LEPTOSPIRAL INFECTION RATES OF WILD RATS IN BRITAIN

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(With 1 Map in the Text)

Following the publication of a report by Broom & Gibson (1953) on the infection rate with *Leptospira icterohaemorrhagiae* of *Rattus norvegicus* in a rural area in Wales, Mr R. A. Davis of the Infestation Control Division of the Ministry of Agriculture and Fisheries, kindly offered to ask the help of the Technical Officers of the Division to enable the survey to be extended to other parts of England and Wales. The areas where the rats were obtained are shown on the map by circles, and certain towns indicated in Table 2 are denoted by letters. The collection included *R. norvegicus* and *R. rattus*, some trapped alive and others killed by poison or other means. An additional series of *R. rattus* gassed during the fumigation of ships was kindly supplied by Prof. D. T. Robinson of the Public Health Laboratory, Liverpool. For the purposes of this survey it will be convenient to consider the two species separately, and also to regard the ship rats as distinct from *R. rattus* taken on shore.

When rats were collected after death, the only materials available for examination were kidneys fixed in formol-saline. One complete kidney from each rat was removed and placed in approximately 15 ml. of normal saline containing 10 % of formalin by volume. When the kidneys were received in London they were split longitudinally and one-half of each was stained by Levaditi's method of silver impregnation. For microscopical examinations, only one complete section was used as a rule. The whole section was scanned at a magnification of $\times 100$, which is sufficiently high to enable tubules containing colonies of leptospires to be detected. Any suggestive areas were then examined with a 2 mm. oil-immersion objective, and a positive diagnosis was made if complete leptospires of typical morphological appearance could be distinguished.

When only sections of kidney were available for examination, there was of course no definite proof of the identity of the leptospires present, since the different serotypes cannot be identified by their morphological appearances. In the case of indigenous *R. norvegicus*, however, it seems justifiable to assume that the leptospires were *L. icterohaemorrhagiae*, because all the strains isolated from the living rats belong to that serotype, and no other has been found in rats in Britain.

RATTUS NORVEGICUS

Rats collected after death

The aggregate of 850 consisted of 403 from rural districts and 447 from urban areas; the latter included 130 rats from the sewers of two cities. The total number infected was 370 (43 %), and the rats' type of habitat apparently made no difference to the infection rates when they were calculated from the figures for the whole country. The rates were: rural, 43 %; urban (excluding sewers), 45 %; sewers, 43 %. As is shown in Table 1, however, there were some variations in infection rates among rats from different areas, and certain towns (Table 2) showed rates distinctly above or below the general average, both for surface and for sewer rats. The numbers of rats taken in circumscribed areas in rural districts were too small to allow any conclusions to be drawn about possible local variations in infection rates.

Table 1. *Variations in infection rates in different areas*

Area	Proportion infected
South Wales	59/81 (75 %)
Northern England	53/90 (60 %)
Upper midlands	63/127 (50 %)
Central midlands	154/325 (47 %)
South-west England	33/78 (40 %)
London and Home Counties	46/160 (30 %)
East Anglia	57/208 (30 %)

Table 2. *Variations in infection rates in individual towns*

Town (see map)	Proportion infected
A	20/27 (75 %)
B	33/55 (60 %)
C	3/33 (10 %)
D (sewers)	36/47 (75 %)
E (sewers)	19/80 (25 %)

A number of different poisons had been used to destroy the rats, but there was no indication that any of the poisons prevented the staining of leptospires by silver impregnation.

