PLAGUE CONDITIONS IN A RURAL ENDEMIC AREA OF KENYA (KERUGUYA DISTRICT, KIKUYU PROVINCE)

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(With 1 Figure in the text)

CONTENTS

I. Introduction

Plague occurs regularly in the Keruguya district, and for the past 10 years, since knowledge of the area has been available, not a month has passed without the disease being reported in either man or rats. Valuable information as to the conditions existing in this highly endemic area is furnished in the reports of administrative and medical officers who have been stationed there.

For 1930 and 1931 it is stated that:

Owing to the fertile nature of this area, the majority of the inhabitants are very prosperous, taxes are easily paid and every one has more than enough leisure to indulge in litigation, dances or drinking, according to their respective tastes.... From an agricultural point of view, the area is extremely prosperous. The soil, especially in the centre and high locations, is very rich and fertile, so that the natives who are keen agriculturists are able to produce good crops with the minimum of trouble.

The upper and main portion of the Keruguya area is fertile, well watered, and there is ample rainfall. Food is therefore plentiful, but the diet is ill-balanced. The standard of living of the inhabitants is low. It is the practice to graze many, or from some locations most, of the cattle in the lower country for the greater part of the year. As a rule cattle are not employed for dairying or slaughter. There is a shortage of milk for consumption except in the grazing area. Meat does not figure to a great extent in the diet.

The villages compare unfavourably with those in many other districts. The huts are of a very primitive type, the walls are low and the untrimmed thatch hangs down often touching the ground. Light and ventilation are absent. Grass and weeds and other growth extend to the walls of the dwellings, often concealing them to the passer-by. There is no attempt to keep an open space around the huts, or even, in some cases, between buildings. Refuse of all sorts lies strewn about usually. Latrines are non-existent.

Such is the condition of the native population of the main endemic plague area of Kenya.

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II. Topography

The Keruguya district is situated among the southern foothills of Mount Kenya, at an altitude ranging from 4200 to 5200 ft. above sea-level, at lat. 0·31° S., long. 37·20° E. It consists of a series of valleys running southwards from the mountain.

The heaviest rainfall in the Mount Kenya region falls on the southern and eastern slopes and is brought about by the south-east wind which blows most of the year. It is generally acknowledged that in the past forests on the rainy sides of the mountain covered a much greater area than they do to-day and extended down to the edge of the savannah country bordering the valley of the river Tana.

The Kikuyu cultivator has, however, gradually changed the topography of this region by his methods of shifting agriculture and has been the main cause of forest destruction. He is entirely ignorant of methods of improvement or conservation of fertility in his soils, and each year unless placed under restraint will destroy forest land in order to obtain virgin soil for his crops. The idea of preserving forest land to supply his own needs in timber and firewood is novel to him, likewise the importance of forests in regulating climatic factors.

These forest soils are remarkably fertile, and coupled with an ample and regular rainfall give ideal growing conditions to many crops. Also, perennial streams flow down from the mountain, so that most of the area is well watered.

III. Climate and local conditions

Rainfall being the only climatic factor known for the area, it is proposed to deal with its incidence and relationship to the seasonal rhythms of occupation of the people, seasonal conditions for crops and domestic animals and its effects upon these.

The average number of days on which rain fell and the average rainfall for Keruguya, Embu and Fort Hall, is given in Table I.

Table I

	Keruguya				Embu			Fort Hall		
	Average rainfall over 7 years in.	Average No. of rainy days over 7 years			Average rainfall over 26 years in.	Average no. of rainy days over 5 years		Average rainfall over 33 years in.	Average no. of rainy days over 5 years	
Jan.	1·74	7	Reaping	11	1·07	4	6	1·39	4	7
Feb.	0·52	4	millets		0·87	2		1·62	3	
Mar.	4·39	9			4·43	9		5·17	10	
Apr.	9·14	14	Maize planting		10·48	17		11·96	17	
May	11·66	21	and growing	73	5·67	15	53	6·29	14	51
June	1·60	15	season		1·51	5		1·59	5	
July	1·54	14			1·01	7		0·85	5	
Aug.	2·68	14	Maize	21	1·10	11	17	0·88	8	13
Sept.	2·50	7	reaping		0·89	6		1·09	5	
Oct.	6·72	12	Millet planting		4·60	11		4·69	12	
Nov.	8·68	15	and growing	39	7·64	16	37	7·26	16	38
Dec.	2·55	12	season		2·18	10		2·97	10	
	53·22	144 days			41·45	113 days		45·16	109 days	

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Throughout the various reports dealing with administrative or medical work in the area attention is invariably directed to the rainfall of the year and its effects. The report for 1930 states: "Perhaps the most remarkable feature of 1930 has been the heavy rainfall which amounted to very nearly 60 inches during the year, and the fact that the short rains were quite as heavy as the long rains. Bumper crops were obtained after the September harvest, but it is feared that the abnormal character of the short rains may have an injurious effect on the forthcoming harvest." It is stated that "The long rains of 1932 were plentiful and a bumper crop of maize resulted. Old men state they had not seen such a crop since Mr Wade's time. The short rains have been good and the millet crop stands out well throughout the district."

Rainfall has a seasonal distribution over two definite seasons, the short rains which commence in October mark the opening of one planting season, mainly millets, and the long rains commencing in March cover the main planting season for maize. Through this seasonal distribution of rainfall there is a very marked seasonal rhythm in most walks of life, such as in the daily avocations, feeding, dancing and drinking, which in turn exert a strong influence on the health, growth and recurrence of the sexual cycle in the human and animal populations.

Table II gives the rainfall figures for the maize and millet planting and growing seasons at Keruguya with those for two adjacent areas where plague only occurs sporadically.

Table II

	Keruguya		Embu		Fort Hall	
	Total rainfall in.	No. of rainy days	Total rainfall in.	No. of rainy days	Total rainfall in.	No. of rainy days
Maize season (March to August)	28·33	73	23·10	53	25·86	51
Mwele season (October to December)	17·95	39	14·42	37	14·92	38

Although many interesting meteorological data for the area are lacking, the little evidence that is available indicates some relationship between the rate of precipitation and the incidence of plague. This relationship is reflected in heavy production of foodstuffs and consequent wastage, which allow a much denser population of rats and human beings to be carried than is normally encountered.

