

PLAGUE CONDITIONS IN AN URBAN AREA OF KENYA  
(NAIROBI TOWNSHIP)

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(With 2 Graphs)

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I. INTRODUCTION

THERE is still some confusion concerning the distribution of the *Xenopsylla* species, *cheopis* and *brasiliensis*, in East Africa. In this paper an important difference in the habits of the two species is indicated.

Surveys of rats and fleas conducted in Nairobi, at intervals during the last twenty years, have produced the impression that the enormous rat population is heavily infested with both species, *cheopis* predominating, however, in the more permanent types of buildings and *brasiliensis* in the temporary abodes of the native population.

In Nairobi the use of thatch is prohibited. Consequently the rat population lives under conditions differing from those in the native reserves, where thatched buildings are universal. Urban areas have an admixture of species with *cheopis* predominating, but in rural areas in thatched roof habitations, *brasiliensis* is almost the sole ectoparasite of *Rattus rattus*. *Xenopsylla cheopis* is not entirely absent from native reserves, for it is often found associated with the *Rattus* population of the Indian trading centres and on field rats, particularly *Mastomys coucha* and *Arvicanthis abyssinicus*, and an occasional one may be taken from rats in native huts, but it appears to be unable to establish itself there.

Most workers on the plague problem have recognized that types of buildings exercise an influence on the ectoparasites of the rats living in them. Hirst (1933) states that "Experience in both Colombo surveys had demonstrated the close dependence of the figures for *cheopis* infestation on types of premises trapped", and "It is therefore essential in a flea survey of such an area to take into account the type of premises trapped and the nature of the goods they hold, particularly if they are imported from abroad."

The evidence from Nairobi also suggests that it is some factor connected with different types of buildings which is responsible for the distribution of various flea species. The factor seems to be the varied harbourages and nesting facilities offered to and accepted by *Rattus rattus* in different types of premises.

## II. PHYSICAL, CLIMATIC AND ECONOMIC CONDITIONS IN NAIROBI TOWNSHIP

### *Physical*

Nairobi township is situated at an altitude ranging from 5452 to 5700 ft. above sea-level. It has very different features both physically and climatically from other large towns such as Mombasa on the coast or Kisumu on the shores of Lake Victoria, but the flea index figures are very similar, and the same features are recognizable in regard to the distribution of the two main species of the *Xenopsylla* group of fleas.

The township lies on the edge of the well-known Athi Plains Game Reserve and its position marks the commencement of what is termed the Kenya Highlands. Pumwani and Pangani (African residential areas) and the Indian community's residential and commercial areas lie at the lower altitudes on black cotton soil and murram formations, whereas the King's African Rifles lines are at a higher altitude, also on black cotton soil, and the European residential area is partly on black cotton soil and partly on red or murram soils, at the higher altitudes. The whole area is provided with a network of roads, and the railway runs through the centre of the township. The large, recently constructed, railway goods sheds are, from a plague prevention point of view, very satisfactory and, up to the present, no outbreaks have occurred there. There is also a considerable amount of motor-lorry traffic between the Indian commercial quarter and outlying smaller townships, which carries native produce to the Nairobi markets. An appreciable amount of the cereal crop of the country is conveyed direct by rail to the seaport, Mombasa, but quite large quantities arrive at the many godowns at Nairobi, and are thence either redistributed to the local flour mills or exported overseas. There is also a big interterritorial trade in cereals between Tanganyika, Uganda and Kenya with Nairobi as headquarters.

The rail and motor-lorry traffics convey cereals direct from plague-infected centres in the native reserves and consequently a rapid exchange of fleas, rats and plague subjects might be expected. The township, however, only records outbreaks at regular intervals and enjoys quite lengthy quiescent periods.

This, on the contrary, suggests that the transference of infected fleas, rats or materials is rare.

The Bazaar area in Nairobi is congested and includes numerous habitations and commercial premises huddled together and a network of paths and streets. A large part of the area is occupied by low single-storey buildings, opening upon the main thoroughfare, where various commodities are exposed to view, but at the rear of such premises there are dark ill-ventilated rooms and quarters for native servants. This area permits a constant interchange of rats between the huts of native servants and Indian domestic and commercial quarters. Few efforts at rat-proofing buildings have been made and merchandise is freely exposed to inroads of rats.

*Climatic and economic conditions*

Nairobi is recognized as having four seasons, but the divisions are arbitrary. They are based on rainfall as recorded in Table I.

Table I. *Rainfall in Nairobi, average during the last 28 years*

		in.				in.	
Short dry season:	Jan.	1.72	} 3.80	Long dry season:	June	1.50	} 4.34
	Feb.	2.08			July	0.72	
				Aug.	0.96		
				Sept.	1.16		
Long rain season:	Mar.	4.63	} 18.11	Short rain season:	Oct.	2.15	} 9.69
	Apr.	8.23			Nov.	4.80	
	May	5.25			Dec.	2.74	

Average annual rainfall = 35.94 in.

The ranges of other meteorological factors over the last five years were:

- Mean max. temps. range from 81.8 in March to 70° F. in July.
- Mean min. temps. range from 57.0 in April to 50° F. in July.
- Relative humidities range from 87 per cent. in April to 45 per cent. in March.
- Saturation deficiencies range from 8 mm. in February to 2 mm. in November.

During 1929-34, both heavy rainfall and drought periods have been experienced, and Table II records the total rainfall in each of the seasons during this period and the number of human plague cases observed.

Table II

Year	Short dry		Long rain		Long dry		Short rain		Total rain in.	Total plague cases
	Rain in.	Plague cases	Rain in.	Plague cases	Rain in.	Plague cases	Rain in.	Plague cases		
1929	0.47	—	19.65	—	6.27	1	13.75	—	39.54	1
1930	4.76	2	41.03	7	5.51	43	11.83	55	66.13	107
1931	3.16	39	19.92	1	6.57	1	9.93	10	39.58	51
1932	4.61	2	19.68	1	3.27	4	12.29	—	39.85	7
1933	5.06	—	4.54	—	3.51	—	9.57	—	22.68	—
1934	2.20	—	9.35	—	4.09	—	7.48	—	23.12	—
Average rainfall	3.80	43	18.11	9	4.34	49	9.69	65	35.94	

This table shows that (a) an epidemic followed the heavy precipitation of the long rain season of 1930, and that (b) in 1933 and 1934, years of relative drought for the area, there were no cases of plague.