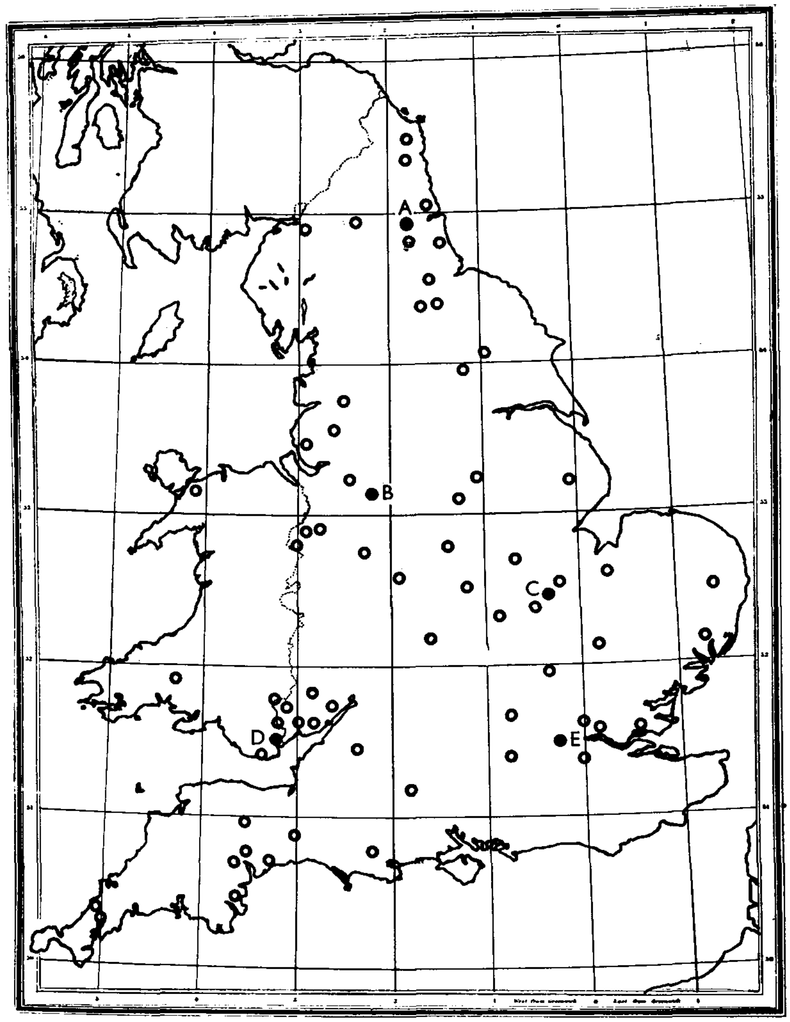
The sex ratio of the whole series was males 424, and females 426, with infection rates of 45 and 42 %, respectively. This approximately equal incidence of infection in the sexes is found in most surveys, but an unusual feature emerged from our series when the rates were computed separately for young and adult rats. Of 222 young rats, 77 (35 %) were infected, and of 628 adults, 293 (46 %). Such a high rate among young rats is a most uncommon finding. For instance Schüffner (1934) gives rates of 3 % for young, and up to 45 % for adult rats in Holland, and Broom & Gibson (1953) found only 1 infected young rat among 82 examined.

Ostertag (1950) thought that the difference in infection rates between young and adult rats was evidence in favour of a venereal route of transmission, because his observations indicated that the change in carrier rate coincided with sexual maturity. Most of the rats in the present series were classified (as requested) into 'adult' or 'young' (which does not necessarily mean 'immature') but the actual weights of 195 of the animals were also recorded. According to Leslie, Perry & Watson (1946) the median weight at which *R. norvegicus* reaches sexual maturity varies greatly in different environments, and may range between 115 and 210 g.

for females, with males slightly heavier. Table 3 shows that leptospires were demonstrated in 24 (40 %) of the 59 rats in this group which weighed 225 g. or less. Even if the lowest weight of 115 g. is taken as the criterion, 11 of the 19 rats below that limit showed infection. There is thus no evidence in this series that a low infection rate was associated with sexual immaturity.

Table 3. *The numbers of infected and uninfected young rats of different weights*

Weight (g.) ...	Up to 70	71–85	86–115	116–140	141–170	171–200	201–225	Total
No. infected	4	4	3	8	0	3	2	24
No. uninfected	2	2	4	6	6	10	5	35



Map showing areas where rats were collected.

A, B and D = towns with high infection rates. C and E = towns with low infection rates.

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Rats caught alive

This series comprised 219 rats, 97 caught in a refuse destructor in a midland town and 122 from three London dormitory boroughs, two on the north-east and one on the south-east of the city. The rats were brought alive to the laboratory where they were chloroformed, blood was taken for agglutination tests, and cultures were made in Korthof's medium from one kidney of each rat. The combined results of these two tests indicated that 93 (43 %) of the rats were infected—45 rats were positive in both tests, 28 by agglutination only and 20 by culture only. Silver-stained sections were prepared from 69 of the midland rats, and Table 4 shows the relative efficiency of the three methods of estimating infection rates in this particular group. The joint results from all three examinations showed that 39 (55 %) were infected. It will be noted, however, as has been found by other workers, that no single test can be relied on to detect every carrier.

