restore a man to complete health, the period of the voyage home is calculated in the leave period, the voyage having usually marked beneficial effects. That after a short tour there is a more rapid return to full efficiency is our experience. Leave then has been fixed at a period of three months from the date of sailing from to the date of returning to the country. This has been found in all except exceptional cases to be ample to ensure complete return to health.

It is of interest to examine some of the reasons for the high malarial incidence in the European staff.

Throughout the Protectorate, in my experience a stereotyped cycle occurs on the commencement of any industrial undertaking. Labourers migrate to the scene of activity, usually in very much greater numbers than can ever hope for employment. These occupy the villages in the neighbourhood, grossly overcrowding them. Many squat in shimbekes. Soon their families arrive, then petty traders. The nearer the site of work, which is almost invariably near the site of the European houses, the natives can get, the better pleased they are. Overcrowding in the villages leads to a burst of unplanned building there. Shimbekes gradually acquire mud walls, then a thatch roof, and in place of a temporary shimbeke there now stands a permanent house. So that, very shortly after commencing work in any area, the European housing site is closely surrounded by overcrowded villages and shimbekes, built without any plan and placed convenient to water. This process can in the course of a few weeks rapidly transform a European camp previously well segregated into a site surrounded closely on all sides with a large reservoir of infection for anophelines. The inevitable result is a marked incidence of malaria in the Europeans living in that camp. The longer the life of the European camp the more firmly entrenched become the natives in the immediate vicinity of it, and the more difficult does it become to ameliorate matters by moving them. It is this difficulty in maintaining adequate segregation for European Camps which/

which leads in a great measure to the high malarial incidence. Particularly in the flat Coastal Belt where it is difficult owing to the numerous villages and multitudinous swamps to find a suitable site for a European Camp does this process cause its worst effects.

Again the fact that a very low density of infective anophelines is capable of causing a considerable incidence of malaria in a European staff indicates that a very high degree of segregation is required to prevent malaria among such a staff. The question of what degree of segregation is advisable has been discussed previously. The probable limits suggested are very much greater than is the accepted practice in Sierra Leone. It is likely that inadequate distances of segregation have been operative in maintaining the high malarial incidence experienced.

The expense of anti-malarial programmes is considerable. The biology of the main malaria vectors and the nature of the country render this inevitable. The amount of money which any commercial undertaking is able to spend on the prevention of malaria is limited. Uncontrolled building and native squatting in close proximity to European Camp sites leads to a great increase in the area which it is necessary to control to prevent malaria, and this increase of area may increase the cost of prevention beyond the capacity of the undertaking; or the increased area is dealt with at the cost of a small area, with poor results. Particularly is this so in the case of small temporary camps or camps of small commercial undertakings.

The main factors then in causing a high malaria incidence are.

(1) Hyperendemic malaria in the native population, with wide prevalence of anopheline vectors of whom even a low infective density is capable of producing considerable malaria among a European population.

(2) Inadequate application of the most valuable preventative, segregation.

(3) Extreme difficulty in maintaining adequate segregation owing to influx of labour around industrial undertakings, resulting in uncontrolled building near European camps within the limits to which it is advisable to extend the boundaries of segregation.

(4) Difficulty and expense of anti-malarial programmes owing to the prevalence and biology of the vectors and the nature of the country.

Improvement in the incidence of malaria in Europeans can only come as the result of improvement of one or all of these ~~three~~ factors. Nothing immediate can be hoped for with regard to (1) above. Economic improvement of the status of the native will have its undoubted effect in producing a higher standard of living and a lessening of their malaria, but this will be a long slow process. The question of expense is one to be dealt with by the Company desirous of protecting its staff, and the amount available for anti-malarial schemes will vary widely depending both on the magnitude of the undertaking, the degree of protection desired and the attitude of the company or individual towards these matters. Definite improvement could be obtained by increasing the limits of segregation to those indicated previously and by maintaining it more stringently. Both in this and in regard to (3) above legislative measures bulk largely. As it will be shown that a re-orientation of the attitude towards improving the health of the natives dependent on large industrial occupations would result in solving segregation difficulties, it is necessary first to/

to examine the conditions of health in the natives.

Figures comparable to those for Europeans are not available for the African staff of the Sierra Leone Development Company. In general it can be said that since the beginning of the Sierra Leone Development Company's operations, marked benefits have accrued to the natives employed. Since commencing operations it has been the custom to make payment part in money and part by a daily issue of rice. Regular work and regular rations have physically greatly benefited the labour employed. Regular pay has increased their standard of living, and a better standard of housing and clothing is noticeable in these villages and towns in which numbers of labourers live.

Assistance was given to the Sierra Leone Development Company by a loan from the Colonial Development Fund. One of the conditions of this loan was that suitable housing for labour employed on the mine was provided by the Company. To meet this provision there were built at Marampa a Labour Camp and a Clerk's Camp. The former consists of concrete houses, essentially aggregations of single rooms in size 12 feet by 10 feet. The floors are raised and of concrete, the roofs are of galvanised iron, adequate lighting and ventilation have been provided by windows and by leaving a space between the top of the wall plate and the roof. There is a shade verandah in front of the house. Adequate provision for cooking in kitchens has been made, bathrooms and latrines of good type are present, good water is laid on to the bathrooms and to standpipes in the streets, and provision for a native market made. The Clerk's Camp is of similar construction except that the unit of housing is two rooms of the above size, interconnected. Both camps are adequately sanitated.

The provision of labour housing schemes of the type made obligatory at Marampa entails very considerable expense to a Company. It is therefore essential to evaluate as accurately as possible the results obtained from this great expenditure. To do this the attendances at the Company hospital for 1934 have been analysed, a division being made of those attending into those living in the Company houses and those living elsewhere. It is impossible by this method to assess the absolute amount of sickness in the populations of the different places but some idea of the relative proportions of the different groups of diseases may be obtained. It was found that among those living in the Company houses there was a smaller percentage of malaria, of gastro-intestinal diseases and of dysenteric diseases in the total amount of sickness than in those living outside the Company schemes, a result to be expected from the better sanitary conditions prevailing in the one place from the other. Respiratory diseases appeared increased relative to the total amount of sickness in the Company compounds. On the whole no very marked benefits seemed to accrue from living in the Company houses. The short time which has elapsed since the Company houses were occupied, and probably of much greater importance, the continual tendency for the population to change, probably explains the lack of apparent benefit.

While it was not possible to obtain figures showing the relation between the absolute amount of sickness in the one area as compared to the other, the opinion formed was that the total incidence of sickness among those living in the Company houses was little if any less than in those living elsewhere.

Experience of our labour camps has shown that the native has a marked preference for living in his villages to living in these camps. The reasons for this preference are various.

(1)/

(1) The village as opposed to the Company's house is more comfortable to the native. He objects to any degree of ventilation, preferring an unventilated house to a well ventilated. He commonly sleeps on the floor, and an earth floor, though it may be damp is to him preferable to a concrete floor. He can add to the native house easily with daub and wattle; the limits of the concrete house are fixed. He prefers his own insanitary shallow latrine in his native backyard to the latrine some distance from his house however good it may be. In favour of the concrete house he has the freedom from maintenance; the thatch native house roof requires renewal freqnently;and the convenience of water laid on in the streets.

(2) He prefers the social amenities of the larger native village to the smaller Company labour lines.