The general tendency is to correlate outbreaks of plague with climatic conditions, and Table II supports the view that climate has an influence on the incidence of the disease. What direct effect climate may have on rat and flea populations is a subject about which little is known, particularly under natural conditions, but many interesting facts concerning indirect effects can be observed, and in this respect the *Report of the Agricultural Department of Kenya* is helpful. It states in regard to 1930 that:

The year was one of general world over-production of staple crops, and the consequent depression has been markedly felt in Kenya... The heavy rains of late 1929 produced large crops of maize and wheat, and these crops brought to an end the food shortage which had been more or less severe throughout the whole of 1929, in some native reserves, notably Meru, Embu and Kitui. The prolongation of these heavy rains, however, well into 1930 produced conditions in which it was difficult to export the surplus crops as soon as available. Not only did the wet weather make it difficult to dry the crops sufficiently for export, but transport was disorganised and in many cases great delay was experienced in getting the crop away from the farm.

From the above extracts the indirect effects of climate upon the rat population can be realized, for rats are provided with an abundance of cereals through delayed export, caused by delay in drying the crop, transport difficulties along waterlogged roads from farms, and storage over longer periods than usual of food in non-rat-proofed buildings.

The economic conditions under which plague flourishes are years of cereal abundance, when owing to low prices export quotas are small, the quantities in storage large and wastage great. In fact, the prodigality of all classes in these highly productive years is undoubtedly an important factor governing the rise in the rat population. Improvidence and negligence sum up the economic state conducive to plague.

### III. TYPES OF PREMISES, FOOD STORAGE AND FACILITIES FOR HARBOURAGE AND NESTING OF RATS IN THE VARIOUS AREAS

The *Indian commercial and residential areas* contain innumerable shops, large and small. The more modern commercial and residential buildings which have been constructed of stone or other permanent material, largely with rat-proofing methods, have remained free of plague although frequently situated close to infected premises. The buildings in which most rats are found and which offer the best facilities for rat harbourage are the non-permanent types. These are of such varied characters that description is difficult. However, though the walls may be of either stone or iron and the floors of either cement or murram, they all possess corrugated iron roofs.

The bulk of the grain trade is confined to this area, both in warehouses and shops, and large quantities are always in stock on premises under conditions distinctly not rat-proof. Though rats have been found nesting in the roofs under the corrugated iron in corners formed by roofing timbers, the

majority were found in warrens in the floors. Wherever floors were made of cement or other hard material rat nests were found in the roof, or behind materials or sacks of foodstuffs, and, particularly if there was suitable earth alongside the cement, in warrens. On premises with earthen floors there was a tendency to form underground warrens only.

Plague is found to occur in congested, insanitary premises, particularly those built with earthen floors, in which numerous rat holes lead from outside into the buildings. It is this type of building, laden with foodstuffs in a free and accessible form, that constitutes the danger. The disease commences and has its highest incidence at what would be considered, climatically, the most unfavourable season, and when the rat and flea populations are lowest or slightly increasing. The amount of grain in storage is, however, highest at this period, when the surplus grain of the native reserves is arriving.

Maize, rice and millets constitute the bulk of grain in storage.

*Pumvani and Pangani*, African locations, have premises conforming more or less to a type. The municipal laws do not allow any building to be roofed with grass or other vegetable matter, so that every roof in these areas is built of iron in some form or another, such as corrugated iron or beaten out petrol tins. The walls of most of the houses are made of poles and mud, but sometimes pieces of tin are used for filling in purposes. The floors of all houses are formed of the normal soil of the area, well trodden down in the centre of the huts but loose below the walls. In this area the rats nearly always live in earth warrens, and it is rare to find a nest above floor-level.

Large quantities of foodstuffs are not stored in these areas, and the rats are entirely dependent on what food they can obtain from the people in the form of waste.

*King's African Rifles lines*. All buildings in this area have been built to one pattern, with corrugated iron roofs and walls. The floors are made of murrum, well beaten down and hard set, and each occupier is made responsible for the upkeep of his floor. Prior to the 1930 outbreak of plague in the area great attention was not devoted to flooring, but during the reconstruction of the lines special care was bestowed upon floors, and they have been carefully attended to subsequently. At the present time rats are very scarce and it is extremely rare to find a rat hole in the floors, the few nests found were in the joints of roofing timbers.

The only food available to rats is that due to waste or small quantities of unused cereals.

*Vicinity of K.A.R. lines*. The buildings in this locality are occupied by Europeans and vary in construction, some being of stone and some of corrugated iron, but most have iron roofs. The majority are elevated from the ground by plinths. Most of the rats were trapped in native servants' quarters.

There are few rat-attracting foodstuffs and rats are scarce.

IV. THE POPULATION OF INDIANS AND AFRICANS IN NAIROBI TOWNSHIP AND THE INCIDENCE OF PLAGUE IN THE TWO COMMUNITIES IN THE RECENT OUTBREAK

Table III

Estimated population	Indians		Africans		Number of cases of plague	
	♂♂	♀♀	♂♂	♀♀	Indians	Africans
1930	9,156	4,402	22,979	3,782	22	90
1931	13,558	26,761	13	38		
1932	14,700	26,765	5	2		

The figures for 1931 are taken from the census returns.

Statistics from the Health Office, Nairobi, show that, from 1918 to 1930, there have been 133 cases of plague in the Indian commercial and residential areas (Bazaar and River Road), and 140 cases for the same period in the two large African locations at Pumwani and Pangani.