During the period of the present survey it is known that good crops of maize and mwele were reaped, but much less than in seasons such as 1932 when 59·95 in. of rain fell and the two previous seasons 1930 and 1931 with 52·99 and 66·97 in. respectively. Table III gives the monthly rainfall and the incidence of the disease.

The early planted maize was reaped in June, so that throughout June, July and August the granaries would be full and plague increased at that period.

The inhabitants have been compelled to observe for themselves the natural signs which mark the times for various operations in agriculture so that their occupational rhythms are shaped to the incidence of rainfall. A year of heavy rainfall would thus see them planting and reaping maize almost continuously throughout the year, but seasons as recorded in Table III, when rainfall was less generally distributed, would find them planting and reaping only two main crops.

Table III

	Rainfall in.	No. of rainy days	Plague cases Rat	Plague cases Human	
1934, Sept.	0·280	1	14	7	Maize reaping and storage
Oct.	9·740	11	11	5	Mwele planting
Nov.	4·460	8	10	3	Growing season
Dec.	5·310	12	9	2	
1935, Jan.	—	—	2	—	Mwele reaping and storage
Feb.	4·465	11	3	—	Maize planting
Mar.	1·730	7	8	2	
Apr.	4·880	16	3	—	Growing season
May	10·195	18	7	9	
June	1·660	9	26	1	Early and main maize reaping
July	0·705	4	27	20	
Aug.	2·985	8	19	11	
	46·410	105	139	60	

Habitations

The native villages in the Keruguya district are small, the largest consisting of only about ten living huts. Each of these huts represents a wife of the owner and she has, in addition, three or four grain stores. Some of the villages are surrounded by a thorn fence, others not, and grass and weeds grow close up to the huts.

Most of the circular walls of the huts are built of poles and twigs interlaced for support, and both surfaces are plastered over with a mixture of mud and dung. The hut is covered with a thatch which consists of first, a layer of banana leaves over the roof framework, then a layer of bracken about 6–9 in. thick. Over this grass is piled, until a very thick and dense thatch is formed, which in some instances is about 24 in. deep. The people take no pride in their dwelling places and in most instances continue to add more grass for rain-proofing purposes until the thatch often touches the ground. The area between the bracken and grass forms the nesting and living places of *Rattus rattus* from which the rats sally forth on foraging expeditions to the grain stores during the night.

The huts are usually divided into two parts by wooden stakes, one side of the hut forming a pen for goats or sheep, and the other half the living quarters of the family. The goat pen is sunken and sodden with large quantities of garbage and litter. In the living quarters beds are made by partitioning off portions of the hut with wooden stakes, and this space is filled with twigs and bracken. When first laid down the beds are only a foot high, but constant addition of bracken increases the bulk and weight. Sometimes these beds have been found to harbour large numbers of rats.

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Clothing

The women of the Keruguya district form the conservative element in the matter of customs, and they adhere to the traditional goat-skin dress of the Kikuyu.

In connexion with clothing, the habit of copiously anointing the body and hair with a mixture of red earth and castor oil should be mentioned. The womenfolk, particularly the younger ones who attend dances, are far more addicted to this habit than the men, who have taken a strong fancy to combs and safety pins to decorate the hair, and this new departure in decoration does not allow of any greasing to be performed.

The ancient and primitive habit of anointing the body with castor oil possibly arose from knowledge that the oil repels certain insects, particularly fleas. Plague shows a slightly higher incidence among males, and the substitution of soap and water for oil, and cotton blankets for skins, may have disadvantages in this community.

Domestic animals

The Ndia and Kichugu people graze most of their cattle in the low country. This area is held as a communal grazing ground, and in the high country, which is devoted to agriculture, very few cattle are to be seen. No attempt appears to be made in dairying, neither are the cattle slaughtered for meat. They appear to be held merely as a sign of wealth to be used chiefly in relation to marriage security, and should they die, then as a source of hides and meat.

It is the duty of the male members of the tribe to look after the cattle and small stock, and, although in most parts their numbers do not appear excessive, goats give rise to a considerable amount of litigation on the part of the elders. They are not slaughtered for consumption except on sacrificial occasions, their main use being also in connexion with marriage security.

Origin of the Ndia and Kichugu people

The majority of the present inhabitants are descendants of immigrants into the area and they generally trace their descent to the Mkamba tribe, but as they stand to-day they undoubtedly represent a fusion of members of several tribes and even races. Intermarriage, and penetration by individuals seeking a haven of rest and plenty in this "garden of Kenya", have produced a composite type. As the area is one of enormous fertility and never known to have suffered a famine, people from even distant places stream in during bad times elsewhere and some eventually settle at Keruguya.

An instance of this penetration is quoted from the report of the Commissioner for South Nyeri, who states in regard to 1934: "The year opened in the most distressing fashion possible. The drought of 1932 and the complete failure of the long rains of 1933 had absorbed all the savings of the South Nyeri natives, and in certain areas, the locations of Chiefs Mathenge, Njairia, Gachenja and Njakais in particular, famine conditions existed. Parties of natives could be seen daily making for the more fortunate areas of Ndia and Kichugu in Embu district hoping, either by barter of stock or pledges of future payment, to obtain sufficient food to tide over the crisis."

The Wakamba, who represent the main parent stock, live mainly on cereals, but eat more millet than maize, and add milk to their porridge, but their diet varies with the crops in season. They are also fond of meat. Many of the original immigrants were at least people accustomed to a varied dietary with additions of milk and meat, an important point to be remembered when considering present-day standards.

Food

The Keruguya dietary to-day is monotonous and inadequate, mainly carbohydrate in composition with little or no protein, with a large intake as food is plentiful. The morning, midday and evening meals are fundamentally similar. "Uji", maize flour boiled in water, is widely used, but for the evening they prepare a meal by boiling whole maize grains, to which may be added potatoes, green vegetables, soda and salt, as available in the season. This is boiled with little water and pounded into a sticky mass, and any left over is eaten cold the following day.