(3) He has more security of tenure in the native village than in the Company houses. It is necessary to charge rents for the Company houses, otherwise no control would be possible over their occupation and the houses would be filled with non-employees. These rents are made the same as those prevailing in the neighbouring villages, so that no hindrance is put in the way of employees desirous of living in the Company houses. The only possible method of collecting these rents, by deduction from the employees' pay, is adopted by the Company. When an employee is discharged, he automatically becomes liable to be put out of his Company house. The native never saves any money; he seldom has a penny the day following the monthly pay. In the native village however if a man is discharged he need not leave his house. He can either owe the rent to the house-owner, or go to work for him in some way or other, usually on his farm. Agriculture is the great pool from which labour is drawn to industrial undertakings in the country, and in most cases discharged employees return to agricultural employments of some form or other, until the opportunity returns to re-enter an industrial undertaking, which has a higher rate of pay.

(4) He can never hope to own a Company house, whereas he can within a reasonable time own a house in a native village if he so desires. The family is the unit of native economic and social life. The goal of the average native is to own a house and have farming rights over an area of land; to have several wives and a large family by whose efforts he can exist in comfort. The lack of the prospect of ever owning a house in the company lines deters him from living there.

Experience at Marampa has shown that the houses built by the Company are seldom fully occupied, only about fifty per cent of them on an average being filled. While it is possible then to oblige a company to build houses for its labour, it is impossible to force the labour to occupy them.

Since the beginning of work at Marampa there has been a great increase in the size of the villages nearby. The main increase has been in one village, Lunsahr. Originally a small village of little over a dozen houses, it has grown to a very considerable town of about three hundred houses. Lack of control over this building has resulted in an unplanned growth without proper regard to healthy siting, resulting in the production of a scattered, illbuilt, badly sited town without any sanitation. In it live a percentage of the labour employed on the mine, the numerous traders attracted to the area, the unemployed and the 'hangers on' who live on the employed, the original native population of the area engaged on agriculture etc. and the various temporary visitors such as cattle dealers who visit the area in the hope of trading. Places such as this form potential centres of epidemics as well as being an area whose inhabitants are/

are exposed to the endemic diseases of the country in an aggravated degree.

Whatever benefit may have accrued to that percentage of the labour who elected to reside in the Company houses, it is clear that to those living outside these places and to the large numbers of traders and other natives attracted to the locality and dependent on the Company's operations indirectly for their livelihood, no benefit to health has been achieved. In fact, a consideration of the unsanitary conditions resulting from rapid uncontrolled and unplanned building suggests that the health conditions under which these people live are probably considerably below the average for the country as a whole.

From the foregoing then we must conclude

(1) That regular industrial employment with part payment in food rations is beneficial to the indigenous natives, both physically and by raising his general standard of living.

(2) That the provision of expensive housing schemes for native labour fails to improve their health to any marked extent, due probably to the fact that the native is averse to living continuously in these houses.

(3) That housing schemes for labour in industrial employments do nothing to improve the health conditions of large numbers of natives attracted to the area who are dependent indirectly on the industry for their livelihood.

(4) That uncontrolled building of insanitary towns and villages, necessary to house these people, leads to lowering of the health conditions under which they live; the uncontrolled building probably reflecting also in an increased malaria incidence in the European staff through encroachment on the desirable segregation of their camp.

No one would suggest that it is but just that companies developing the resources of a country should have their operations so directed that lowered conditions of health for the natives of the country are avoided, and improved conditions obtained if possible. The defects exposed in the method of housing labour directly employed leads to the question of what method can be adopted to prevent harm and ensure benefit.

First it is necessary to examine the diseases which affect the native and which of these it is possible to attack. In PART 3 a short account of the prevalent diseases is given. From this it is seen that malaria, gonorrhoea, yaws, filariasis, the dysenteries, smallpox and yellow fever occur, the first three being of primary importance. Those due to insect vectors, particularly malaria, owe to a very great extent their high incidence to the invariable habit of the native of building his town or village close to water. To a great extent the dysenteries and diseases such as schistosomiasis are spread by a fouling of the water supplies. These thoughts suggest the clue to improving the health conditions of the native is to be found in the water supply difficulty.

Suppose it were possible to construct a native town two miles away from water in every direction, receiving a pure domestic water supply through pipes inside the town. It is undeniable that the incidence of malaria, filariasis, yellow fever, and the dysenteries would immediately fall very considerably. It is a well known fact that a marked reduction in hyperendemic malaria affecting a community is followed by a reduction in many of the other diseases affecting them, to which the continual infection with malaria renders them more susceptible. We could expect, then, in the hypothetical town, a considerable improvement in the general health of the inhabitants. In this town would live all the labour required

by/

by the operating company and all those attracted to the area to make their living indirectly as the result of the operations. There the native would be free to pursue his ambitions and subject to the native law and customs to which he is accustomed. Any fluctuations in the demand for labour by the operating company would be automatically adjusted by return to or withdrawal from the agricultural pool without undue upset to the individual concerned.

It seems then a much better plan to substitute for schemes of limited value for housing labour, the conception of a well planned, well sanitated town, built at an adequate distance from mosquito breeding grounds and furnished with a safe piped water supply. Danger to the European Camps in the locality could be avoided in the choice of site for the town and by concentrating all the building of native houses in the locality in that one centre.

To construct and maintain such a town four factors are required; a piped water supply, the building of the town, the provision and maintenance of the necessary sanitary structures, and control of the entire scheme.

The piped water supply I would suggest should be installed by the operating company as their contribution, the maintenance of the system falling on the town. Methods which require little upkeep cost should be adopted for obtaining the water; the method I have in mind would be by a ram pump.

The building of the town would take care of itself. The only difficulty experienced in these matters is to control the building.

The provision and maintenance of the sanitary structures required should be a charge on the Paramount Chief of the district who will benefit very considerably by the operations of the company and by the building of the town.

Control of the entire scheme would require assistance from Government both by legislation and by the enforcing of such legislation as is already in being. This brings us to a consideration of the existing legislation concerning health in the Protectorate.

Practically the entire legislation in connection with matters of health in the Protectorate of Sierra Leone is contained in "AN ORDINANCE FOR PROMOTING THE PUBLIC HEALTH IN THE PROTECTORATE. (19th June, 1926.)" and "RULES MADE BY THE GOVERNOR IN COUNCIL UNDER SECTION SIX OF THE PUBLIC HEALTH PROTECTORATE ORDINANCE, 1926. (14th December, 1929.)."

These two enactments provide rules governing

(1) The building, drainage and maintenance in a sanitary condition of houses and compounds.

(2) The position of houses, buildings and erections, relative to neighbouring roads, streets or open spaces, and to other houses, and on the plot of land on which the same are built, and the area of such plot which may be occupied by any houses, buildings or erections.

(3) The construction, drainage, and maintenance of roads, the preservation of places as open spaces in and around towns and villages.

(4) The disposal of refuse and the regulation of cesspits, ashpits and latrines.

(5)/

(5) The selection, protection and maintenance of water supplies, including gathering areas, and the selection of sites for, and the supervision and protection of wells or other means employed for the storage of water.

(6) The control and regulation of places selected as markets and slaughterhouses, the inspection and sale of food and the disposal of food which shall be condemned as being unsound, and the disposal of the carcases of animals.

(7) The control and keeping of cattle and other domestic animals in such a manner as not to be a nuisance or injurious to the public health.

(8) The selection and maintenance of burial grounds, and the burial of dead persons.

(9) Epidemic and epizootic diseases, including malaria and other insect borne diseases.

(10) The maintenance in a sanitary condition of ships, boats and canoes.

(11) The selection of sites for, and the maintenance of, rest-houses and camps.

(12) The fees chargeable for the use of markets and slaughterhouses and other sanitary services and in respect of interments in cemeteries, and the collection and application of such fees.

(13) Such other matters as may be necessary for carrying out the provisions of the Ordinance.

These rules do not apply to the entire Protectorate in general, but only to defined areas declared by the Governor in Council, by Order to be a 'sanitary district' under Section 3 of the ORDINANCE FOR PROMOTING PUBLIC HEALTH IN THE PROTECTORATE.