Table IV. *The racial incidence of plague by comparison of outbreaks in the Bazaar and River Road areas with Pumwani and Pangani locations*

	1930		1931		1932	
	Indian	African	Indian	African	Indian	African
Jan.	—	—	—	23	1	1
Feb.	2	—	1	4	—	—
Mar.	1	1	—	—	1	—
Apr.	1	—	—	—	—	—
May	1	2	—	—	—	—
June	1	—	—	—	—	—
July	1	1	1	—	—	—
Aug.	5	2	—	—	3	—
Sept.	4	1	—	—	1	—
Oct.	3	2	7	1	—	—
Nov.	2	7	2	—	—	—
Dec.	1	14	—	—	—	—
	22	30	11	28	6	1

During the first 7 months of 1930 plague occurred sporadically, there being seven Indian and four African cases. In each month from February to July there were cases among Indians in the Bazaar and River Road areas. The figures for 1932 demonstrate effectively the area in which recrudescence takes place and the racial types responsible, there being three Indian cases in August and one in September, after the epidemic among Africans had ended. Locality distribution of plague shows that during the first 9 months of 1930, before the disease had really assumed epidemic form, there were nineteen human cases from the Indian inhabited areas, including Africans residing there, and only nine cases from the purely African inhabited areas, and in 1932, at the end of the epidemic, there were six Indian cases and one African.

The evidence therefore shows that the outbreak commenced in the Indian residential and commercial quarters and persisted longest there, and that the

Indians were the first to contract the disease and that it persisted among them. Past records for outbreaks in Nairobi are also in agreement with this evidence.

## V. RAT AND FLEA SPECIES DISTRIBUTION IN SELECTED AREAS OF NAIROBI

### (a) *The Indian Bazaar and residential quarter*

A survey was conducted over a period of 22 months from 1 March 1931 to December 1932, twenty traps being set regularly for 2 days of each week. The figures do not give an accurate indication of the rat population density, as this particular area was being heavily trapped by the health authorities, but they present a fair picture of the flea fauna, which is of particular interest.

497 *Rattus rattus* were trapped, of which 373 were infested with *X. cheopis*, and yielded 1722 fleas, 830 ♂♂ and 892 ♀♀. The average number per rat was therefore 3.5.

The monthly average number of *X. cheopis* per rat ranged between 1.0 and 5.9, and only in 2 months out of the 22 did it fall below 2.0.

128 rats were infested with *X. brasiliensis* and yielded 400 fleas, 216 ♂♂ and 184 ♀♀.

The average number of *X. brasiliensis* per rat trapped was 0.8, and the monthly average number of *X. brasiliensis* per rat ranged between 0.03 and 2.9.

### (b) *Pumwani*

588 *Rattus rattus* were trapped in twenty traps set on 2 days of each week.

446 rats were infested with *X. cheopis* and yielded 993 ♂ and 921 ♀ fleas.

The average number of *X. cheopis* per rat trapped was 3.3, and the monthly average per rat ranged between 2.1 and 5.3.

44 rats were infested with *X. brasiliensis*, of which 56 ♂♂ and 28 ♀♀ were taken.

The average number of *X. brasiliensis* per rat trapped was 0.1, and the monthly average per rat ranged between 0.02 and 0.6, but during 5 months no specimens of this species were taken.

### *Embryonic rate for the two areas.*

As very few differences in the embryonic rates, trapping figures or percentage infestation with fleas could be detected, these are grouped together for the two areas.

Lowest percentage of ♀♀ pregnant = 14 per cent. in August 1932.

Highest percentage of ♀♀ pregnant = 50 per cent. in September 1931.

Total number of ♀♀ pregnant = 147.

Percentage pregnancy rate 1931 = 27.5 per cent.

Percentage pregnancy rate 1932 = 26.8 per cent.

Total number of embryos = 1080.

Average number of embryos per pregnant female = 7.3.

### *Trapping figures.*

Monthly number of rats caught per 100 traps ranged between 9 and 23 per cent.

During 1931 the trapping figure was 14 per cent.

During 1932 the trapping figure was 13.7 per cent.

Percentage infestation with fleas = 76 per cent.



(c) *King's African Rifles lines*

During December 1930 and January 1931, the following rats and fleas were obtained:

*Rattus rattus*. 46 ♂♂ and 71 ♀♀ = 117.

The number of rats infested with *X. brasiliensis* was 58, yielding 145 ♂♂ and 165 ♀♀ = 310 fleas, with an average of 2.6 per rat.

The number of rats infested with *X. cheopis* was 16, yielding 63 ♂♂ and 48 ♀♀ = 111 fleas, with an average of 0.9 per rat.

Since the floors were reconditioned in 1931, and murram instituted, the following rats and fleas were obtained. Trapping figures were irregular owing to scarcity of rats.

*Rattus rattus*. 57 ♂♂ and 64 ♀♀ = 121.

87 (72 per cent.) were infested with fleas and yielded 214 ♂♂ and 181 ♀♀ = 395 *X. brasiliensis*, and 2 ♂♂ and 3 ♀♀ = 5 *X. cheopis*.

*Mastomys coucha*. 25 ♂♂ and 51 ♀♀ = 76.

63 (83 per cent.) rats were infested with fleas and yielded 292 ♂♂ and 113 ♀♀ = 405 *X. brasiliensis*, and 8 ♂♂ and 16 ♀♀ = 24 *X. cheopis*.

(d) *Vicinity of K.A.R. lines*

A survey was conducted between March 1931 and February 1932 in the buildings and bush surrounding the K.A.R. lines, so as to obtain an indication of the fauna likely to intermingle with the fauna of the lines. Most of the buildings are isolated dwelling houses occupied by Europeans, and the bush is largely waste, uncultivated land.

*Rattus rattus*. 31 ♂♂ and 37 ♀♀ = 68. All trapped in buildings. Percentage infestation with fleas = 81 per cent.

*X. brasiliensis*

Number of rats infested = 6.