Within recent years, owing to a drought in the neighbouring Ukamba country and failure of their crops, the Wakamba have been trading freely in the Keruguya district and barter their cattle for maize and mwele. These Kamba cattle succumb readily to various diseases in the cold and humid conditions at Keruguya, and they can only be used as slaughter cattle. The barter started about 1931, and nowadays it is quite a common sight to see twenty or more carcases for sale in native markets. A goat sells for two to three shillings and oxen from twenty-five to thirty shillings, and the people come with small amounts of cereals in exchange for meat.

There has always existed a desire for meat, as they have a word "kuthuti" which means "to have a longing for meat", but for some obscure reason they would not sacrifice their own herds or cereal stores in the past to satisfy this desire.

General

The Ndia and Kichugu people still hold the greater part of their maize in store, and the little that is sold or bartered only represents the immediate need of obtaining money for payment of taxes, or to buy some coveted article. In most years when large crops have been reaped and they are anxious to dispose of the surplus, the profits obtained are small, due partly to the cost of transport to the railhead, and partly to the fact that most of the maize is of poor quality and often damp and dirty and in an unmarketable condition. On the whole the people may be regarded as leading a life identical with that practised by their forefathers for generations back. Their primitive instincts guide them to hoard what is already guaranteed to them in the fertility of their land, possibly through fear of failure of the next season's crop and through the still lingering fear of raids by their stronger brethren. Consequently large stocks of maize are kept continuously in rat-infested structures in all their villages.

IV. HUMAN POPULATION FIGURES

The 1934 count of human population in the districts is given in Table IV.

Table IV

	Adults		Children		Total	
	♂♂	♀♀	♂♂	♀♀		
Ndia: 11 locations	11,071	19,417	10,509	9,863	50,860	80,193
Kichugu: 8 locations	6,089	9,915	6,176	6,653	29,333	
Embu: 9 locations	9,037	13,230	7,943	8,717	38,927	60,150
Mberre: 3 locations	5,454	7,584	4,121	4,064	21,223	

The main concentration of the population is in the Ndia and Kichugu areas, and the accompanying Maps (Fig. 1), illustrating crop-growing and cattle-grazing districts, show concentration in the agricultural parts.

V. HUMAN AND RAT PLAGUE

The reported cases both in man and rat (Table V) represent only those from which blood smears were obtained and confirmation obtained microscopically, no reliance being placed on verbal reports from the native population. Such figures do not give a true representation of the actual incidence of the disease throughout the area, but, in the absence of a complete record, the microscopically positive figures furnish a guide to the endemic nature of the disease and its periodicity.

Table V

Cases in man, 1929–33

Year	Cases	Deaths
1929	76	46
1930	108	101
1931	188	144
1932	156	110
1933	117	73

Cases in man and rat, 1934

	1934		
		Plague	
Month	Rainfall in.	Human	Rat
Jan.	?	13	19
Feb.	?	4	11
Mar.	1·545	3	8
Apr.	9·596	1	1
May	12·820	2	1
June	3·890	6	7
July	3·240	2	8
Aug.	3·185	6	9
Sept.	0·280	7	14
Oct.	9·740	5	11
Nov.	4·460	3	10
Dec.	5·310	2	9
		54	108

Rat mortality was reported from seventeen out of the nineteen locations in the Ndia and Kichugu areas during 1934, but only a few show a heavy incidence.

Table VI. *Number of times plague was reported in main endemic locations*

	1933		1934	
	Human	Rodent	Human	Rodent
Kagai	7	7	11	24
Mugera	9	7	7	20
Kurugu	9	7	3	10
Njiritu	13	12	11	9
Johanna	6	13	3	9

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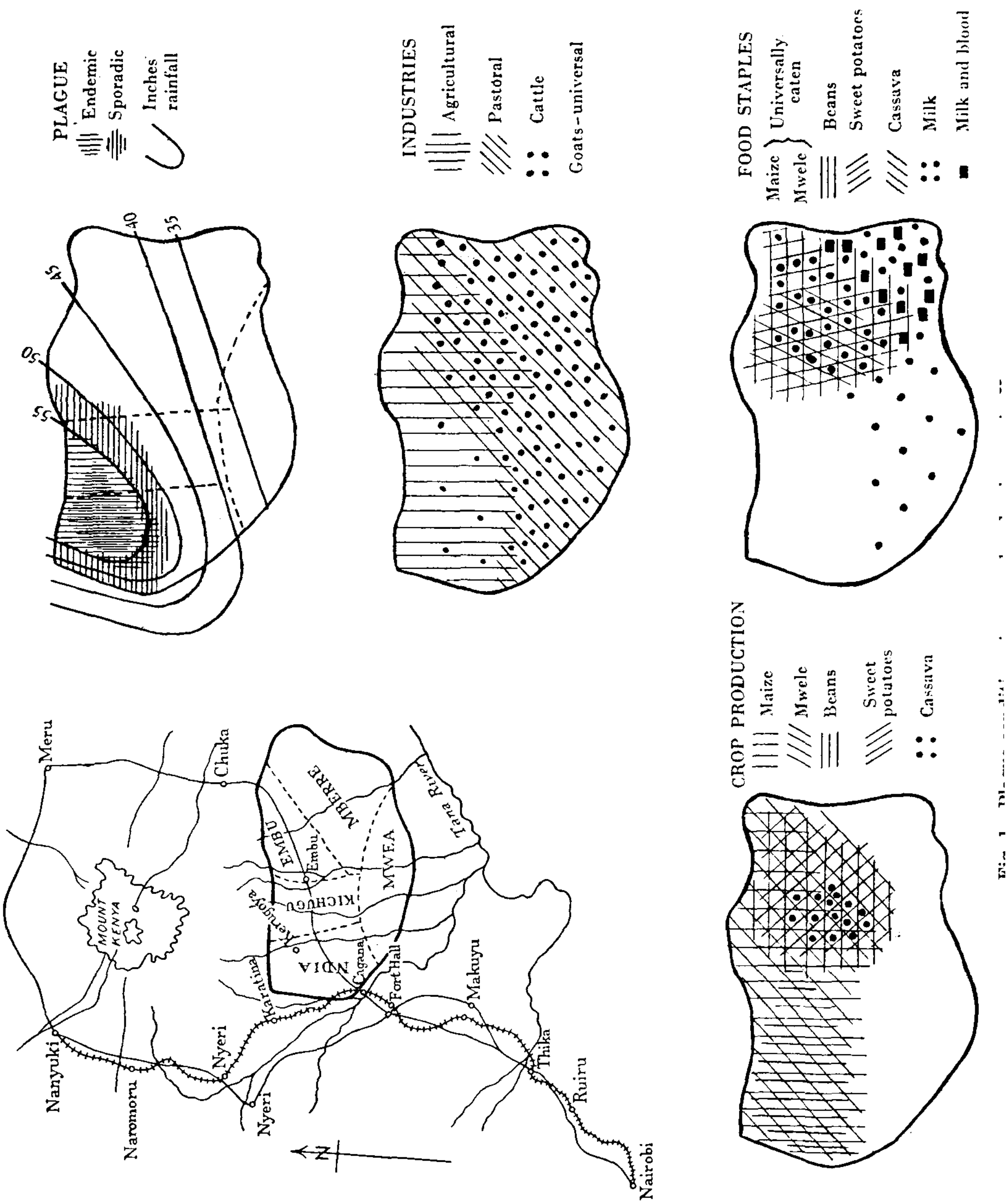

