PRELIMINARY RAT-FLEA SURVEY AND SOME NOTES ON ITS RELATION TO LOCAL PLAGUE, HONGKONG.

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Period under survey	= One year (1929–30)
Territory under survey	= City of Victoria and other urban areas on Hongkong Island
Local rodents examined	= *Rattus rattus, Rattus norvegicus*
Total rats examined	= 442
Total fleas examined	= 2286
General "cheopis index"	= 4·78

The chief object of the research here recorded was to try and bring this Colony into line with other plague centres from which valuable figures on this subject have already been recorded.

Hongkong is peculiarly important in the history of plague, and a contribution from this endemic centre is long overdue. Although, in recent years, cases have been few, and there is a remarkable lack of evidence of this epizootic among the local rats, the danger which threatens this Colony every summer cannot be ignored.

I shall confine myself to dealing with the subjects of (*a*) the "cheopis index" (*i.e.* the average number of plague-carrying fleas, *Xenopsylla cheopis*, per rat); (*b*) the other fleas found on the local rats; (*c*) the incidence of rat-plague, both seasonal and regional; these subjects being of world-wide importance.

Minor facts, valuable but of more local interest, are the flea indices for each month, correlated with the climatic changes; the flea indices for each district in relation to population, type of premises and human plague incidence; estimated rat population; the species of rodent and the maximum or minimum number of fleas per rat.

The number of rats caught (per month or per district) would also be of interest. At present, however, such figures are very unreliable in Hongkong, because traps are not evenly distributed over the island, but have to be set with the more urgent object of destroying the greatest number of vermin in the most important areas. I have, however, sought to obtain a fair sample from all the urban districts.

Moreover, the majority of rats destroyed in the Colony are killed or found dead by the inhabitants, and deposited in special bins hung in every street for this purpose. Even those caught alive are mostly found on the "bird-lime" boards, which are so successful as traps. It naturally follows that only a small proportion of the total catch is from *wire-traps*, undamaged, fresh and dry.

Unfortunately, also, this investigation had to be carried out in spare moments, without a laboratory or the best of apparatus, and I could not continue it beyond a full year. Even then, some weeks were occupied in perfecting the technique and organising the procedure from rat-trap to microscope.

Nevertheless, what has been done is of some value, if only as a guide to future research under similar conditions.

The procedure finally adopted for obtaining specimens was as follows: All living, healthy and uninjured rats caught were collected daily, each trap with its contained rat being placed in a separate white canvas bag on the site where the trap was set. These bags were then sent from the various Health Districts (into which the city is divided) to the central sanitary station, each labelled with date, address where caught, etc. On arrival at the Sanitary Station, sack, cage and rat were put, untouched, into airtight chloroform boxes. When dead, the rat was removed, carefully combed by a trained coolie and the sack inverted and shaken over a white table. All fleas thus found were collected and put into a tube, containing absolute alcohol, to which the rat-catcher's label was affixed. These tubes, each representing one rat, were then sent to me and the contained fleas dehydrated, cleared, mounted, and classified under the microscope. All dead rats were, ultimately, sent to the pathologist for classification and examination for signs of plague, etc.

I have not attempted to note from which species of *Rattus* these fleas were taken. It is not only of minor importance in a preliminary survey, but would have entailed another expert to check classification. As it was, I could not superintend, regularly, the trapping and combing, but had to rely on the inspectors of my staff to whom thanks and praise are due for the conscientious and reliable manner in which this work was done.

In addition to the flea survey, I instituted a weekly return of all rats caught, showing numbers and types of traps set, bait used and rats captured in each Health District. This not only gives an idea of the rat population but the relative value of traps and baits. Owing to the large amount of edible refuse, rice warehouses, etc., in Chinese cities, traps must be baited with great skill and the results are often disappointing. Thus, for the five months, August to I ecember 1928, 5798 traps were set but only 736 rats caught *alive*. This gives a *rat population index* of about 13. Most of these were found on the "bird-lime" boards, and were useless for combing.

As previously mentioned, by far the greatest number of rats and mice destroyed in Hongkong are found, already dead and often decomposed, in the dumping-bins placed everywhere for this purpose. Thus, the number *destroyed* during this period (August to December 1928), was as high as 58,310, but only 259 of these were available for combing. That the city is seriously rat-infested is shown by the enormous yearly destruction of these vermin which, in 1928, totalled 155,572 or an average of 426 a day.