Number of fleas = 2 ♂♂ and 5 ♀♀ = 7.

Average per rat = 0.1.

*X. cheopis*

Number of rats infested = 43.

Number of fleas = 66 ♂♂ and 86 ♀♀ = 152.

Average per rat = 2.2.

*Mastomys coucha*. 151 ♂♂ and 89 ♀♀ = 240. All trapped in the open. Percentage infestation with fleas = 86 per cent.

*X. brasiliensis*

Number of rats infested = 14.

Number of fleas = 10 ♂♂ and 9 ♀♀ = 19.

Average per rat = 0.07.

*X. cheopis*

Number of rats infested = 70.

Number of fleas = 61 ♂♂ and 57 ♀♀ = 118.

Average per rat = 0.5.

*Arvicanthi abyssinicus*. 170 ♂♂ and 148 ♀♀ = 318. All trapped in the open. Percentage infestation with fleas = 61 per cent.

*X. brasiliensis*

Number of rats infested = 3.

Number of fleas = 2 ♂♂ and 2 ♀♀ = 4.

Average per rat = 0.01.

*X. cheopis*

Number of rats infested = 42.

Number of fleas = 23 ♂♂ and 30 ♀♀ = 53.

Average per rat = 0.1.

*Otomys angoniensis*. 233 ♂♂ and 179 ♀♀ = 412. All trapped in the open. Percentage infestation with fleas = 83 per cent.

*X. brasiliensis*

Number of rats infested = 5.

Number of fleas = 1 ♂ and 4 ♀♀ = 5.

Average per rat = 0.01.

*X. cheopis*

Number of rats infested = 35.

Number of fleas = 18 ♂♂ and 33 ♀♀ = 51.

Average per rat = 0.1.



*Rhodomys pumilio*. 40 ♂♂ and 24 ♀♀ = 64. All trapped in the open. Percentage infestation with fleas = 61 per cent.

Two specimens had 1 ♂ and 3 ♀ *X. cheopis* on them.

*Lemniscomys massaicus*. 13 ♂♂ and 4 ♀♀ = 17. Trapped in the open. Percentage infestation with fleas = 94 per cent.

One rat had 1 ♂ *X. brasiliensis*. Two rats had 1 ♂ and 1 ♀ *X. cheopis*.

Total number of house rats:  
*Rattus rattus* = 68.

Total number of *Xenopsylla* species:  
7 *X. brasiliensis*, 0.1 per rat.  
152 *X. cheopis*, 2.2 per rat.

Total number of field rats:  
1051

Total number of *Xenopsylla* species:  
29 *X. brasiliensis*, 0.02 per rat.  
227 *X. cheopis*, 0.21 per rat.

#### (e) *Infectious Diseases Hospital, Nairobi*

A small catch was obtained from this area in October and November 1930. Most of the buildings have either iron or stone walls and concrete floors, and all have iron roofs. The hospital lies on black cotton soil at a low altitude.

*Rattus rattus*. 27 ♂♂ and 33 ♀♀ = 60.

35 rats yielded 49 ♂ and 64 ♀ *Xenopsylla cheopis*, an average of 1.9 per rat.

*Arvicanthus*. 10 ♂♂ and 5 ♀♀ = 15.

Three rats yielded 4 ♂ and 6 ♀ *X. cheopis*.

*M. coucha*. 2 ♂♂ and 2 ♀♀ = 4. No *Xenopsylla* species.

*Otomys*. 1 ♂ had 1 ♀ *X. cheopis*.

#### (f) *Aerodrome*

All the rats obtained in this area were field rats; there were no human habitations. The aerodrome is situated on the outskirts of the town and is an area fenced off the Athi Plains Game Reserve.

*Otomys*. 237 ♂♂ and 160 ♀♀ = 397.

Two rats yielded 2 ♂ and 1 ♀ *X. cheopis*.

*Arvicanthus*. 116 ♂♂ and 63 ♀♀ = 179.

Six rats yielded 2 ♂ and 5 ♀ *X. cheopis*.

*M. coucha*. 54 ♂♂ and 33 ♀♀ = 87.

Four rats yielded 1 ♂ and 5 ♀ *X. cheopis*.

*Lemniscomys*. 34 ♂♂ and 15 ♀♀ = 49.

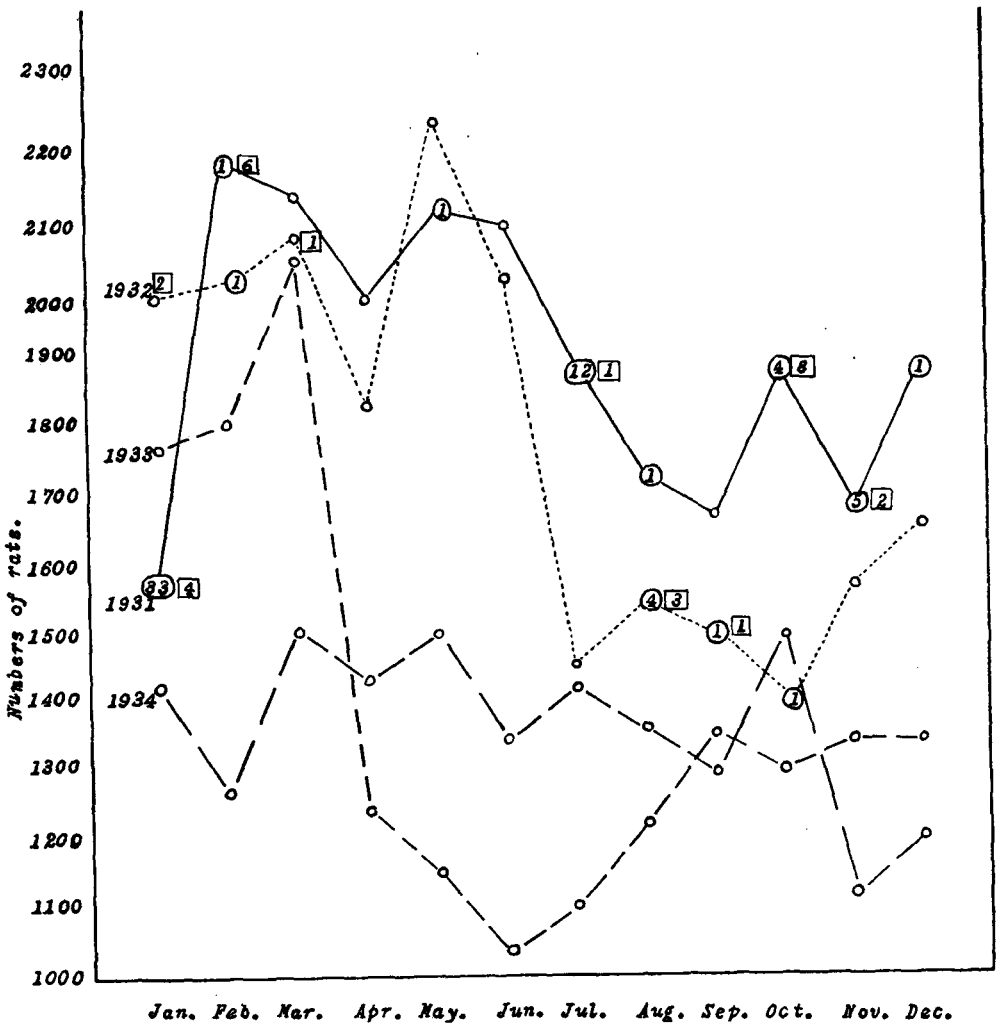
One rat yielded 1 ♀ *X. cheopis*.