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During the years 1932, 1933 and 1934, intervals of 7, 8 and 14 weeks elapsed respectively wherein no rat mortality was notified.

During the present survey the position was as shown in Table VII.

Table VII

	Plague Rat	Plague Man	Rainfall in.	No. of rainy days	No. of *Rattus* caught	*X. brasiliensis* index	
1934, Sept.	14	7	0·280	1	334	3·0	Maize reaping
Oct.	11	5	9·740	11	327	2·2	Mwele planting
Nov.	10	3	4·460	8	398	1·5	Growing season
Dec.	9	2	5·310	12	501	1·9	
1935, Jan.	2	—	—	—	625	1·8	Mwele reaping
Feb.	3	—	4·465	11	734	1·7	Maize planting
Mar.	8	2	1·730	7	640	2·4	
Apr.	3	—	4·880	16	538	2·6	Growing season
May	7	9	10·195	18	726	3·9	
June	26	1	1·660	9	718	3·9	
July	27	20	0·705	4	650	2·2	Early and main maize reaping
Aug.	19	11	2·985	8	592	3·7	
	139	60	46·410	105	6915	2·6	

The higher incidence of plague followed the reaping and storage of maize in the two seasons 1934 and 1935. Rat-trapping figures had been increasing for some time prior to the rise in plague incidence, the flea index being highest during the outbreak.

VI. Rat and flea survey in domestic premises

A. During 1931 and 1932 a small survey of the rat and flea fauna in the Keruguya district was carried out in domestic premises and in the field with the results shown below.

Rattus rattus. 438 ♂♂ and 522 ♀♀ were trapped.

199 were pregnant. Percentage pregnancy = 38 per cent.

1419 embryos were counted, giving an average of 7·1 per pregnant female.

Fleas. 302 ♂ rats were infested, a percentage of 68·9 per cent.

344 ♀ rats were infested, a percentage of 65·9 per cent.

1071 ♂ and 790 ♀ *X. brasiliensis* were taken, an average of 1·9 per rat.

61 per cent. of the total *Rattus* trapped were infested with this species.

Also 1 ♂ *X. cheopis.* 24 ♂, 26 ♀ *Ct. cabirus.*
26 ♂, 418 ♀ *E. gallinaceus.* 2 ♂, 2 ♀ *D. lypusus.*
7 ♂, 3 ♀ *Ct. felis.* 1 ♂, 1 ♀ *S. tortus.*
1 ♀ *L. segnis.*

Otomys angoniensis. 16 ♂♂ and 31 ♀♀ = 47. 1 ♀ pregnant with 3 embryos.

Fleas. 6 ♂, 6 ♀ *X. brasiliensis.* 22 ♂, 19 ♀ *Ct. cabirus.*
2 ♂, 2 ♀ *D. lypusus.* 1 ♂ *Ct. felis.*

Lemniscomys massaicus. 95 ♂♂ and 65 ♀♀ = 160. 7 ♀♀ pregnant with 27 embryos.

Fleas. 12 ♂, 12 ♀ *X. brasiliensis.* 74 ♂, 77 ♀ *Ct. cabirus.*
4 ♀ *D. lypusus.* 1 ♀ *S. tortus.*
2 ♂, 1 ♀ *Ct. felis.*

Lophuromys aquilus. 50 ♂♂ and 64 ♀♀ = 115. 4 ♀♀ pregnant with 9 embryos.

Fleas. 10 ♂, 14 ♀ *X. brasiliensis.* 1 ♂, 2 ♀ *X. cheopis.*
22 ♂, 30 ♀ *Ct. cabirus.* 2 ♀ *E. gallinaceus.*
2 ♂, 2 ♀ *S. tortus.* 8 ♂, 8 ♀ *D. lypusus.*

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Mastomys coucha. 4 ♂♂ and 5 ♀♀ = 9. No fleas.

Moles. *Tachyoryctes* spp. 5 ♂♂ and 4 ♀♀ = 9. No fleas.