It is the duty of the Sanitary Authority of any area to which these rules have been applied to enforce their observance. The enactments define the Sanitary Authority as

(1) The Chief of the district declared to be a Sanitary District.

or

(2) Where in any sanitary district it appears to the Governor in Council that there is a considerable non-native population the Governor in Council may by order direct that there shall be a Special Sanitary Authority for such district constituted as follows:-

(a) The District Commissioner of the district in which such sanitary district is situated.

(b) The Medical Officer (i.e. the Government Medical Officer) who is for the time being stationed in the sanitary district or at any of such towns or places as the Order in Council may specify.

(c) The Paramount Chief of the Chiefdom in which the sanitary district is situated or the local chief of the sanitary district as the Order in Council may appoint.

(d) Such other person, being a non-native, as the Order in Council may appoint.

Two/

Two members of such a Special Sanitary Authority shall form a quorum; provided that no business shall be transacted at a meeting if neither the District Commissioner nor the Medical Officer is present.

The Health Rules are themselves excellent, and cover every reasonable need of the country in its present condition. In practice however it is found that these rules suffer from two great disadvantages. First, they are not applicable to the entire country, but only to areas specifically declared by Order in Council of the Governor to be sanitary districts. There is frequently a lag between the time when it is wise and necessary to declare an area to be a 'sanitary district' and the passage of the Order in Council. During this space of time when there is no sanitary law applicable to an area sufficient harm may be done by uncontrolled building by natives to render it impossible to rectify matters after the passage of the Order in Council. Many months passed after the commencement of the Sierra Leone Development Company's operations before either of the areas of the main camps at Marampa, Sahr Marank or Pepel were declared health areas, and during that time lack of control led to many abuses whose ill effects are still felt. During the railway construction period no health area was ever declared except the three mentioned above, so that no control was possible at any point along the line outside these three areas. It would have been much better to have declared the whole area from end to end of the proposed railway line to be a sanitary district, and to have done this before the commencement of any work at all. It would also be better in declaring a sanitary district to make much wider boundaries to it than is at present customary. The usual limits stated are a mile wide belt round the declared area. This limit could with benefit be doubled.

The second and greatest disadvantage is the difficulty in efficiently applying these Health Rules. Where the Chief of the sanitary district is responsible for the enforcement of observance of the laws his complete ignorance of sanitation coupled with the fact that he sees no monetary return for work done on sanitation usually leads to nothing of value being done. Where he can be instructed what to do and compelled by action or threat of action against him in the court of the District Commissioner (Section 8 of An Ordinance for Promoting the Public Health in the Protectorate, 1926) to see that the work is done, results of value may accrue. The paucity of European Officials, particularly Medical Officers, in the Protectorate sufficiently interested in sanitation to instruct Chiefs and compel them to fulfil their duties in the sanitary districts negatives the hope that much can be expected from action by the Chiefs. In the case of sanitary districts where the authority is the Special Sanitary Authority set out in (2) above the following practical defects are apparent:-

(1) The District Commissioner may be resident at a considerable distance from the Sanitary District. Distance, pressure of other work and recent economies, necessitated by financial stringency, effected in the travelling allowances of District Commissioners prevent him coming as frequently to the Sanitary District as he would require to do if the Sanitary Authority is to function often enough to work efficiently. Similar factors operate against the frequent attendance of the Medical Officer should there be one in the District. The Protectorate is divided into twelve Districts for administrative purposes. Each of these has a District Commissioner, some in addition have one or at most two Assistant District Commissioners. (Owing to retrenchment there is not a Medical Officer always in every District). Without the presence of either the District Commissioner or the Medical Officer the Special Sanitary Authority cannot function. It can be readily appreciated therefore that it is an infrequent occurrence for the Special Sanitary Authority to meet to transact business. If then a period of/

of several months has to elapse before a decision can be taken or a complaint laid about an insanitary latrine or the pollution of a water supply the application of the law becomes somewhat farcical. One cannot expect the native to wait three or four months to learn whether the site on which he desires to build a house is suitable or not, because by that time it may be too late in the dry season for him to commence building. In actual practice he simply builds his house. If it is in an unsuitable position it will remain there until condemned by the Special Sanitary Authority. It is hardly fair to force a native to knock down a house which he had to build because he could not wait for the sanction of a body which meets seldom if ever.

(2) Any necessary sanitary work is expected to be done by the Chief, who has authority to call upon the residents of the districts to give work for this purpose. In practice one finds that the Chief is most unwilling to supply labour for works whose purpose he does not understand and for whose completion he gains no financial advantage. It is a moot point whether, should a chief default in supplying labour, any action can be taken against him for his failure as, from his position on the Special Health Authority, he shares with the other members of this body, protection against prosecution in regard to matters in or execution of powers conferred by the Ordinance for Promoting the Public Health in the Protectorate, 1926.

(3) The fourth member of the Special Health Authority (see d. above) having no authority to do anything but sit on the Special Health Authority when it meets, can do nothing to ameliorate any insanitary conditions which may, in his opinion, require to be dealt with, except hopefully bring these matters up for consideration by the Special Health Authority when it does meet.

It is clear that some modification of the Special Health Authority is required that the existing laws be more speedily and efficiently applied. The actual constitution of the Special Health Authority is good. It provides an expert opinion on sanitary matters, the Medical Officer; it gives means of expression for the interests of the native and non-native resident in the area; and the administrative and judicial aspect is taken care of by the District Commissioner. Designed clearly with a view to intelligent application of the health legislation while preventing abuses, it is a constitution worth retaining. Its defects lie in the limitation of power of action in practice through the necessity for a properly constituted meeting of the Authority to take place before action can be taken, and the difficulty for obtaining such meetings as frequently as desirable. This at once suggests that if the functioning of the Authority could be improved, a marked amelioration of its practical defects would be acheived. Under the present conditions, it is impossible to expect that District Commissioners and Medical Officers can more frequently go to the various Health Areas to attend more frequent meetings of the Authorities for these areas. The only solution appears to be to furnish the Special Sanitary Authority with power to delegate some of its function of enforcing the observance of the health rules, retaining to itself the power of decisions on large questions of policy etc. In practice this would mean that the Special Sanitary Authority would meet, and from the information at its disposal, would decide that a certain course be pursued. Having decided the main lines of the programme it would then delegate to a certain individual or individuals the task of attending to the daily details of such a programme. For instance suppose the question of the advisability of treating a swamp near a village which was a breeding ground for anophelines arose. The Special Sanitary Authority would meet, decide on the evidence at its disposal whether or not the swamp should be dealt with; if the/

the decision was to deal with the swamp, it would decide the method to be adopted, instruct the Chief if necessary to supply the requisite labour, and delegate the supervision of the actual work to a certain individual, who would be invested with the powers and privileges against prosecution of the Special Sanitary Authority for the purpose of seeing the specific task performed. Again suppose a new village was to be built. The special Sanitary Authority having met, decided upon the site and method of lay-out, and other relevant matters, could then delegate its powers to an individual to supervise the building, to grant permission to applicants desirous of building, to mark out for them the sites on which they should build, to see that the sites for borrow-pits for earth for house building which had been laid down were used and no others, to stop immediately on its commencement any building contrary to the plan passed by the Authority and ensure its demolition, and so on. The presence on the spot of someone with the necessary authority would, for the natives, make of the health laws a guide for their ignorance rather than a whip for the correction of their mistakes, which is the true purpose of the legislation.