The lists of purely field fleas obtained have been omitted from the above results.

### VI. THE RAT POPULATION DURING OUTBREAKS AND QUIESCENT PERIODS

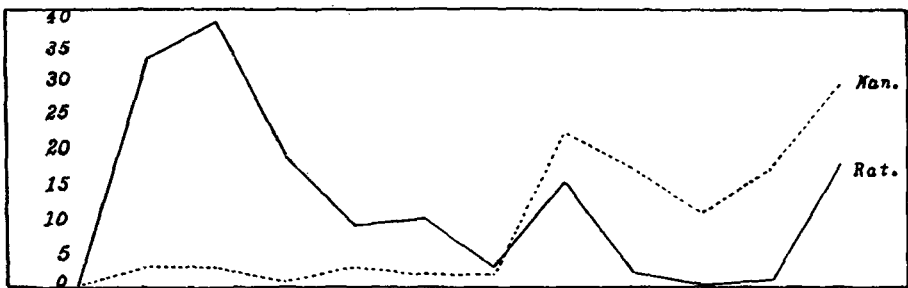
Six Africans have been employed regularly on rat trapping by the Nairobi Health Authorities since 1931, and their records are given in Table V.

The fluctuations in the numbers of rats caught show that the rat population densities are usually highest in February and March, at the commencement of the long rain season, a season showing highest temperatures and lowest humidities. The decline in population density sets in over the long rain period and reaches its minimum towards the end of the long dry season and starts recovering during the short rains period.



Graph 1. Rat trapping figures for 4 years in Nairobi, by a squad of six Africans.

□ = Human plague cases.      ○ = Rat plague cases.



Graph 2. Number of positive human and rat plague cases recorded at the laboratory for Nairobi township during 1930.

Table V

	1931			1932			1933		1934	
	No. of rats caught	Plague cases	Rain-fall in.	No. of rats caught	Plague cases	Rain-fall in.	No. of rats caught	Rain-fall in.	No. of rats caught	Rain-fall in.
Jan.	1571	33	3-16	1987	2	4-61	1779	5-06	1429	2-20
Feb.	2171	6	—	1994	—	—	1803	—	1276	—
Mar.	2140	—	—	2072	1	—	2036	—	1506	—
Apr.	1978	—	—	1808	—	—	1238	—	1423	—
May	2125	—	19-92	2238	—	19-68	1150	4-54	1506	9-35
June	2090	—	—	2007	—	—	1026	—	1339	—
July	1897	1	—	1438	—	—	1108	—	1418	—
Aug.	1700	—	6-57	1526	3	3-27	1216	3-51	1360	4-09
Sept.	1668	—	—	1500	1	—	1359	—	1318	—
Oct.	1876	8	—	1402	—	—	1285	—	1493	—
Nov.	1679	2	9-93	1571	—	12-29	1338	9-57	1118	7-48
Dec.	1874	—	—	1665	—	—	1342	—	1154	—
	22,769	50	39-58	21,208	7	39-85	16,679	22-68	16,340	23-12
<i>Average number of rats caught in seasons</i>										
Short dry:	Jan. 1604	}	1618				Long dry:	June 1523	}	1451
	Feb. 1632			July 1449						
		Aug. 1420								
		Sept. 1413								
Long rain:	Mar. 1794	}	1672				Short rain:	Oct. 1507	}	1407
	Apr. 1549			Nov. 1323						
	May 1672			Dec. 1390						

Over several years, plague has been observed to break out mainly during the long rain or long dry seasons, but also, in these periods, epidemics have diminished or died out altogether. The incidence of the disease has been highest in the short rain and short dry seasons. Although sufficient data are not available to draw concrete conclusions, it appears that the disease displays its highest incidence when the rat population density is on the increase, but that actual outbreaks are associated with the lowering of the rat density and even when at its minimum.

In Table V the influence of rainfall can also be observed, particularly during the long rain season. 1931 and 1932, both with 19 in. of rain, had almost equal numbers of rats, 6243 and 6118 respectively. 1933 with only 4-54 in. had 4424 rats and 1934, with a poor rainfall in the short dry season and 9-35 in. in the long rain season, had only 4435 rats.

The figures indicate that there is some factor, other than high density, responsible for outbreaks of plague among rats.