Rattus rattus with *X. brasiliensis*:

19. xii. 31	♀	4 ♂, 13 ♀	*X. brasiliensis*.	
2. i. 32	♀	4 ♂, 7 ♀	,,	
2. i. 32	♀	7 ♂, 8 ♀	,,	6 embryos.
13. i. 32	♀	3 ♂, 8 ♀	,,	8 embryos.
25. iii. 32	♀	6 ♂, 9 ♀	,,	8 embryos.
18. iv. 32	♀	11 ♂, 6 ♀	,,	
18. iv. 32	♀	13 ♂, 10 ♀	,,	
22. iv. 32	♀	7 ♂, 5 ♀	,,	

B. *Rat and flea survey in domestic premises over* 12 *months*, 1934–5

	Rattus rattus			*X. brasiliensis*			Trapping figure
	♂♂	♀♀	Total	♂♂	♀♀	Average	%
1934, Sept.	138	196	334	584	419	3·0	35·0
Oct.	140	187	327	483	258	2·2	31·5
Nov.	161	237	398	347	246	1·5	38·5
Dec.	222	279	501	563	423	1·9	52·0
1935, Jan.	273	352	625	638	524	1·8	58·0
Feb.	336	398	734	796	474	1·7	76·5
Mar.	261	379	640	870	654	2·4	61·5
Apr.	207	331	538	849	537	2·6	51·5
May	290	436	726	1534	1364	3·9	71·5
June	327	391	718	1569	1215	3·9	71·5
July	261	389	650	782	673	2·2	60·0
Aug.	247	345	592	1244	930	3·7	57·0
	2916	3999	6915	10,259	7717	2·6	

The following species of fleas were also taken from *Rattus*:

17 ♂, 22 ♀ *X. cheopis*.
273 ♂, 160 ♀ *X. robertsi*.
12 ♂, 29 ♀ *D. lypusus*.
86 ♂, 144 ♀ *Ct. cabirus*.
30 ♂, 798 ♀ *E. gallinaceus*.
43 ♂, 53 ♀ *Ct. felis*.
2 ♂, 3 ♀ *S. tortus*.
3 ♀ *L. segnis*.

Table VIII

(*a*) *Embryonic rates for* Rattus rattus

No. of embryos per pregnant female	No. of females in each number group												Total no. of females
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	
1	—	—	—	—	—	1	—	—	1	—	—	—	2
2	—	—	—	1	—	—	3	—	7	—	3	4	18
3	3	—	1	—	—	5	1	2	3	1	1	4	21
4	1	2	2	—	4	1	9	9	6	8	6	6	54
5	7	3	5	4	11	15	19	20	16	21	25	12	158
6	7	12	8	10	12	21	25	20	36	25	20	14	210
7	9	12	25	25	29	16	42	31	37	30	30	37	323
8	5	14	16	16	16	17	22	29	38	20	27	23	243
9	4	7	16	11	17	17	30	37	30	15	17	29	230
10	—	4	13	14	10	7	9	14	12	5	10	5	103
11	—	—	6	2	1	4	4	6	6	4	4	3	40
12	—	—	—	1	2	1	1	1	1	1	1	1	10
13	—	—	—	—	1	—	—	—	1	1	—	1	4
14	—	—	—	—	—	—	—	—	—	—	—	1	1
15	—	—	—	—	—	—	—	—	—	1	—	—	1
16	—	—	—	—	—	—	—	1	—	—	—	—	1
Total no. of females pregnant	36	54	92	84	103	105	165	170	194	132	144	140	1419

Table VIII (*continued*)

(*b*) *Breeding rates for* Rattus rattus

	Total no. of females pregnant	Percentage pregnancy	Total no. of embryos	Average no. per female pregnant
1934, Sept.	36	18	229	6·4
Oct.	54	28	394	7·3
Nov.	92	38	727	7·9
Dec.	84	30	658	7·8
1935, Jan.	103	29	775	7·5
Feb.	105	27	746	7·1
Mar.	165	43	1180	7·2
Apr.	170	51	1275	7·5
May	194	45	1388	7·2
June	132	34	929	7·0
July	144	37	1013	7·0
Aug.	140	40	1014	7·2
	1419	35	10,328	7·3

The increase in birth-rates thus took place during the long rain season prior to the harvesting of the main maize crop, so that there was a resultant denser population during harvesting.

In the survey of 1931–2, it was noted that only female *Rattus* had infestations of ten or more fleas. The figures have again been analysed to find out whether female rats were liable to heavier infestations of fleas than males (see Table IX).

Table IX

	Nos. of male *Rattus*	*X. brasiliensis* ♂♂	*X. brasiliensis* ♀♀	Nos. of female *Rattus*	*X. brasiliensis* ♂♂	*X. brasiliensis* ♀♀	Ratios of nos. of fleas on male to female rats ♂♂ : ♀♀
1934, Sept.	138	219	155	196	365	264	2·7 : 3·2
Oct.	140	218	132	187	291	132	2·5 : 2·3
Nov.	161	167	196	238	182	139	1·7 : 1·4
Dec.	222	254	204	279	335	230	2·0 : 2·0
1935, Jan.	273	269	217	352	358	300	1·8 : 1·9
Feb.	335	391	219	398	410	256	1·8 : 1·7
Mar.	262	378	268	380	488	377	2·5 : 2·3
Apr.	207	373	245	332	476	294	3·0 : 2·3
May	289	600	555	437	923	806	4·0 : 4·0
June	327	705	559	391	850	650	3·9 : 4·0
July	261	318	284	388	461	384	2·3 : 2·2
Aug.	249	545	391	343	704	537	3·7 : 3·6
	2916	4437	3425	3999	5843	4369	2·7 : 2·6

The average number of *X. brasiliensis* on male and female rats does not show that females are liable to heavier infestations even during the period when birth-rates are highest.

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Rattus *with ten or more* X. brasiliensis

Males. 67 male rats had over 10 fleas, yielding a total of 539 ♂, 397 ♀ *X. brasiliensis.* Average per rat = 14·0. 2·3 per cent. male *Rattus* had over 10 fleas each.

Females. 82 female rats had over 10 fleas, yielding a total of 642 ♂, 445 ♀ *X. brasiliensis.* Average per rat = 13·2. 2·05 per cent. female *Rattus* had over 10 fleas each.

Rattus *with twenty or more* X. brasiliensis

♂♂ *Rattus*	♀♀ *Rattus*
1. 10 ♂♂, 11 ♀♀ = 21.	1. 12 ♂♂, 8 ♀♀ = 20.
2. 15 ♂♂, 6 ♀♀ = 21.	2. 12 ♂♂, 12 ♀♀ = 24.
3. 7 ♂♂, 14 ♀♀ = 21.	3. 7 ♂♂, 14 ♀♀ = 21.
4. 12 ♂♂, 15 ♀♀ = 27.	4. 10 ♂♂, 14 ♀♀ = 24.
5. 10 ♂♂, 11 ♀♀ = 21.	5. 19 ♂♂, 11 ♀♀ = 30.
6. 22 ♂♂, 6 ♀♀ = 28.	6. 18 ♂♂, 13 ♀♀ = 31.
7. 12 ♂♂, 9 ♀♀ = 21.	7. 17 ♂♂, 3 ♀♀ = 20.
8. 11 ♂♂, 9 ♀♀ = 20.	
9. 20 ♂♂, 2 ♀♀ = 22.	