In the case of Sanitary Districts declared in areas where large commercial undertakings were operating, the delegation by the Special Sanitary Authority of its 'day to day working' powers to the non-Government Medical Officer employed by such undertakings would ensure far greater efficiency and smoothness of application of the existing laws, and enable that co-operation by private practitioners in schemes controlled by Government which it is so desirable to obtain.

The only modification which would be required to the existing legislation would be the insertion in 'An Ordinance for Promoting the Public Health in the Protectorate, 1926' of a clause somewhat as follows:-

'It shall be lawful for a Special Sanitary Authority to delegate any or all of the powers and privileges with which this Ordinance invests it to an individual or individuals resident in the sanitary district.'

The lag in declaring an area a 'sanitary district' cannot be entirely blamed on delay in Government Departments. Some of the cause is that these departments are ignorant of the exact areas in which a company intends to operate, and until operations commence are therefore unable to define boundaries for the declaration of sanitary districts, i.e. until in many cases it is too late to obtain the full benefit of declaring a sanitary district. This difficulty could be met by passing legislation making it incumbent upon any company desirous of operating in the country to supply to the apposite Government Departments information of the intended area of operation sufficiently detailed to allow of the declaration of adequate sanitary districts before operations are begun.

<u>SUMMARY OF PART 9</u>.

(1) The health results of a European staff working in the Protectorate of Sierra Leone are detailed. It is shown that the greatest cause of sickness among them is malaria. The most hopeful method of preventing malaria among them is shown to be by adequate segregation. The extent of this is set out, and the difficulties of obtaining and maintaining adequate limits are discussed.

(2) The results on the health of native communities of industrial operations on a large scale are discussed, particularly in regard to measures designed to improve the conditions under which they live/

live. It is shown that the building of expensive housing schemes purely for employees to live in brings very small health benefits and that only to those directly employed. The large majority of the people attracted to an area by a large industry are not benefited; indeed it is likely that their living conditions are lower than the average. A method is suggested whereby model towns could be built in which all the natives attracted to the area would live and where their health conditions would be greatly improved. Such towns being within the power of native communities to build with very little financial assistance would prove examples to be copied by corporate action in other non-industrual areas in the country.

(3) To enable action to be taken for the safeguarding of the health of European staffs and to ensure that the new towns arising as the result of industrial undertakings are built on sound and healthy lines, changes in the legislation with regard to health, particularly with a view to the better application of the laws at present existing are required. The requisite changes are detailed.

PART 10.

CONCLUSION.

Malaria is undoubtedly the most important disease in the Protectorate of Sierra Leone, affecting both the indigenous natives and Europeans resident there. The high endemicity of the disease has been shown to be due to a combination of the granitic composition of the country leading to a high water table in the flat Coastal plain, the meteorological conditions, the presence of efficient vectors of the disease in A. costalis and to a lesser extent A. funestus, and the great volume of the disease among the native population consequent on their low standard of living, the necessity for living close to water, their ignorance of methods of prevention and their inability to secure efficient treatment.

A. costalis and to a lesser extent A. funestus are by far the commonest house-haunting mosquitoes. This, coupled with their high natural infection rates with malaria, incriminates them as responsible for practically the entire transmission of malaria. Marked seasonal variation of the infection rates in A. costalis occur, caused for the most part by variation in breeding rates, and not related to variation in temperature and humidity. A. costalis disperses widely, assisted by the wind to some extent, and suitable breeding grounds within half a mile of any camp lead to marked infestation of that camp with the mosquito. A very small density of infective A. costalis is sufficient to maintain a high degree of malaria transmission. Transmission occurs mainly by indoor biting, but a small percentage is probably transmitted by outdoor biting. Transmission occurs continuously throughout the year, the times when the danger of contracting malaria is greatest being during the rainy season and at the end of the dry season. The average life span of A. costalis is believed to be about 16 days with a maximum period of survival of some 28 days.

Many species of mosquitoes are found breeding continuously throughout the year, the vast majority of it occurring in the swamps so numerous in the Coastal plain. The geological formation of the swamps and their location relative to the influence of the tide and salt water influence the breeding within them. Methods of malaria control by treatment of the main breeding grounds in swamp of the vectors are based on the geology of the swamps and the biology of the mosquitoes, and prove effective. Malaria control by the treatment of gametocyte carriers with plasmoquine has not proved a success.

The health of the European staffs in industrial occupations can be safeguarded by straightforward sanitation of their camps, reasonable length of tours, good housing, and sound anti-malarial programmes. A much wider area of segregation from native habitations than previously customary and a much stricter enforcement of segregation would certainly lead to a very much diminished incidence of malaria among European staffs. It seems possible also that centralisation of housing and better provision for the supply of good food thereupon possible would add much to the comfort and well-being of European staffs.

The economic status and physical condition of natives is improved by their employment in industrial occupations. The health of large numbers of natives attracted to the area of these industries and indirectly dependent on them is not improved and the conditions under which they live are probably worse than the average./

average. The provision of housing schemes for labour directly employed is without definite health benefit to these employees and is open to many objections. Very definite improvement in the conditions of living and of health, not only of natives directly employed but of the entire population attracted to an industrial area could be secured by intelligent planning of native towns. To secure the building of model towns in these industrial areas and to assist in achieving better health results among European staffs, modification of the existing health legislation and more efficient application of this legislation are essential.

APPENDIX.

[illegible]

[illegible]

MONTH.	MAXIMUM TEMPERATURE.	MINIMUM TEMPERATURE.	HUMIDITY (2 P.M.
1933.			
August	80.5	74.5	89.6
September	84.1	75.6	92.6
October	86.2	75.2	88.5
November	84.7	75.7	80.1
December	86.3	74.0	76.8
1934.			
January	86.5	73.4	72.5
February	89.1	73.9	52.8
March	90.8	73.4	68.8
April	91.2	74.2	89.7
May	91.0	76.8	87.0
June	85.3	73.3	69.6
July	81.8	73.7	72.8
August	82.7	73.4	69.5
September	85.1	73.2	66.6
October	85.8	71.5	62.1
November	86.5	70.5	64.5
December	87.0	67.9	53.7

APPENDIX.

MONTH.	MAXIMUM TEMPERATURE.	MINIMUM TEMPERATURE.	HUMIDITY (2 P.M.
1935.			
January	88.4	65.0	49.3
February	90.9	68.7	46.9
March	94.4	68.1	40.3
April	94.6	72.5	50.0
May	88.9	71.6	74.8
June	85.4	71.0	70.5
July	85.4	70.5	63.5

Details of daily rainfall, maximum and minimum sh temperatures, and humidity from dry and wet bulb thermomete were kept at Marampa as a Company routine. The direction of the wind was recorded daily at 6 a.m. and 6 p.m. At first a record was made of the wind velocity estimated by an adaptation of the Beaufort nautical scale for use on land. was decided to be an unnecessary refinement and was discon the only additional data recorded being the occurrence of h winds or tornadoes.

MARAMPA MINES - METEOROLOGICAL RECORDS.

MONTHLY AVERAGES.

MONTH.	MAXIMUM TEMPERATURE.	MINIMUM TEMPERATURE.	HUMIDITY (2 P.M.)
1933.			
August	80.5	74.5	89.6
September	84.1	75.6	92.6
October	86.2	75.2	88.5
November	84.7	75.7	80.1
December	86.3	74.0	76.8
1934.			
January	86.5	73.4	72.5
February	89.1	73.9	52.8
March	90.8	73.4	68.8
April	91.2	74.2	89.7
May	91.0	76.8	87.0
June	85.3	73.3	69.6
July	81.8	73.7	72.8
August	82.7	73.4	69.5
September	85.1	73.2	66.6
October	85.8	71.5	62.1
November	86.5	70.5	64.5
December	87.0	67.9	53.7
1935.			
January	88.4	65.0	49.3
February	90.9	68.7	46.9
March	94.4	68.1	40.3
April	94.6	72.5	50.0
May	88.9	71.6	74.8
June	85.4	71.6	70.5
July	85.4	70.5	63.5

Details of daily rainfall, maximum and minimum shade temperatures, and humidity from dry and wet bulb thermometers were kept at Marampa as a Company routine. The direction of the wind was recorded daily at 6 a.m. and 6 p.m. At first a record was made of the wind velocity estimated by an adaptation of the Beaufort nautical scale for use on land. This was decided to be an unnecessary refinement and was discontinued the only additional data recorded being the occurrence of high winds or tornadoes.