VII. INTERPRETATION OF RESULTS OF SURVEY TO INDICATE FACTORS DETERMINING SPECIES DISTRIBUTION OF FLEAS

It is generally acknowledged that the type of building has something to do with flea species distribution, but no satisfactory method of distinguishing types, in such a manner that it would be possible to predict the species of fleas likely to be found within them has been devised. In survey work in Kenya, different types of premises have been distinguished in the records, such as brick or stone buildings, wood and iron buildings, native huts, etc.,

and it is noted whether they are used as dwellings or stores, or permanent, semi-permanent or temporary buildings.

Surveys carried out amongst pure African communities in their reserves have always shown *Xenopsylla brasiliensis* to be the dominant species on *Rattus* infesting their premises, and this flea has come to be regarded as the one associated with Africans. The surveys at Pumwani and Pangani have however shown that African communities can also have *Xenopsylla cheopis* as the dominant flea in their premises, but this was regarded as being due to having iron roofs instead of thatch.

The exception to all this provisional classification came from another pure African community, consisting of the askaris of the K.A.R., inhabiting premises constructed of wood and iron, not very dissimilar from those of the other locations, which had in all recent surveys shown a pure *brasiliensis* colony. As the buildings there come into the semi-permanent category, they should harbour *X. cheopis*, and in the vicinity of the lines, *X. cheopis* was dominant in buildings. In reviewing the records for the K.A.R. lines it was found that a change in the proportion of flea species had taken place since the first surveys were carried out in 1930. When the lines were trapped then in order to obtain fleas for plague transmission tests there was a fair proportion of *X. cheopis*. The figures for the survey in 1930 showed that *brasiliensis* averaged 2.6 per rat and *cheopis* averaged 0.9 per rat trapped.

In December 1930, plague broke out among the *Rattus* population and all the troops were sent out under canvas, and in the meantime renovations were carried out. The old buildings were limewashed and new murrum floors put in and all the old rat holes blocked up. Prior to this, the old earth floors had deteriorated badly and contained numerous rat holes. Since then, great care has been exercised by the occupants of these buildings in preserving their floors intact, and supervision is constant to avoid a repetition of the 1930 outbreak. Any hole or fissure is filled up with cowdung and moistened earth, and not a single rat hole is to be seen there at the present time. Over the last four years, following these renovations, occasional surveys have yielded only five *Xenopsylla cheopis* from *Rattus rattus* and twenty-four from *Mastomys coucha*.

These records for the K.A.R. lines afforded one of the main clues to the problem of flea species distribution in different types of premises. Prior to the making of sound murrum floors, when rats were able to colonize holes in the ground together with nests in the roofs, there was a mixture of species. At the present day no rat nests are to be found underground, the few nests obtained being in the roof, and *Xenopsylla brasiliensis* is almost the sole flea species. This suggested that there was a definite connexion between *X. cheopis* and ground nests and that *X. brasiliensis* was connected with nests in roofs. Should this suggestion be verified by a nest survey, it would explain many of the problems in the native reserves and urban areas, and contribute a working hypothesis for the explanation of the erratic distribution of the two species.

To this end a survey has been carried out in the three main areas discussed

in this paper to find out the nesting sites of *Rattus rattus* in different types of buildings, the flea fauna of which were known.

*K.A.R. lines.* A 4-day search was made in this area, but as the rat population was very low the results are rather meagre. They nevertheless are sufficient to illustrate the position in regard to rat nesting sites.

No rat holes or runs were discovered in the earthen floors or outside the buildings, but seven nests were obtained from the timber supports to the roof. The nests obtained, which had been constructed of every conceivable material, were kept in tins for 3 weeks to note the emergence of fleas.

1 ♂ and 1 ♀ *Xenopsylla brasiliensis* were obtained from one nest.

*Pumwani.* A 3-day search was conducted in this area.

No. of houses searched	Roofs	Walls	Floors	Roof supports	No. of nests in floors or in roof or other places
7	7 scrap iron	Poles and mud	3 murrum 4 earth	1 matting 6 poles	32 nests underground (1 nest in wall)
8	2 scrap iron 6 corrugated iron	Poles and mud	8 earth	6 matting 2 poles	50 nests underground
11	8 scrap iron 3 corrugated iron	1 stone and 10 poles and mud	5 murrum 1 wooden 5 earth	2 matting 9 poles	38 nests underground

For Pumwani, therefore, twenty-six houses carefully searched showed that there were: (a) no nests in roofs; (b) 120 rat nests underground; (c) one nest in wall.

*Indian residential and commercial quarters*

No. of premises		Walls	Floors	No. of rat nests found	
Domestic	Shops			Underground	Elsewhere
4	1	5 corrugated iron	4 cement 1 stone	Nil	Nil
3	1	4 corrugated iron	1 cement 3 stone	3	—
6	1	6 corrugated iron 1 stone	4 cement 3 stone	11	1 (in box)
3		2 corrugated iron 1 stone	3 cement	—	1 behind goods 2 in wooden supports
3	1	3 iron 1 mud and poles	3 stone 1 earth	12	Nil
6		3 iron 2 stone 1 tins and mud	3 stone 2 cement 1 earth	7	2 (young found after removal of boxes in store)
	3	2 iron 1 stone	3 stone	6	—
5		3 stone 1 iron	3 stone 2 wood	5	3 (found under wooden floor)
4	1	1 wood 5 stone	4 stone 1 wood	6	—

The survey gave the following results:

	Roofs	Walls	Floors
34 domestic premises 8 shops	42 corrugated iron	26 iron 13 stone 2 mud 1 wood	14 cement 23 stone 2 earth 3 wood
50 rat nests underground 2 nests in roof 1 nest in box		3 nests behind boxes 3 nests under wooden floor	

It is necessary to qualify the terms for flooring materials, as in many instances these have been laid down almost since the birth of Nairobi township and are in a very dilapidated condition. Large cracks are often found in many of the cement floors and the stones are usually loose. Rat holes are commonly observed in great numbers outside the premises and communicate to the interior where the goods are stored. It appears that, in future, such terms as "types of premises" need more precise definition, particularly in regard to flooring materials and their condition, so that it may be possible to judge the nesting facilities offered to rats.