Weights and flea infestations

All rats trapped over a 10-day period were weighed (weight in grammes) and the numbers of fleas recorded with the following results:

Male Rattus

100 g. and under	101–150 g.	150 g. and over
15 rats with 25 ♂ and 21 ♀ fleas	24 rats with 25 ♂ and 39 ♀ fleas	6 rats with 6 ♂ and 3 ♀ fleas
Average = 3·1	Average = 2·6	Average = 1·5

Female Rattus

100 g. and under	101–150 g.	150 g. and over
37 rats with 54 ♂ and 33 ♀ fleas	40 rats with 48 ♂ and 25 ♀ fleas	12 rats with 18 ♂ and 9 ♀ fleas
Average = 2·3	Average = 1·8	Average = 2·2

Comparison between flea infestations of pregnant and non-pregnant females

Of the above weighed rats it was found that

35 non-pregnant females had 52 ♂ and 28 ♀ *X. brasiliensis*, an average of 2·3 fleas per female.

54 pregnant females had 68 ♂ and 39 ♀ *X. brasiliensis*, an average of 2·0 fleas per female. These 54 pregnant females had an average of 7·6 embryos each.

The weights of pregnant female Rattus

			Weights: Lowest	Weights: Highest
7 ♀♀	with 11 embryos each.	Average weight 155·5 g.	120	210
6 ♀♀	„ 10 „	„ 134·0 g.	99	150
11 ♀♀	„ 9 „	„ 128·0 g.	100	170
10 ♀♀	„ 8 „	„ 109·1 g.	85	150
17 ♀♀	„ 7 „	„ 101·5 g.	80	160
15 ♀♀	„ 6 „	„ 128·4 g.	100	170
8 ♀♀	„ 5 „	„ 127·1 g.	70	170
2 ♀♀	„ 4 „	„ 110·0 g.	65	155

It was realized that the weight of each pregnant female would vary with the state of parturition, but it had been thought that some old females might possibly feel the urge to breed and conceive, and have only a few embryos. Females with four, five and six embryos had greater average weights than those with seven, eight and nine embryos, and possibly such is the case in the breeding season.

The weights of male Rattus

The heaviest weights recorded among males were three with 200 g. and one with 205 g. The majority of what appeared to be full-grown adults ranged between 140 and 170 g.

COMMENTS

The most striking fact in the rat and flea survey of domestic premises at Keruguya is the very decided dominance of females to males in the *Rattus* population, a superiority which was maintained in each month. George & Webster (1934) also found the same state of affairs in their endemic area in the Cumbum Valley, South India. They stated that "One point of interest is that of 7143 rats trapped singly no less than 4485 or 62·8 per cent. were females." The figures for Keruguya were 3999 females to 2916 males or 73 per cent. females.

The highest averages of embryos per pregnant female took place in October (7·3), November (7·9) and January (7·5), immediately following the harvesting of the main maize crop. However, taking the period of gestation as being approximately three weeks, it is found that the main breeding season commenced in February, and the percentage pregnancy rates kept at a high level for the ensuing months. In January there had been no rain, February had 4·465 in. and March 1·730 in., and the humidity figures for such a period would be low.

It is a general rule in nature that climatic forces which stimulate the activity of the generative functions are also associated with a plentiful supply of food; the conditions which excite the one ensure the supply of the other. This is to a certain extent true for *Rattus* at Keruguya. During February the millet crop would be in storage after the January harvest, but the availability of this source of food supply would be slender to the rat population. Large quantities of maize from the previous crop and quite large additions from that planted during the short rains would, however, be available. The fresh supply of maize coming into store at this period would possibly stimulate breeding, but conversely, following the main maize crop, the breeding rates remain low, although the embryonic rates remain high.

Several important problems in connexion with rat populations in endemic areas await investigation, such as the factors influencing production of females, and the significance to be attached to this female dominance and the seasonal effect upon breeding in female rats.

Susceptibility of Rattus *to plague*

Rattus rattus from Keruguya have been tested periodically for their susceptibility to plague and autopsies performed to find out whether lesions existed in old rats. They have been found equally susceptible to the disease as rats from non-endemic areas and no lesions resembling those described for chronic plague have been seen. George & Webster (1934) also state that they found "that Cumbum Valley rats appear to be quite as susceptible to plague as Madras rats".

Rat birth-rates increased in March but plague in man and rats did not show an increase until June, four months afterwards. These figures indicate that there is little connexion between the addition of non-immune members to the rat population and the rise in the disease. Throughout the year, a large monthly addition of non-immune members was being made without the disease showing any signs of increase, and in 1934 the higher incidence of plague did not take place until September, some considerable time after increased birth-rates. Nor did the disease show any signs of increasing after high embryonic rates at the end of 1934.

Theories, attributing higher resistance to plague in rats from endemic areas or that the addition of large numbers of non-immune members to a population leads to epizootics, receive no support from work done in a Kenya endemic centre.

VII. Field rodents and their fleas

Concurrent with the trapping of rats in domestic premises, traps were laid in the bush and gardens surrounding the villages. Owing to the small numbers of certain species of rats obtained only the totals in each case are given.

Mastomys coucha. 110 ♂♂, 52 ♀♀ = 162. 21 were pregnant with a total of 197 embryos. Average number of embryos per female = 9·4. Main breeding season extends over period March to August.

Fleas.	24 ♂, 21 ♀ *X. brasiliensis.*	25 ♂, 24 ♀ *Ct. cabirus.*
	26 ♂, 21 ♀ *X. cheopis.*	14 ♂, 15 ♀ *D. lypusus.*
	1 ♀ *X. robertsi.*	4 ♂, 7 ♀ *S. tortus.*
		4 ♀ *E. gallinaceus.*

An occasional *M. coucha* would be trapped in huts and invariably on these occasions they would be infested with *X. brasiliensis*, but when trapped near their nests or runs in the field, *X. cheopis* or the other two main field species would be taken.