Figures for infective density: CHART No.8.

Month & Year.		European Camp.	Servants Quarters	Magbenkiti Village	Mafawki Village	Rochendata Village.
August 1933		.046	.171	-		
September 1933		.098	.803	-		
October	"	.015	.391	.113		
November	"	.014	.112	.092		
December	"	.013	.105	.031		
January	1934	.007	-	-		
April	"	Nil	Nil	.066		
May		.005	.155	.065		
June	"	.012	.111	.030		
July	"	.009	.269	.131	.094	.084
August	"	.004	.191	.181	.308	.340
September	"	.013	.201	.186	.219	.147
October	"	.001	.139	.047	.073	.019
November	"	Nil	.119	.083	.039	Nil
December	"	Nil	Nil	Nil	Nil	Nil
January	1935	.006	Nil	Nil	.013	.046
February	"	.013	.058	.125	.090	.120
March	"	.023	.102	.132	.069	.196
April	"	.007	.045	.050	.049	.068
May	"	.018	.024	.088	.169	.043

- ANNUAL RAINFALL -

	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	Average
BATKANU	131.97	111.07	96.64	97.68	113.23	121.36	107.71	145.40	118.03	107.71	114.6
Bo	124.58	117.19	114.77	100.42	135.32	123.24	108.40	No	Record		117.3
BONTHE	138.67	145.82	167.30	166.46	170.87	141.90	165.96	168.01	160.46	149.84	156.9
KABALA	92.00	92.07	85.82	89.90	98.82	78.29	81.05	88.27	103.52	95.91	90.1
MOYAMBA	114.03	114.51	91.53	101.66	140.37	122.55	123.35	112.21	89.11	82.89	107.8
NJALA	No	Record	106.55	107.22	139.50	108.16	128.07	109.80	115.04	115.08	114.6

- RELATIVE HUMIDITY - 1932 -

	January	February	March	April	May	June	July	August	September	October	November	December	Dry Season Average.	Wet Season Average
BATKANU	32.9	40.7	44.9	49.1	66.5	70.9	77.5	79.2	75.3	78.0	73.0	65.0	46.5	74.3
KABALA	47.3	60.1	58.5	64.7	62.8	69.4	79.6	82.0	79.3	79.0	73.0	58.0	57.7	75.0
MOYAMBA	No Record	63.9	61.7	68.4	74.0	75.0	80.9	79.6	80.1	75.7	72.2	No Rec.	64.7	76.8
NJALA	59.0	61.0	64.0	73.0	78.0	80.0	86.0	85.0	86.0	76.0	74.8	76.0	66.6	80.8

Note:- Records for BO and BONTHE not available.

- THERMOMETERS - 1932 - (Shade)

	January		February		March		April		May		June		July		August		Septemb.		October		November		Decr.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min
BATKANU	91.5	66.2	96.4	71.2	94.8	72.2	92.9	72.7	91.4	72.4	87.3	71.5	82.6	73.0	83.0	71.1	86.6	71.6	91.0	71.0	93.0	71.0	93.0	68.
KABALA	88.6	59.8	93.9	67.5	92.5	70.0	90.0	69.0	89.0	70.0	75.0	67.5	79.5	67.1	79.3	66.9	82.3	67.9	86.0	68.0	88.0	67.0	88.0	63.
MOYAMBA	No Record		93.2	68.7	92.2	71.9	95.0	59.0	89.1	71.0	87.8	71.8	82.2	70.3	81.6	70.3	84.4	70.7	88.3	71.0	90.2	71.7	No Record	
NJALA	91.0	64.0	95.0	70.0	95.0	72.0	92.0	71.0	91.0	71.0	88.0	71.0	83.0	71.0	82.0	71.0	85.0	71.0	90.0	72.0	92.7	71.4	91.0	69.

Note: Records for BO and BONTHE not available.

Month & Year.	European Camp.		Servant's Quart.		Mabbenkiti Village		Mafawki Village		Rochendata Village	
	Mosquito Room Index	Number of Rooms Searched	Mosquito Room Index	Number of Rooms Searched	Mosquito Room Index	Number of Rooms Searched	Mosqui. Room Index.	No. of Rms. Srchd.	Mos. Rm. Ind.	No. of Rms. Srchd.
1933										
Feby.	.31	72								
July	.56	32								
Aug.	1.11	251	6.0	4	1.3	20				
Sept.	.41	476	3.3	86	1.5	10				
Oct.	.18	685	1.9	82	.87	90				
Nov.	.14	936	1.7	117	.61	150				
Decr.	.13	1117	1.6	101	.65	220				
1934.										
Jan.	.09	960	1.2	59	.43	230				
Feb.	.10	417	1.2	34	.41	100				
March	.08	819	1.2	43	.39	160				
Apl.	.09	1150	1.2	76	.39	219				
May	.12	1196	1.3	79	.47	210				
June	.21	1043	1.9	38	.62	69				
July	.33	1242	3.8	70	1.9	85	2.2	85	1.6	60
Aug.	.27	460	5.3	18	4.3	35	5.4	30	6.8	66
Sept.	.08	576	1.4	125	1.2	133	1.5	110	.6	105
Oct.	.03	828	.83	120	.30	155	.42	130	.26	110
Nov.	.04	552	.81	90	.63	136	.30	111	.08	170
Dec.	.05	460	.60	90	.54	80	.53	75	.30	70
1935.										
Jan.	.09	474	.81	135	.50	140	.57	140	.55	135
Feb.	.22	850	1.03	140	.64	140	.85	140	1.91	120
March	.23	864	1.2	150	1.0	150	1.0	150	1.2	160
April	.26	610	1.89	160	1.13	265	1.05	240	1.06	150
May	.32	457	2.3	80	2.0	130	2.2	110	2.1	80

Above figures show the number of rooms searched monthly in the places under observation, with the ascertained monthly room index of A. costalis. CHART No. 2 based on the above figures.

ABSTRACT OF RESULTS OF DISSECTION

AND

WING GRADING OF MOSQUITOES.