Returning to the fleas themselves, the results for the 12 months under survey were:

Total number of rats searched = 442

The fleas collected were as follows (females greatly predominating):

Xenopsylla cheopis	= 2117
Leptopsylla musculi	= 163
Ctenocephalus sp.	= 3
Pulex sp.	= 3
Total number of fleas	= 2286

Only the one species of *Xenopsylla* (*cheopis*) was found, although *X. astia* was carefully searched for. The *Pulex* are probably accidental to the rats concerned. Apart from *X. cheopis*, there were only 169 other fleas and the "cheopis index" was as high as 4·78.

The number of rats from which *no fleas* were obtained was 108 or 25 per cent. of the total, and the majority of these were caught in the colder and drier months.

The *maximum number of fleas* obtained from one rat was as high as 67, all *X. cheopis*, and caught in No. 10 Health District. Other heavy, individual infestations of *X. cheopis* were:

Rat caught in	No. 8	District in	August	= 57 fleas
,,	No. 8	,,	June	= 50 ,,
,,	No. 8	,,	June	= 41 ,,
,,	No. 1*a*	,,	April	= 39 ,,
,,	No. 1*a*	,,	September	= 35 ,,
,,	No. 9	,,	May	= 30 ,,

Ten other rats had over 20 *X. cheopis* each, from the central districts, in the summer months. The four highest cheopis counts were all from warehouses, three of the rats being caught in a rice merchant's store. Curiously, No. 8 District is at the opposite end of the town to the area wherein the 1928 plague cases occurred, but not far from the few 1929 cases, human and rat. As shown later, however (Table III), this district has a high "cheopis index."

It is of interest to study the "cheopis indices" for the different *months* and Health *Districts* and compare them with the incidence of human and rat plague. Owing to the fact that so few cases have been notified since 1924 (only six cases in man and four in rats), it has been necessary to go back many years and take the total figures for the last decennium. This, unfortunately, creates a possible, comparative error.

Table I shows that the "cheopis index" rose suddenly in March, the beginning of the hot, wet season, and, after reaching a maximum in May, fell more gradually in the second half of the year. The lowest index, 1·2, was actually reached in February when the mean temperature was at its lowest also and the rainfall slight. Only three months later, it attained the peak at

8·5 in the month which also shows the greatest number of plague cases and the highest *relative humidity*. The most striking feature of this table is that so many of the factors have their maxima in the same month, May, showing the important, *close relation between rat-plague, number of* X. cheopis, *human cases, rainfall and relative humidity*. The succeeding months also show this correspondence and, not only is the incidence of plague (both animal and human) higher in the warm, wet season, April to July, but these months give very large cheopis averages.

Table I. *Showing all the correlative factors for the year under survey, in the figures for each month.*

		Fleas found					Cases of plague for last ten years		Climate		
Months	Rats caught	*X. cheopis*	*Lepto-psylla*	*Cteno-cephalus*	*Pulex*	Cheopis index	Human	Rat	Temp. mean (F.)	Rainfall (inches)	Humidity (relative)
Jan.	39	108	12	—	—	2·8	11	3	61·6	1·88	82
Feb.	33	39	26	—	—	1·2	33	—	58·7	3·57	82
March	49	222	30	—	—	4·5	107	1	63·2	5·18	86
April	45	238	31	1	—	5·3	365	34	70·9	4·10	81
May	44	**373**	5	1	—	**8·5**	**730**	**68**	77·4	**18·41**	**87**
June	31	241	—	—	—	7·8	539	40	79·9	15·13	83
July	17	123	—	1	2	7·2	171	5	**83·5**	4·78	80
Aug.	30	213	—	—	—	7·1	63	—	82·4	12·91	84
Sept.	29	151	—	—	—	5·2	14	1	81·6	3·91	75
Oct.	27	94	2	—	—	3·5	12	—	75·1	0·43	65
Nov.	48	168	**49**	—	—	3·5	20	—	69·3	0·81	67
Dec.	**50**	147	8	—	1	2·9	10	—	65·6	0·02	72
Totals or Averages	442	2117	163	3	3	—	2075	152	72·4	—	—

The apparent discrepancies, such as the rather low "cheopis index" for March with a high relative humidity, and the large number of plague cases in April when the index and humidity are only moderately high, may be accounted for by having to compare ten-year readings of plague with one-year figures of fleas and meteorological data. In the absence of sufficient plague cases for the years under survey, it would have given more consistent results if decennial indices, humidities, etc., could have been tabulated. Unfortunately, no previous flea counts are available. In spite of this relative error, however, Table I is clear enough, if carefully studied, to confirm the striking constancy of the factors which regulate the bionomics of the plague vector. Of these factors, a high relative humidity seems to be the most important. For the greater part of the year, Hongkong is an ideal incubator for *X. cheopis*. A large seabord trade, an enormous, uncontrolled, floating community, ample food for rats (such as rice), and an over-crowded insanitary population, all favour a continuance of plague.