Otomys angoniensis. 59 ♂♂, 46 ♀♀ = 105. 29 were pregnant with a total of 69 embryos. Average number of embryos per female = 2·4. Main breeding season extends over period January to June.

Fleas.	10 ♂, 6 ♀ *X. brasiliensis.*	21 ♂, 53 ♀ *Ct. cabirus.*
	1 ♂ *X. cheopis.*	4 ♂, 5 ♀ *D. lypusus.*
	1 ♂ *X. robertsi.*	1 ♀ *Ct. felis.*

This species was generally trapped in valleys amongst dense vegetation near water.

Lemniscomys massaicus. 320 ♂♂, 211 ♀♀ = 531. 59 were pregnant with a total of 273 embryos. Average number of embryos per female = 4·7. Main breeding season extends over period February to June.

Fleas.	55 ♂, 54 ♀ *X. brasiliensis.*	315 ♂, 496 ♀ *Ct. cabirus.*
	1 ♂, 3 ♀ *X. cheopis.*	8 ♂, 4 ♀ *D. lypusus.*
	1 ♂ *X. robertsi.*	2 ♀ *Ct. felis.*
	2 ♂, 4 ♀ *E. gallinaceus.*	2 ♂, 5 ♀ *St. tortus.*

This species is generally trapped in cultivated ground.

Lophuromys aquilus. 185 ♂♂, 176 ♀♀ = 361. 53 were pregnant with a total of 132 embryos. Average number per female = 2·4. Main breeding season extends over period March to May.

Fleas.	35 ♂, 30 ♀ *X. brasiliensis.*	149 ♂, 218 ♀ *Ct. cabirus.*
	3 ♂, 6 ♀ *X. cheopis.*	19 ♂, 21 ♀ *D. lypusus.*
	3 ♂, *X. robertsi.*	3 ♀ *Ct. felis.*
	1 ♀ *E. gallinaceus.*	8 ♂, 5 ♀ *St. tortus.*

This species is found in thick bush or heavily wooded country.

The main interest in connexion with trapping of field rodents is to find out if any interchange of fleas takes place between them and house rats. There is little doubt that *Rattus* during its nightly wanderings passes through field rodent areas and picks up their fleas, particularly *Ctenophthalmus cabirus*, of which 86 ♂ and 144 ♀ were taken and 12 ♂ and 29 ♀ *D. lypusus*, which gives an average of 0·04 field flea to each *Rattus*.

Likewise, periodically, field rats come close up to native habitations and in some instances are actually trapped within huts, particularly *Lophuromys* and *Mastomys*, and *Lemniscomys* has its habitat in gardens over which *Rattus* must traverse at night. One of the most interesting features of the flea fauna of field rodents is the affinity of *cheopis* to *Mastomys*, which nests underground, but when this species is trapped within huts it mainly harbours *Xenopsylla brasiliensis*.

The absence of plague in field rats. As there is undoubtedly an interchange of fleas between the various species of rats it was expected that field rodents would also be found infected and that even epizootics would occur among them. Every effort has been made to obtain specimens of field rodents naturally infected, apart from the chances of obtaining a fair sample from the native population, who, under the threat of fines, are compelled to bring in every dead rat found.

So far, not a single field rat has been found naturally infected with plague in the Keruguya area.

VIII. THE CARRIAGE OF INFECTION FROM KERUGUYA

Surplus maize, when sold, is bought by Indian and Swahili traders, and this is eventually brought to the nearest railhead, Sagana, about 20 miles distant. It is usually in a very dirty condition, weevily and damp, and requires much sorting to bring it to a marketable condition. The sorting is often carried out under insanitary conditions, and it would be expected that large numbers of rats and fleas would accompany the maize and that Sagana station would suffer from outbreaks of plague.

At the station a few *Rattus* have been trapped mainly in godowns storing maize ready for export, but only *Xenopsylla cheopis* were recovered, and it appears that either *X. brasiliensis* is not carried in maize from Keruguya, or else when carried it fails to establish itself.

Some loads of maize were searched as they were coming in, but no rats or fleas were taken.

IX. Comparison between Indian and Kenyan endemic centres

Some references have already been made to the similarity of results obtained from an investigation carried out in the Cumbum Valley, South India, with those obtained at Keruguya. In most respects the report agrees with conditions in the Kenya endemic centre, both being extremely fertile areas, raising large quantities of cereals. The degree of fertility is the most striking similarity and it must be assumed that somehow or other there is negligence in storage of produce in both areas to support enormous rat populations. Also, since agriculture is the sole industry in the two areas, agricultural products, particularly cereals, will form the chief sustenance of the populations.

There are however two important differences. Cumbum has two main flea species, *X. cheopis* and *X. astia*, with the former greatly predominating, whereas at Keruguya, *brasiliensis* is almost the sole flea species in human habitations. Also Cumbum suffers much more from plague in the human population than does Keruguya.

In view of a previous discovery in Kenya that *cheopis* is associated with *Rattus* living in earth burrows and that *brasiliensis* is associated with *Rattus* nesting in roofs, these differences in flea species distribution in the two areas can now be partly explained by these facts. At Keruguya, no *Rattus* nesting underground has yet been found in domestic premises and *cheopis* is extremely rare. As far as can be judged from the Cumbum report, the rat population there is mainly confined to earth and *cheopis* is dominant.

The human population of Cumbum is about 300,000 and that of Keruguya about 150,000. The human incidence of plague in the two communities is recorded below, and it shows that plague is much more prevalent at Cumbum than Keruguya in which only a smouldering type occurs, never reaching the epidemic proportions so often met with in *cheopis* areas whether in Kenya or India.