Month and Year.		A. COSTALIS					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing Grade.				Total	Wing Grade.				Total	Wing Grade.				Total.
		1	2	3	4		1	2	3	4		1	2	3	4	
1933. Oct.	Number per grade	7	25	16	3	51			1		1					
	Number infected in stomach per grade.		3	4	1	8										
	" " in stomach & glands " "	1	1	3		5										
	" " " glands " "		4	1		5										
	" " with filaria " "		3	1		4										
Nov.	Number per grade.	4	19	12	2	37	1	2			3					
	Number infected in stomach per grade.		4			4	1				1					
	" " in stomach & glands " "			1		1					0					
	" " " glands " "		2	2		4		1			1					
	" " with filaria " "			1		1		1			1					
Dec.	Number per grade.	9	35	13	3	60	1	2	0	1	4	10	37	13	4	64
	Number infected in stomach per grade.	1	3			4						1	3			4
	" " in stomach & glands " "				1	1									1	1
	" " " glands " "		2	1	1	4							2	1	1	4
	" " with filaria " "		4	1		5							4	1		5
1934. Jan.	Number per grade.	1	3	4	2	10										
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
April	Number per grade		7	3		10			1		1		7	4		11
	Number infected in stomach per grade.		1			1							1			1
	" " in stomach & glands " "		-			-							-			-
	" " " glands " "		2			2							2			2
	" " with filaria " "					-										-

MAGBENKITI.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total.
1934. May.	Number per Grade.	5	19	12	2	38		1	1		2	5	20	13	2	40
	Number infected in stomach per grade.	3	2			5						3	2			5
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "	1	1	2	1	5						1	1	2	1	5
	" " with filaria " "		1	2		3							1	2		3
June	Number per grade.	34	40	27	7	108	2	2	4		8	36	42	31	7	116
	" infected in stomach per grade.	1	1	1		3						1	1	1		3
	" " in stomach & glands " "			2		2								2		2
	" " " glands " "		2	1	1	4							2	1	1	4
	" " with filaria " "	1				1						1				1
July	Number per grade.	75	82	28	1	186	1	1	2		4	76	83	30	1	190
	Number infected in stomach per grade.	1	6	3	1	11						1	6	3	1	11
	" " in stomach & glands " "	2	1			3						2	1			3
	" " " glands " "	2	8	1		11						2	8	1		11
	" " with filaria	2	3			5			1		1	2	3	1		6
Aug.	Number per grade.	57	54	6	1	118						57	54	6	1	118
	Number infected in stomach per grade.	1	1			2						1	1			2
	" " in stomach & glands " "					-										-
	" " " glands " "	1	3		1	5						1	3		1	5
	" " with filaria " "	2				2						2				2
Sept.	Number per grade.	57	28	10	2	97						57	28	10	2	97
	Number infected in stomach per grade.	3	5	1		9						3	5	1		9
	" " in stomach & glands " "	2	2	1	1	6						2	2	1	1	6
	" " " glands " "	4	4	1		9						4	4	1		9
	" " with filaria " "	1		1		2						1		1		2

MAGBENKITI.

Month and Year.		A. COSTALIS.					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing. Grade,				Total	Wing. Grade.				Total	Wing Grade.				~~Total~~.
		1	2	3	4		1	2	3	4		1	2	3	4	
Oct.	Number per grade	15	19	4		38						15	19	4		38
	Number infected in stomach per grade		2	1		3							2	1		3
	" " in stomach & glands " "		3			3							3			3
	" " " glands " "		1	2		3							1	2		3
	" " with filaria " "		2	2		4							2	2		4
Nov.	Number per grade	25	21	6	1	53						25	21	6	1	53
	Number infected in stomach per grade.	1	2	1		4						1	2	1		4
	" " in stomach & glands " "		2	1		3							2	1		3
	" " " glands " "		3	1		4							3	1		4
	" " with filaria		2			2							2			2
Dec.	Number per grade.	2				2						2				2
	Number infected in stomach per grade.					-										-
	" " in stomach & glands " "					-										-
	" " " glands " "					-										-
	" " with filaria					-										-
1935. Jan.	Number per grade.	22	13	4	3	42	5	1	1		7	27	14	5	3	49
	Number infected in stomach per grade.					-					-					-
	" " in stomach & glands " "					-					-					-
	" " " glands " "					-					-					-
	" " with filaria " "	1		1		2					-	1		1		2
Feb.	Number per grade.	19	17	4		40	1				1	20	17	4		41
	Number infected in stomach per grade.		3			3							3			3
	" " in stomach & glands " "					-										-
	" " " glands " "	3	4	1		8						3	4	1		8
	" " with filaria " "	1				1						1				1

MAGBENKITI.

Month and Year.		A. COSTALIS. Wing Grade 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1935. March	Number per grade.	36	16	11	1	64	2	2			4	38	18	11	1	68
	Number infected in stomach per grade.	1	1			2						1	1			2
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "	2	3	5		8						2	3	3		8
	" " with filaria " "	2	2	1		5	1				1	3	2	1		6
April	Number per grade.	74	42	7	1	124	1		2		3	75	42	9	1	127
	Number infected in stomach per grade.	3	2			5						3	2			5
	" " in stomach & glands " "	1		1		2						1		1		2
	" " " glands " "		3			3			1		1		3	1		4
	" " with filaria " "	1	2			3						1	2			3
May	Number per grade.	45	33	11		89		1	1		2					91
	Number infected in stomach per grade.		3	2		5										
	" " in stomach & glands " "					-										
	" " " glands " "		1	2		3			1		1					
	" " with filaria " "	2	2			4										

EUROPEAN CAMP.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1933. Aug.	Number per grade.	34	79	22	1	136	1		1		2	Add 35 A.Costalis				173
	Number infected in stomach per grade.		1	1		2	Both A.				Nil	wing grade unknown				3
	" " in stomach & glands " "		3			3	Squamosus.				"	with 1 infection				3
	" " " glands " "		2	2		4					"	in stomach and 1				5
	" " with filaria " "		3			3					"					3
Sept.	Number per grade.	Unknown.				76										76
	Number infected in stomach per grade.					5										5
	" " in stomach & glands " "					6										6
	" " " glands " "					13										13
	" " with filaria " "					4										4
Oct.	Number per grade.	18	27	3		48	1	1			2	Add, wing grades unknown, 1 A.				84
	Number infected in stomach per grade.	2		1		3						funestus not infected & 33 A.				5
	" " in stomach & glands " "	1	1			2						costalis with 2				2
	" " " glands " "		3			3						stomach, 2 glands &				5
	" " with filaria " "		2			2						3 filarial infections.				5
Nov.	Number per grade.	5	26	14	1	46										46
	Number infected in stomach per grade.	1	1	1	1	4										4
	" " in stomach & glands " "		1	1		2										2
	" " " glands " "		2	1		3										3
	" " with filarial		1			1										1
Dec.	Number per grade.	3	28	16	7	54	1			1	2	4	28	16	8	56
	Number infected in stomach per grade.		6		2	8							6		2	8
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "		4	1		5							4	1		5
	" " with filarial " "		1	1		2							1	1		2

EUROPEAN CAMP.

Month and Year.		A. COSTALIS.					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing grade.				Total	Wing Grade.				Total	Wing Grade.				Total
		1	2	3	4		1	2	3	4		1	2	3	4	
1934. Jan.	Number per grade.	2	5	2	3	12						2	5	2	3	12
	Number infected in stomach per grade.															
	" " in stomach & glands " "			1		1								1		1
	" " " glands " "															
	" " with filaria " "															
April	Number per grade.		2		1	3	1	1	4		6	1	3	4	1	9
	Number infected in stomach per grade.				1										1	1
	" " in stomach & glands " "															
	" " " glands " "								1					1		1
	" " with filaria " "								2					2		2
May	Number per grade.	4	24	17	2	47			1		1	4	24	18	2	48
	Number infected in stomach per grade.		1	2		3							1	2		3
	" " in stomach & glands " "															
	" " " glands " "			2		2								2		2
	" " with filaria " "			1		1								1		1
June	Number per grade.	18	43	14		75	3		1		4	21	43	15		79
	Number infected in stomach per grade.	1	2	2		5	1				1	2	2	2		6
	" " in stomach & glands " "		1	1		2							1	1		2
	" " " glands " "		2	-		2			1		1		2	1		3
	" " with filaria " "															
July	Number per grade.	139	58	16	1	214		1			1	139	59	16	1	215
	Number infected in stomach per grade.	9	2	2		13						9	2	2		13
	" " in stomach & glands " "			1		1								1		1
	" " " glands " "	2	3			5						2	3			5
	" " with filaria	2	3			5						2	3			5