The *regional flea counts*, although of more limited interest, are worthy of record as indicating the type of premises and human environment most favourable to the plague vector. When tabulated with the corresponding cases of plague, there is evidence of a definite relationship.

For the purposes of sanitary administration, Hongkong is divided into defined areas, thirteen of which are allotted to the City, numbered in sequence from East to West. They vary much in size but, with some grouping, can be treated as natural divisions of a cosmopolitan town into social and racial, as well as topographical, sections.

From the *regional figures of Table II*, it will be observed that the Districts 1*a* and 2*a* combined, at the east end of the town, had both the highest case incidence of human plague and the highest "cheopis index." The rat epizootic, however, seems to have been heaviest in No. 9 District; a densely populated and poor class area. Here also the "cheopis index" and plague incidence were fairly high, while the number of rats caught was only exceeded in the adjoining District, No. 10, which is somewhat similar in type. It is difficult to account for the large flea count in No. 8 area which has not given

Table II. *Showing cheopis indices and plague-case incidence (decennial summary) for each District of Hongkong.*

Health districts	Rats caught	Cheopis index	Cases of plague for last ten years: Human	Rat
1	12	4·0	153	10
1*a* and 2*a*	30	**6·6**	**319**	19
2	21	6·1	227	19
3	17	2·6	12	2
4	20	3·9	122	13
5	7	3·0	88	10
6 and 6*a*	41	3·1	70	10
7 and 7*a*	21	2·5	92	15
8	82	6·0	55	12
9	67	5·8	156	**24**
10	**97**	4·9	106	14
Sai'wan	14	2·0	30	—
Aberdeen	13	3·8	24	—
TOTALS	442	—	1454	148

many cases of plague; although it includes better class dwellings, there are a large number of big rice stores. The remainder of the Districts show a very consistent correlation of figures, and bear out my suspicions that it is the *boat-communities and seabord commerce*, rather than the class of people or the rat population, which are the chief factors in these regional variations.

It is of interest to note that the four plague cases, occurring in the period under review, were from Nos. 1 and 1*a* Districts.

A few words are here needed on the *type of premises* and topographical nature of the health districts mentioned.

The grouped Districts, *Nos.* 1, 1*a*, 2*a and* 2, where the maximum number of plague cases (both human and rat) have occurred, are at the east end of the town which, bounded on the north by the sea-harbour and, on the south, by rapidly rising hills, forms a densely populated, long, narrow strip of mostly Chinese houses.

No. 1 *area* is a large one, consisting chiefly of better-class residential houses on the foothills, but including, near the sea, a small, over-populated area of old Chinese houses. It also borders on a sheltered bay, where sampans and junks with merchandise come and go in large numbers.

Nos. 1*a and* 2*a*, which are of special interest in Table II, are smaller areas but densely populated in the village of Wanchai, and with a large influx of small shipping. Some of the houses are old and the streets very narrow. A big portion of the coast has recently been reclaimed here, and new warehouses, increased shipping, etc., will probably attract more rats.

No. 2 *area* is large but less important; it includes the naval dockyards and military barracks, and only one small over-crowded area adjoining No. 2*a* Health District.

No. 3 is mostly European and residential. It includes Government House and the Public Gardens. It is the least dangerous area and has had fewest cases of plague in the whole city.

No. 4, with a surprisingly high plague incidence, is again small and, although mostly shops and offices, includes some very crowded streets, and a busy waterfront with several food-merchants' stores.

Nos. 5, 6 *and* 7 *Districts*, although small, are very crowded, Chinese, business areas, but Nos. 5 and 6, at any rate, show comparatively few cases in past years, and the "cheopis index" is low in all this area. In fact, Nos. 7 and 7*a* give the lowest index in the city.