	Keruguya		Cumbum	
	Cases	Deaths	Cases	Deaths
1929	76	46	912	383
1930	108	101	1104	515
1931	188	144	1160	529
1932	156	110	2014	701
1933	117	73	1638	483
	595	474	6828	2611

X. Discussion

Many people have carried out investigations on the attractiveness of human blood to the various species of *Xenopsylla*, in the hope that experimental work of this nature would throw light on the epidemicity of plague. The general opinion, in spite of the negative evidence obtained for greater or lesser attractiveness, is that *X. cheopis* is a much more efficient vector of plague to man than other species, and that the presence of this species serves to indicate such areas as liable to epidemic outbreaks in distinction to the endemic nature of the disease in *X. astia* and *X. brasiliensis* zones.

Hirst (1927) states that "The conclusion is drawn that the factors influencing the biting powers of fleas are so numerous and difficult to control that the utmost caution should be exercised in making a comparison between the appetite of various species of rat-fleas for human blood." "On the whole, after making allowance for the difference in biting habits and different intervals between feeds upon their natural host, I am inclined to the opinion that *X. cheopis* bites man somewhat more readily than *X. astia*, but the difference does not appear to be sufficient to account for the correlation between the relative distribution of *X. cheopis* and that of epidemic plague."

Webster (1930) concluded that "From these various results, it seems reasonable to conclude that starved individuals of both sexes of the three species feed quite readily on human blood. It does not appear that, other things being equal, the rat-to-man transmission of plague in India would depend on the lesser attractiveness of man to one or other of these species."

The same experimental work has been repeated in Kenya and no differences have been found to account for the greater efficiency of *X. cheopis* as a carrier of plague to man.

Other workers have also attempted to correlate the relatively more important part played by certain species of fleas in transmission to man as being due to relatively greater efficiency under certain climatic conditions. Experimental evidence however offers no solution to the problem, as each species was found to be equally attracted to human blood at all temperatures even over 80° F.

Experimental evidence on the ability of fleas as transmitters of plague from rat to rat indicates that *X. astia* is definitely inferior to either *X. cheopis* or *X. brasiliensis*, and that a higher *astia* index per rat is required for the continuance of epizootic plague with this species. However, in East Africa, the two species *cheopis* and *brasiliensis* can be regarded as equally efficient transmitters, under experimental conditions, which was also found to be the case at Bombay (Webster, 1930). Experimental transmission work has also failed to help in distinguishing between the ability of *cheopis* as the epidemic vector and *brasiliensis* as the endemic one.

It is suggested that the difference in habits discovered for these two species in Africa offers help in the solution of the problem. As *X. cheopis* is found associated with *Rattus* nesting underground and as the occupants of huts generally sleep on the floor or low beds, it follows that fleas from these burrow nests are naturally attracted to the human occupants and that rats prowling around the floors for waste food would also distribute fleas. The nesting sites of *Rattus* are to be found quite close to floor levels, the greatest depth at which they have been found being only 3 ft., and even the debris on floors is generally productive of *Xenopsylla cheopis*; whereas *X. brasiliensis* is attracted to rats with nesting sites in roofs, and the habits of these roof rats of living there by day and feeding in outside cereal stores at night gives little opportunity for this species to gain access to floors of huts or even to the occupants, as they generally emerge on the outside of the hut. The opportunities of contact with man is thus very much less remote for *brasiliensis* than it is for *cheopis*. In a typical thatched roof hut of the native reserves, fleas on floors are scarce, whereas in an iron or stone hut fleas are being continually delivered on to the floors during egress of rats from their holes.

In Africa, human habitations with *Rattus* in the roofs suffer from plague in an endemic form and habitations with *Rattus* underground suffer from epidemic plague.

The Keruguya endemic centre does not appear to be in any way dangerous to other areas in the dissemination of plague at the present time, as it appears to be a purely local affair connected with special features characteristic of the area.

Some of the special features associated with plague in rural endemic areas in Kenya are listed below.

(1) There is an enormous *Rattus* population.

(2) The flea index is never particularly high.

(3) Human cases of plague are relatively scarce and sporadic.

(4) *Xenopsylla brasiliensis* associated with *Rattus* living in thatched roofs is not offered many chances of contact with man.

(5) The areas are characterized by enormous fertility and the main energies of the people are devoted to raising cereal crops to which they confine their diet.

(6) There is prodigality and waste. The rat population, living in affluence, remains in close proximity to cereal stores and confines itself to a diet of cereals.

(7) Methods of storage for cereal crops are primitive and offer easy access to rats and, generally, accommodation is inadequate in years of abundance.

(8) Man and *Rattus* only contract plague in these areas. The great similarity between them is the cereal diet. Areas free from plague have people and rats forced to live on a mixed diet with liberal additions of milk and meat. Field rats, which also remain free from plague, live on mixed diets with liberal additions of proteins from vegetables and grasses.

XI. Summary

1. In the introduction, the characteristics of the people are given from the observations of administrative and medical officers well acquainted with the area, fertility of the land and ample rainfall being the main theme of each observation.

2. The topography, climate and local conditions are given, including notes on crop production, habitations, clothing, domestic animals, origin of the people and food.

3. The population figures and rat and human plague figures are discussed. The rat and flea population figures over a twelve month trapping period are given and notes made on interesting biological problems arising out of these figures.

4. The male and female ratios in a *Rattus* population in plague endemic areas offer an interesting problem for further investigation. It would be instructive to find out what are the factors responsible for high female ratios and the significance of such female dominance being peculiar to endemic areas.

5. The field rodent and flea survey figures are discussed. Although an interchange of fleas takes place between them and house rats, plague remains absent from such communities.

6. There is no evidence to show that there is carriage of infection from endemic centres, either by rats, fleas, merchandise or man.

7. A comparison is drawn between a Kenya endemic centre and an Indian one, similarities and differences being noted. The similarities are that both areas are extremely fertile, large crops of cereals being grown, and the diets of both man and rats are confined to this inadequate source of nourishment. The great differences between Indian and Kenyan endemic centres are the flea species present and that India suffers a much heavier mortality rate in man than does Kenya.

8. It is suggested that the low incidence of plague in man in Kenya is partly explained by the habits of *Rattus*, which in the typical dwellings of native areas nests in the thatch. Its ectoparasites are then unlikely to come into contact with man. In buildings where rats nest underground contact between its flea (then *Xenopsylla cheopis*) and man is likely to be very close and constant, and areas containing such buildings are usually distinguished by the epidemic nature of the disease.

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