#### VIII. THE HABITS OF *XENOPSYLLA CHEOPIS* IN NAIROBI AND ELSEWHERE

An opportunity to investigate the flea fauna of *Rattus* nests from an area outside the township boundaries was afforded recently, and the results are given below as they agree with the facts recorded previously. A large institution about 7 miles outside the town was reported to be heavily infested with rats and attention was devoted mainly to the investigation of nesting sites. The rats were trapped in all situations within the buildings, in the roof and ceilings, in walls and under floors, but not a single nest was obtained above floor-level, each one taken was from underground in or near a food store for animals. The buildings were constructed of stone, with concrete floors, and the animal food store of corrugated iron walls and roof, with concrete floor.

A very large number of fleas was taken from these underground nests and the species obtained demonstrate effectively the nature of the flea fauna to be expected from such nesting sites, in spite of the fact that the buildings are situated close to a native reserve where *Xenopsylla brasiliensis* is dominant on the *Rattus* of huts.

*Rattus rattus* trapped. 53 ♂♂ and 56 ♀♀.

19 ♀♀ were pregnant, with 109 foetuses. Average = 5.7.

Fleas obtained from rats: 95 ♂ and 223 ♀ *X. cheopis*.

40 ♂ and 59 ♀ *Ceratophyllus fasciatus*.

36 ♂ and 79 ♀ *Leptosylla segnis*.

Individual rats with heavy infestations:

1 ♂ with 18 ♀ <i>X. cheopis</i> , 1 ♂ <i>L. segnis</i>	= 19
1 ♀ (young) with 4 ♂ and 5 ♀ <i>X. cheopis</i> , 6 ♂ and 7 ♀ <i>L. segnis</i> , 1 ♀ <i>C. fasciatus</i>	= 23
1 ♂ with 14 ♂ and 30 ♀ <i>X. cheopis</i> , 1 ♂ and 1 ♀ <i>L. segnis</i> , 1 ♂ and 2 ♀ <i>C. fasciatus</i>	= 49
1 ♂ with 5 ♂ and 10 ♀ <i>X. cheopis</i> , 1 ♂ and 2 ♀ <i>L. segnis</i> , 11 ♂ and 6 ♀ <i>C. fasciatus</i>	= 35
1 ♀ with 5 ♂ and 16 ♀ <i>X. cheopis</i> , 1 ♀ <i>L. segnis</i> , 4 ♂ and 8 ♀ <i>C. fasciatus</i>	= 34

Another interesting fact in the life history of *Xenopsylla cheopis* in Kenya is its habit of adopting field rodents as hosts in certain districts. These field rodents have two nests, a surface nest and an underground one. During 12 months, digging for burrow nests was carried out regularly every Monday

Table VI. *Numbers of fleas obtained in nests*

Nest No.	Adult fleas in nest				Total adults in nest	Fleas hatched out in nest				Total fleas hatched out	Total No. of fleas
	<i>X. cheopis</i>		<i>C. fasciatus</i>			<i>X. cheopis</i>		<i>C. fasciatus</i>			
	♂♂	♀♀	♂♂	♀♀		♂♂	♀♀	♂♂	♀♀		
1	12	6	—	3	21	5	3	—	—	8	29
2	122	135	44	73	374	73	89	46	73	281	655
3	1	5	—	1	7	26	115	42	63	246	253
4	7	12	10	23	52	141	355	64	95	655	707
5	28	52	21	45	146	3	1	36	46	86	232
6	1	11	1	4	18	—	—	—	—	—	18
7	2	13	1	2	18	—	2	—	5	7	25
8	16	20	58	83	177	2	2	13	17	34	211
9	53	66	97	73	288	5	3	6	6	20	308
	242	320	232	307	1101	255	570	207	305	1337	2438

morning, and 394 nests were collected and examined, averaging eight per collection in the Nairobi district.

No. of nests collected	No. of nests infested	<i>X. cheopis</i>			<i>X. brasiliensis</i>		
		Nests infested	♂♂	♀♀	Nests infested	♂♂	♀♀
394	143	4	6	6	1	3	3

The surface nests of field rodents have also been taken regularly and examined for fleas. At Nairobi, 155 surface nests were obtained, 64 were infested with fleas but only 1 ♀ *X. cheopis* was taken.

The following figures are given to show the total number of various rats caught over a 2-year period in Nairobi and the numbers of *cheopis* and *brasiliensis* obtained from them.

Total No. of rats	<i>X. cheopis</i>				<i>X. brasiliensis</i>			
	1	2	3	4	1	2	3	4
394 <i>Rattus rattus</i>	89	23	316	0.8	126	32	651	1.6
1252 <i>Mastomys coucha</i>	74	5	131	0.1	73	5	181	0.1
2180 <i>Arvicanthis</i>	174	8	549	0.2	75	3	112	0.05
436 <i>Otomys</i>	7	1	13	0.03	5	1	5	0.01
380 <i>Lemniscomys</i>	4	1	4	0.01	16	4	41	0.1
4248 field rats	259	6	697	0.2	169	4	339	0.08
394 house rats	89	23	316	0.8	126	32	651	1.6

- Column 1. Number of times flea species recorded.
- Column 2. Percentage infestation.
- Column 3. Total number of fleas collected.
- Column 4. Average number of fleas per rat.

At Taveta, at the foot of Mount Kilimanjaro, and at Naivasha, situated on the floor of the Rift Valley, *Xenopsylla cheopis* displayed a much greater affinity for field rats than was found to be the case for Nairobi.