EUROPEAN CAMP.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1934. Aug.	Number per grade.	97	29	5	1	132	1	1			2	98	30	5	1	134
	Number infected in stomach per grade.	5	2			7						5	2			7
	" " in stomach & glands " "															
	" " " glands " "		2			2							2			2
	" " with filaria " "		1			1							1			1
Sept.	Number per grade.	22	19	2		43	1				1					44
	Number infected in stomach per grade.	1	2			3						1	2			3
	" " in stomach & glands " "		2	1		3							2	1		3
	" " " glands " "	1	3			4						1	3			4
	" " with filaria " "			1		1								1		1
Oct.	Number per grade.	15	7	1		23	1 This was an A. Squamosus.				1	16	7	1		24
	Number infected in stomach per grade.	1	2			3						1	2			3
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "															
	" " with filaria " "	2	1			3						2	1			3
Nov.	Number per grade.	6		2		8						6		2		8
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
Dec.	Number per grade.	2	1			3	1				1					
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															

EUROPEAN CAMP.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1935. Jan.	Number per grade.	24	15	5		44	1		1		2	25	15	6		46
	Number infected in stomach per grade.															
	" " in stomach & glands " "			1		1								1		1
	" " " glands " "		1	1		2							1	1		2
	" " with filaria " "	1				1						1				1
Feb.	Number per grade.	44	27	9	3	83	2	1	2		5	46	28	11	3	88
	Number infected in stomach per grade.	1	1	2	1	5						1	1	2	1	5
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "	1	1		1	3			1		1	1	1	1	1	4
	" " with filaria " "			1	1	2								1	1	2
March	Number per grade.	63	22	11		96	5				5	68	22	11		101
	Number infected in stomach per grade.	1	2			3						1	2			3
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "	3	3	3		9						3	3	3		9
	" " with filaria " "	3				3						3				3
April	Number per grade.	60	18			78	3				3	63	18			81
	Number infected in stomach per grade.	3	1			4						3	1			4
	" " in stomach & glands " "						1				1	1				1
	" " " glands " "	1	1			2						1	1			2
	" " with filaria " "		2			2							2			2
May	Number per grade.	13	4			17	2				2					
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															

MAKAWKI.

Month and Year.		A. COSTALIS. Wing Grade 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1934. June	Number per grade.	23	20	20	2	65	1		1		2	24	20	21	2	67
	Number infected in stomach per grade.	1	3	3		7						1	3	3		7
	" " in stomach & glands " "	1				1						1				1
	" " " glands " "	1	1	2		4						1	1	2		4
	" " with filaria " "		1	2		3							1	2		3
July	Number per grade.	62	45	24	4	135	1		1		2	63	45	25	4	137
	Number infected in stomach per grade.		3	1	1	5							3	1	1	5
	" " in stomach & glands " "		1	1		2							1	1		2
	" " " glands " "		4			4							4			4
	" " with filaria " "		2			2							2			2
Aug.	Number per grade.	71	60	8	1	140						71	60	8	1	
	Number infected in stomach per grade.	1	7	2	1	11						1	7	2	1	
	" " in stomach & glands " "	1	2			3						1	2			
	" " " glands " "	3	1	1		5						3	1	1		
	" " with filaria " "		3			3							3			
Sept.	Number per grade.	50	84	10		144						50	84	10		144
	Number infected in stomach per grade.	2	16			18						2	16			18
	" " in stomach & glands " "	2	3	1		6						2	3	1		6
	" " " glands " "	2	9	4		15						2	9	4		15
	" " with filaria " "	1	3			4						1	3			4
Oct.	Number per grade.	16	23	7		46						16	23	7		46
	Number infected in stomach per grade.	1		1		2						1		1		2
	" " in stomach & glands " "	1	1			2						1	1			2
	" " " glands " "		5	1		6							5	1		6
	" " with filaria " "															

MAFAWKI.

Month. and Year.		A. COSTALIS.					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing Grade.				Total	Wing Grade.				Total	Wing Grade.				Total
		1	2	3	4		1	2	3	4		1	2	3	4	
1934. Nov.	Number per grade.	4	13	5		22			1		1	4	13	6		23
	Number infected in stomach per grade.															
	" " stomach & glands " "		1			1							1			1
	" " in Glands " "		1	1		2							1	1		2
	" " with filaria " "															
Dec.	Number per grade.	4	1			5	1				1	5	1			6
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
1935. Jan.	Number per grade.	25	9	7	1	42	1	3			4	26	12	7	1	46
	Number infected in stomach per grade.			1		1								1		1
	" " in stomach & glands " "															
	" " " glands " "			1		1								1		1
	" " with filaria " "			2		2								2		2
Feb.	Number per grade.	18	18	6	2	44	2		1		3	20	18	7	2	47
	Number infected in stomach per grade.	1	2			3						1	2			3
	" " in stomach & glands " "		2	1		3							2	1		3
	" " " glands " "	1		1		2						1		1		2
	" " with filaria " "		1			1							1			1
March	Number per grade.	29	25	15		69	1	1	1		3	30	26	16		72
	Number infected in stomach per grade.	1	1			2						1	1			2
	" " in stomach & glands " "			1										1		1
	" " " glands " "		1	3		4							1	3		4
	" " with filaria " "			1		1								1		1

MAFAWKI.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1935. April	Number per grade.	46	34	5	4	89	1	1	1		3	47	35	6	4	92
	Number infected in stomach per grade	1	2	1		4						1	2	1		4
	" " in stomach & glands " "		1	1		2							1	1		2
	" " " glands " "		1	1	1	3							1	1	1	3
	" " with filaria " "	1	3			4						1	3			4
May	Number per grade.	33	25	6		64			1		1					
	Number infected in stomach per grade		1	2		3										
	" " in stomach & glands " "															
	" " " glands " "	1	3			4			1		1					
	" " with filaria " "	2	3			5										

ROCHENDATA.

Month and Year.		A. COSTALIS.					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing Grade.				Total	Wing Grade.				Total	Wing Grade.				Total
		1	2	3	4		1	2	3	4		1	2	3	4	
1934. June	Number per grade.	35	18			53	13	5	2		20	48	23	2		73
	Number infected in stomach per grade.	2	1			3	2	1	1		4	4	2	1		7
	" " in stomach & glands " "	1	1			2						1	1			2
	" " " glands " "	2	2			4	1		1		2	3	2	1		6
	" " with filaria " "	1				1	1				1	2				2
July	Number per grade.	93	50	18		161	1	1	2		4	94	51	20		165
	Number infected in stomach per grade.	4	3	3		10						4	3	3		10
	" " in stomach & glands " "		2			2							2			2
	" " " glands " "	2	2	1		5						2	2	1		5
	" " with filaria		1	1		2							1	1		2
Aug.	Number per grade.	39	39	3	1	82						39	39	3	1	82
	Number infected in stomach per grade.		4			4							4			4
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "		3			3							3			3
	" " with filaria " "		1			1							1			1
Sept.	Number per grade.	27	22	4		53						27	22	4		53
	Number infected in stomach per grade.	1	3			4						1	3			4
	" " in stomach & glands " "		2			2							2			2
	" " " glands " "	5	5	1		11						5	5	1		11
	" " with filaria " "	1	2			3						1	2			3
Oct.	Number per grade.	13	9	4		26	1				1	14	9	4		27
	" infected in stomach per grade.	3	2			5	1				1	4	2			6
	" " in stomach & glands " "															
	" " " glands " "		2			2							2			2
	" " with filaria " "		1			1							1			1

ROCHENDATA.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1934. Nov.	Number per grade.	3				3						3				3
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
Dec.	Number per grade.	2				2						2				2
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
1935. Jan.	Number per grade.	12	16	10	5	43	2	3			5	14	19	10	5	48
	Number infected in stomach per grade.						1				1	1				1
	" " in stomach & glands " "				1	1									1	1
	" " " glands " "		1	1	1	3							1	1	1	3
	" " with filaria " "	1		1		2						1		1		2
Feb.	Number per grade.	23	23	15	3	64	2	2			4	25	25	15	3	68
	Number infected in stomach per grade.	1	3	2		6						1	3	2		6
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "	2		3	3	8						2		3	3	8
	" " with filaria			1		1								1		1
March	Number per grade.	33	38	27	4	102	2				2	35	38	27	4	104
	Number infected in stomach per grade.	2		2		4						2		2		4
	" " in stomach & glands " "	1		1		2						1		1		2
	" " " glands " "		7	5	3	15							7	5	3	15
	" " with filaria " "	1	5	3		9						1	5	3		9

ROCHENDATA.