No. 8, rather larger, includes schools, hospitals and several institutions. Part of it is European reservation, with a better type of house and more open spaces. A few streets near the sea are narrow and congested. The high "cheopis index," shown on the table, may be accounted for by the warehouses on the bund and the influx of cargo, but it does not, in this one instance, correspond with the very low incidence of plague.

No. 9 *District* is, again, quite small but the most crowded, poor and insanitary in the city; narrow streets, intersecting blocks of old, dark tenements, in which a poor class of Chinese lives in a state of congestion probably unequalled, for so small an area, anywhere else in the world. This area, together with No. 10, furnishes most of the infectious disease of the Island. On Table II it gives us the highest rat-plague figure and the third largest number of human cases, corresponding to a high flea index.

No. 10 is a very big area at the extreme western end of the town and, although less residential and congested, it embraces a long sea frontage and most of the larger warehouses, as well as an Offensive Trade area, slaughterhouses and factories. The ground rises rapidly behind it, leaving quite a narrow strip which supports the important buildings. Most of the rats caught come from these "godowns" (the maximum number in this research came from No. 10), and, although the cheopis count is only moderately high now, it has been a bad plague area in the past.

Sai'wan and Aberdeen are small towns outside the City area and, at present, of lesser importance. The former lies at the eastern end of the north shore, and the latter on the other side of the Island. Plague cases have occurred in both. The busy shipping trade in the harbour of Aberdeen, in view of the fairly high "cheopis index," make of it a potential danger zone.

It is difficult in so short a survey and with restricted figures to draw very reliable *conclusions*. It can, however, be said that, of the fleas found on local rats, *X. cheopis* stands at a very high figure. This, together with a large rat population, an exceptionally large shipping trade along an almost endless coastline, an over-crowded insanitary population and a warm humid climate, presents ideal plague conditions.

It was noted that not only plague but other serious epidemic diseases concentrated, other things being equal, round the points of *small-boat activity*. Thus, Districts Nos. 1 to 2, which gave such high figures, lie round a small bay, in which comes and goes a constant fleet of sampans and junks, in addition to a permanent floating population and insanitary squatters who occupy shacks and derelict craft on the foreshore. A more orderly sea-front might reduce this obvious menace.

These figures show, I think, that a big factor in the problem is the *floating population* and its unrestricted migrations. Thus, if one attempts to predict from the results of a limited survey, future outbreaks of plague may be expected to concentrate on certain areas of which Nos. 1, 1*a* and 2*a*, at the eastern end of the town, come first, followed by Nos. 8, 9 and 10 towards the western side. The distribution of the few cases in 1928 and 1929 bears this out.

Although so many of the rats examined came from the large warehouses at the western end of the city, this does not seem to indicate particular danger in that area. The cheopis count is not very high and, as long as the rats are held up by a sufficient supply of food and away from domestic areas, there is little risk.

The very few cases of *rat plague* discovered and recorded in recent years is due, I am afraid, to inadequate pathological examination. The rat destruction and collection system cannot be blamed, as it is particularly thorough and few carcasses escape. Putrefaction and maceration of the rat carcasses in disinfectants certainly add to the difficulty, and bacteriological confirmation is often impossible. Although there must be a certain amount of endemic infection kept up among the local rodents, it is a short and easy step from the unguarded shipping, constantly arriving from plague foci on the mainland of Asia, to the attractive harbourage of native dwellings around the quays. Lack of water, on the one hand, and rice cargoes, on the other, encourage a constant interchange of rats.

As regards *season*, the figures show that May is the month in which the maximum of cases in men and rats may be expected, while the period April to July is undoubtedly the season of greatest danger. The 1928 cases occurred in May, June and July.

Only constant vigilance can avert a repetition of the catastrophes of the earlier years of the Colony and maintain the excellent results obtaining at present. The 5000 cases of 1894 is a low estimation, and the few cases of recent years must be regarded as warnings rather than indications of a *fait accompli*.

Three measures stand out in connection with the comparative immunity from plague which Hongkong at present enjoys: (1) house to house cleansing and whitewashing in all districts; (2) removal of all superfluous woodwork and hollow spaces in the native houses; (3) vigorous rat destruction. These measures and their originators have not only saved many lives, but reduced the enormous losses in trade and finance which accompany any serious outbreaks of infectious disease in a large port, such as Hongkong. Once again it is demonstrated that public health and disease prevention owe their successes to swift and comprehensive measures, based on carefully determined scientific observations as to causes and conditions.

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