Table 4. *Results of different methods for detecting infection in* 69 Rattus norvegicus *caught alive*

	Agglutination reaction	Kidney culture	Kidney section	Number
	+	+	+	9
	+	+	−	4
	+	−	+	3
	+	−	−	5
	−	+	+	6
	−	+	−	6
	−	−	+	6
Total positive	21	25	24	39*

* Total positive by all methods combined; the remaining 30 rats failed to show any evidence of leptospiral infection.

All the sixty-five strains isolated in culture were tested serologically and proved to be *L. icterohaemorrhagiae*. The subtype of fifty of the strains was also determined, and was found to be *L. icterohaemorrhagiae* (AB) in thirty, and *L. icterohaemorrhagiae* (A) in twenty.

RATTUS RATTUS

Rattus rattus *from towns*

It is thought that *R. rattus* was introduced into Britain about 700 years ago, and it was the only species of rat present until *R. norvegicus* reached this country in the early eighteenth century. Although there is no actual proof that the spread of *R. novegicus* was directly responsible for the subsequent reduction which took place in the numbers of *R. rattus*, the species is now restricted in its distribution. According to the Ministry of Agriculture and Fisheries (1953) *R. rattus* is now found only in or near sea ports and in large towns to which it may be carried in merchandise. This would explain why none of the 123 *R. rattus* we were able to examine came from any of the rural areas included in the survey. Of 88 rats caught in London, 75 were received alive, but all the others were collected after death.

Examination of kidney sections gave the following proportions of infections: London, 0/88; Cardiff, 16/19; Liverpool, 13/14; Wolverhampton, 2/2. One strain, which proved on serological tests to be *L. icterohaemorrhagiae*, was isolated by kidney culture from one of the live rats, all the other cultures being negative. Serum from that rat and from one other contained antibodies for *L. icterohaemorrhagiae*, making the infection rate 2/88 for the London rats by the combined methods.

R. rattus is not generally regarded as a host of election of *L. icterohaemorrhagiae*, and the rate for the London rats conforms to the usual findings for the species; for instance, Austoni (1953) quotes 2% as an average figure. By contrast, the proportion of infections in the other towns is quite abnormal. Unfortunately, no cultures could be made from these rats, so the serotype present is not known.

Rattus rattus *from ships*

This series of 98 rats were also *R. rattus*, but they were collected from ocean-going steamers after fumigation, so it seemed advisable to record them separately. No live rats were included, but kidney sections revealed that no less than 69 were carriers of leptospires.

The various shipping companies owning the steamers kindly supplied information about the last voyages made by the ships before they were fumigated. The areas visited by different ships included North, West and South Africa, India, North and South America, and Australia. There is thus no means of deciding either the country of origin of these rats or the serotypes of leptospires they were carrying.

SUMMARY

1. Microscopical examination of the kidneys of 850 *Rattus norvegicus* killed in various parts of England and Wales showed an infection rate of 43% with leptospires, assumed to be *Leptospira icterohaemorrhagiae* for reasons stated.

2. Infection rates calculated from the whole series were the same for rural, urban and sewer rats, but there were some local differences as between one area and another for both surface and sewer rats.

3. An unusual feature was the finding of a 35% infection rate among young rats.

4. In another series of 219 rats taken alive, agglutination tests and kidney cultures gave an infection rate of 43%. Kidney sections of 69 of these rats were also examined microscopically and the results of the different methods of examination were analysed.

5. A similar survey was made on *R. rattus*. Only 2 of 88 caught in London were positive, compared with 31 of 35 killed in other towns. An additional 98 *R. rattus* killed during the fumigation of ocean-going steamers were examined, and 69 were found to be infected.

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REFERENCES

Austoni, M. (1953). *Le Leptospirosi*, p. 148. Padua: Tipografia del Seminario.
Broom, J. C. & Gibson, E. A. (1953). *J. Hyg., Camb.*, **51**, 416.
Leslie, P. H., Perry, J. S. & Watson, J. S. (1946). *Proc. Zool. Soc. Lond.* **115**, 473.
Ministry of Agriculture & Fisheries (1953). *Rats and Mice on the Farm.* Bulletin No. 30. London: H.M. Stationery Office.
Ostertag, H. (1950). *Z. Hyg. InfektKr.* **131**, 482.
Schüffner, W. (1934). *Trans. R. Soc. trop. Med. Hyg.* **28**, 7.

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