Month and Year.		A. COSTALIS.					A. FUNESTUS ETC.					ALL SPECIES.				
		Wing Grade.				Total	Wing Grade.				Total.	Wing Grade.				Total
		1	2	3	4		1	2	3	4		1	2	3	4	
1935. April	Number per grade.	34	27	11	1	73	1				1	35	27	11	1	74
	Number infected in stomach per grade.															
	" " in glands & stomach " "		2			2							2			2
	" " " glands " "		1	2		3							1	2		3
	" " with filaria " "		2	1		3							2	1		3
May	Number per grade.	9	26	12		47										
	Number infected in stomach per grade.		1			1										
	" " in stomach & glands " "			1		1										
	" " " glands " "															
	" " with filaria " "		1	1		2										

SERVANTS' QUARTERS.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1933. Aug.	Number per grade.	1	4	5		10						Add 23 A.Costalis with 1 infection of stomach & 1 fection of glands.				33
	Number infected in stomach per grade.															1
	" " in stomach & glands " "															
	" " " glands " "															1
	" " with filaria.															
Sept.	Number per grade.		1	2	1	4						Add 91 A.costalis wing grade unknown with 8 infections in stomach, 9 in stomach & glands 13 in glands, and 2 filarial infections.				95
	Number infected in stomach per grade.		1			1										9
	" " in stomach & glands " "				1	1										10
	" " " glands " "			1		1										14
	" " with filaria " "															2
Oct.	Number per grade.	21	59	27	6	113		3		1	4	Add 11 A.costalis with 2 infections of stomach & glands and 1 filarial in-infection; & 1 A. funestus, not infected.				129
	Number infected in stomach per grade	1	2	3		6		1			1					7
	" " in stomach & glands " "	1	3	4	1	9		1			1					12
	" " " glands " "		8	8		16										16
	" " with filaria " "		2			2										3
Nov.	Number per grade.	10	50	34	3	97		2		1	3	10	52	34	4	100
	Number infected in stomach per grade.	1	6	2		9						1	6	2		9
	" " in stomach & glands " "															
	" " " glands " "		1	5	1	7							1	5	1	7
	" " with filaria " "			1		1		1			1		1	1		2
Dec.	Number per grade.		27	12	14	53		3	1		4		30	13	14	57
	Number infected in stomach per grade.				4	4									4	4
	" " in stomach & glands " "															
	" " " glands " "		2	1	1	4		1			1		3	1	1	4
	" " with filaria " "		1	1		2							1	1		2

SERVANTS' QUARTERS.

Month and Year.		A. COSTALIS. Wing Grade.					A. FUNESTUS ETC. Wing Grade.					ALL SPECIES. Wing Grade.				
		1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
1934. Jan.	Number per grade.		1		3	4										
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria.															
April	Number per grade.		2	3		5							2	3		5
	Number infected in stomach per grade.			1		1								1		1
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "															
May	Number per grade.	2	14	12	3	31				1	1	2	14	12	4	32
	Number infected in stomach per grade.		1	1		2							1	1		2
	" " in stomach & glands " "			1		1								1		1
	" " " glands " "		2	1		3							2	1		3
	" " with filaria " "		1			1							1			1
June	Number per grade.	44	40	22		106	1	1	1	1	4	45	41	23	1	110
	Number infected in stomach per grade.	2	4	1		7						2	4	1		7
	" " in stomach & glands " "	2				2						2				2
	" " " glands " "	1	3	1		5						1	3	1		5
	" " with filaria " "	1		1		2						1		1		2
July	Number per grade.	65	58	25	10	158	1		1	1	3	66	58	26	11	161
	Number infected in stomach per grade.	1	4	2		7						1	4	2		7
	" " in stomach & glands " "	2			1	3						2			1	3
	" " " glands " "	5	2	2		9						5	2	2		9
	" " with filaria " "	2	1	2		5						2	1	2		5

SERVANTS' QUARTERS.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1934. Aug.	Number per grade.	39	43	1		83						39	43	1		83
	Number infected in stomach per grade.	1	3	1		5						1	3	1		5
	" " in stomach & glands " "															
	" " " glands " "		3			3							3			3
	" " with filaria " "		2			2							2			2
Sept.	Number per grade.	40	88	8		136						40	88	8		136
	" infected in stomach per grade.	7	6	3		16						7	6	3		16
	" " in stomach & glands " "		6	1		7							6	1		7
	" " " glands " "	1	11	1		13						1	11	1		13
	" " with filaria " "															
Oct.	Number per grade.	31	52	12	1	96						31	52	12	1	96
	Number infected in stomach per grade.	1	7			8						1	7			8
	" " in stomach & glands " "		3	1		4							3	1		4
	" " " glands " "	3	4	4	1	12						3	4	4	1	12
	" " with filaria " "	1	2	2		5						1	2	2		5
Nov.	Number per grade.	14	46	7	1	68						14	46	7	1	68
	Number infected in stomach per grade.	1	4			5						1	4			5
	" " in stomach & glands " "		2			2							2			2
	" " " glands " "	1	5	2		8						1	5	2		8
	" " with filaria " "		2	1		3							2	1		3
Dec.	Number per grade.	1	8	2		11	3	1			4	4	9	2		15
	Number infected in stomach per grade.															
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "		1			1							1			1

SERVANTS' QUARTERS.

Month and Year.		A. COSTALIS. Wing Grade. 1	2	3	4	Total	A. FUNESTUS ETC. Wing Grade. 1	2	3	4	Total	ALL SPECIES. Wing Grade. 1	2	3	4	Total
1935. Jan.	Number per grade.	21	16	5	3	45	8	1	1		10	29	17	6	3	55
	Number infected in stomach per grade.		3			3			1		1		3	1		4
	" " in stomach & glands " "															
	" " " glands " "															
	" " with filaria " "			1		1								1		
Feb.	Number per grade.	28	30	8	2	68	2	1			3	30	31	8	2	71
	Number infected in stomach per grade.		3			3							3			3
	" " in stomach & glands " "															
	" " " glands " "		3		1	4							3		1	4
	" " with filaria " "			1		1								1		1
March	Number per grade.	23	35	17	1	76	3	1	2		6	26	36	19	1	82
	Number infected in stomach per grade.		1			1							1			1
	" " in stomach & glands " "		1			1							1			1
	" " " glands " "		3	2	1	6							3	2	1	6
	" " with filaria " "															
April	Number per grade.	50	19	5	2	76	3	1			4	53	20	5	2	80
	Number infected in stomach per grade.	2	1			3						2	1			3
	" " in stomach & glands " "				1	1									1	1
	" " " glands " "				1	1									1	1
	" " with filaria " "		1		1	2							1		1	2
May	Number per grade.	31	12	3		46		1			1					
	Number infected in stomach per grade.	2				2										
	" " in stomach & glands " "															
	" " " glands " "		1			1										
	" " with filaria " "															

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