	No. of rats trapped	<i>X. cheopis</i>				<i>X. brasiliensis</i>			
		Hosts infested	No. of fleas		Average per rat	Hosts infested	No. of fleas		Average per rat
			♂♂	♀♀			♂♂	♀♀	
<b>Taveta:</b>									
<i>Rattus rattus</i>	40	3	1	2	0.07	26	91	108	4.9
<i>Arvicanthis</i>	138	79	123	233	2.5	13	6	12	0.1
<b>Naivasha:</b>									
<i>Rattus rattus</i>	17	5	12	17	1.7	—	Nil	—	—
<i>Arvicanthis</i>	222	65	95	115	0.95	17	13	12	0.1

*The geographical distribution and carriage of Xenopsylla cheopis and X. brasiliensis*

In Kenya, *X. brasiliensis* is to be found in all localities *Rattus* has been able to colonize, and it thrives in all the different types of climate, from the hot and humid coastal regions to the cold and damp mountain slopes, and even in the very dry areas with high temperatures and little humidity. One would expect that so adaptable a flea would be easily transported from these shores to colonize other parts of the world, but, as far as can be gathered, its geographical distribution is very limited.

This limited geographical distribution of *brasiliensis* can be partly explained by the facts presented in this paper. Its failure to colonize *Rattus* living underground limits its capacity for establishing itself in other countries where its host is mainly confined to earth, whereas *cheopis* establishes itself only on rats living underground and not on rats living in thatch or other forms of roofs. These attachments are also amply borne out by what is known from surveys of field rodents, which also live in earth, and it is found that *Mastomys coucha* and *Arvicanthis* act as hosts to *cheopis* in Kenya. In the native reserves, the African population lives in thatched roof huts in which *Rattus* nests, and *brasiliensis* is almost the sole ectoparasite, whereas in the Indian trading centres in such reserves, with corrugated iron walls and roofs, *Rattus* nests in burrows at the bases of walls and *cheopis* is the ectoparasite.

There seems to be a parallel between *Xenopsylla brasiliensis* in Africa with *X. astia* in eastern Asia. Hirst (1927) states that, "In Colombo, *X. astia* seems to have an affinity for rats living in roofs and burrows in the walls of domestic premises." The habits of *X. cheopis* in the two areas appear to differ as Hirst adds that, "*X. cheopis* seems to have a marked predilection for comparatively dry situations such as granaries and warehouses. Dutch observers such as Otten (1924) have stressed the point that it is not adapted to multiply in nesting places out-of-doors or anywhere liable to marked excess of ground moisture."

#### IX. DISCUSSION

The physical and climatic conditions in Nairobi have been studied and the only factor which can be closely related to plague incidence is that of rainfall, which determines the vegetation. Plague in Kenya, in its broader aspects, is also apparently governed by rainfall, which affects the quantity

and quality of food available to support the rat and flea populations and also influences the survival rates of these animals.

The Nairobi township can be regarded as typical of all townships in Kenya, having *Rattus rattus* as the domestic rat, whether in African, Asian or European residences, or stores or shops, and *Xenopsylla cheopis* is the dominant ectoparasite in semi-permanent or permanent types of buildings. In the larger townships, *X. brasiliensis* is also found in fair numbers, generally associated with Indian bazaars, grain storage depots and some African dwellings. Although types of buildings in general are important in influencing the species of fleas to be found within them, the flooring and roofing materials, and general facilities afforded for the nesting of *Rattus rattus* within these types, have the greatest influence, and determine whether rats are forced to build their nests in underground burrows or adopt their normal habitat in the roof.

According to Hirst (1933), "It is therefore essential in a flea survey of such an area to take into account the type of premises trapped and the nature of the goods they hold, particularly if they are imported from abroad." Experience in Kenya amply corroborates Hirst's statement regarding types of premises, but indicates in addition that main attention should be devoted to flooring and roofing materials and the positions of nests when ascribing the species of flea to such premises. The nature of the goods in different premises does not appear to influence species distribution in Nairobi, since goods of the same nature are present at Pumwani and the K.A.R. lines, yet the species present are different.

An interesting problem now awaiting solution is to find out why *Xenopsylla cheopis* chooses *Rattus* nesting in burrows as a host and why *Xenopsylla brasiliensis* chooses *Rattus* nesting under iron or thatched roofs.

#### X. SUMMARY

1. The physical, climatic and economic conditions in Nairobi township are briefly discussed. The factor which appears to be most closely related with the incidence of plague is rainfall. A growing season producing, mainly by virtue of ample rainfall, large crops of cereals, which for various reasons may be kept in storage for long periods and become easily available to the rat population, is invariably followed by plague.

2. The numbers of Indians and Africans are given together with the incidence of the disease in these two types and the localities where the disease originates and persists.

3. The distribution of rat and flea species is outlined and shows an irregular distribution of the species of *Xenopsylla*. The rat population during outbreaks shows a higher density than during quiescent periods, but not such as to indicate that numerical strength alone is the main factor causing outbreaks of plague in the *Rattus* population. Higher flea populations follow high densities in the rat population.

4. Attention is drawn to the area where plague originates and persists and to the mixed flea population of the locality. Pumwani and Pangani with almost pure *cheopis* colonies do not figure in early outbreaks and in them the disease ceases much earlier, but they suffer heavily during epidemics.

Outbreaks of plague in Nairobi are associated with grain storage areas and negligence and improvidence are important contributory factors.

5. The results of the survey have enabled some advance to be made in understanding the distribution of the two main species of *Xenopsylla*. All *Rattus* living in earth burrows have been found infested with *Xenopsylla cheopis*, and *Rattus* living in roofs or walls with *Xenopsylla brasiliensis*. These facts explain why such places as Pumwani with its African population has a *cheopis* colony and the K.A.R. lines have *brasiliensis*. In the Indian Bazaar with varied facilities for nesting, there is a mixed population of fleas.

The application of these facts to rural areas explains why *brasiliensis* is almost the sole ectoparasite of *Rattus* living in thatched roof habitations, and why field rodents such as *Mastomys coucha* and *Arvicanthis abyssinicus* living underground are hosts to *Xenopsylla cheopis*.

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