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A long-term study of *Rattus norvegicus* in the London Borough of Enfield using baiting returns as an indicator of sewer population levels

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SUMMARY

This is a long-term study that investigates the dynamics of a population of *Rattus norvegicus* (Berk) inhabiting a sewerage system in London. Thirteen years (1986/7–1998/9) of data from sewer baiting records were analysed (a total of 35478 records). Manholes were baited with the anticoagulant Brodifacoum (0·005%) on a pinhead oatmeal bait base. Time series analysis was conducted on the data set to determine the underlying trend of the data and the population fluctuations about this trend. An exponential curve was found to give an accurate and realistic fit to the data and indicated that the rat population had decreased over the study period. Decomposition analysis indicated a 5-year cycle best described fluctuations around this trend.

INTRODUCTION

Recent reports indicate that surface populations of Norway rats (*Rattus norvegicus*) are increasing in the United Kingdom [1, 2]. The 1993 National Rodent Survey [2], for example, found that infestation levels had increased from 4·4% to 4·8% since previous surveys were conducted in the 1970s [3]. There is a widely held belief that in urban areas surface rat infestations often arise from the sewer and that surface populations reflect those in the sewers. The increase in surface infestations has, therefore, sometimes been attributed to both inadequate sewer baiting, and the increased use of materials in pipework which are not resistant to rodent damage [1]. This contention is supported by a recent study on *R. norvegicus* that demonstrated, through an analysis of faecal material, that rats can move between the surface and the sewer [4]. If there is a high degree of movement of rats between surface and sewers, it should follow that sewer rat infestations have increased over the period of the National Rodent survey, as was concluded in the report of that survey. An objective of this study was therefore to examine the underlying trend in a population of sewer rats.

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Populations of small mammals in Northern latitudes typically undergo multi-annual density fluctuations [5]. These fluctuations are either chaotic or cyclical and are between 3 and 5 years in length [6, 7]. In Japan, for example, populations of grey sided voles (*Clethrionomys rufocanus*) were shown to undergo population fluctuations varying from non-periodic to periods of between 2 and 5 years in length [7]. Flying squirrels (*Glaucomys sabrinus*) in Ontario were found to have a population cycle of 4 years in length [8]. When monitoring the long-term trends in a population it is therefore important to take into account variations in the data around this trend. Relatively little information is however available on multi-annual cycles in rat populations. A second objective of the study was to determine if sewer populations of *R. norvegicus* undergo cyclic or chaotic population fluctuations as observed for other rodents.

METHODS

Data were analysed from 13 years (1986/7–1998/9) of records from sewer baiting carried out in a London borough (a total of 35478 manhole baitings, approximately 3000 per year, from which data were recorded). Baiting was conducted annually between April of one

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year and March of the next. Data were obtained from historical treatment records collected as part of a sewer rodent control programme. The data had not been collected specifically to address the objectives of the study. The months in which baiting was conducted and the specific methodology used were not consistent between study years.

Street manholes were selected and baited with the pre-mixed commercial anticoagulant, Brodifacoum (0·005%), on a pinhead oatmeal bait base. Not all manholes in the borough were baited, and the number baited, were different from year to year. The differences were the result of funding and selection (initially by the Environmental Health Officer, EHO, and later by Thames Water). Manholes in a selected area of the borough were baited over a period of one week, then the same manholes revisited during the next week (an interval of 7–14 days between baiting and checking). Prior to 1989, most bait was presented in sealed plastic bags suspended on string with a very small proportion ($< 2\%$) placed loose on benching, or bait trays using a Bait Depositor in the manhole. After 1989, bait was presented exclusively in plastic bags in the manhole because the original fixed bait trays had rusted away and the EHO was unhappy with the effectiveness of loose bench baiting on narrow curved benching.

On revisiting the manhole the bait was examined for signs of consumption by rats. When no bait had been eaten it was recorded as 'no take'. When all bait had been eaten it was recorded as a 'complete take', while any other quantity was recorded as a 'partial take'. Where bait was laid loose, sawdust or sand was added to distinguish complete takes from wash-off (i.e. the bait being washed away). Where loose or bagged bait was washed away, we could not assume either a take or no take and these data were omitted from the analysis. Manholes that were inaccessible on the return visit were also omitted from the data set (i.e. due to flooding or parked cars making inspection impossible). To simplify the results for analysis they were summarized as either a take (partial and complete) or no take.

The proportion of manholes at which there was a take was used as an indicator of the rat population level. The number of rats feeding at bait stations was not quantified in this study. There is evidence that typically 4–10 rats feed at a manhole with up to 40 or 50 in some cases [9]. In this study only approximately 50% of the recorded takes were partial suggesting that there was a relatively small number of rats feeding at these manholes. We could not assume a linear relationship between the level of bait takes and the rat population level. The average number of rats constituting a take at high population density may, for example, be considerably greater than the number at low population densities. The proportion of bait takes and the level of the rat population should show a broadly similar trend.

Statistical analysis

As the total number of manholes baited was not consistent between years, the analysis was conducted on the proportion of bait takes recorded. The data were first examined visually by plotting the annual proportion of bait takes against the year of study. Time series analysis was conducted on the 13-year data set to determine the underlying trend of the data and population fluctuations about this trend. Using the *Minitab* statistical package (release 12), trend analysis was applied to determine which curve best described the observed underlying trend. Decomposition analysis was then conducted on the residuals of the trend analysis (de-trended data) to determine if the variation around the underlying trend was cyclical. The accuracy of the fit of the models was compared using the Mean Squared Deviation (MSD). The smaller the value the better the fit to the model.

RESULTS

The plot of the proportion of bait takes against the year of study, indicated that there was both a gradual decline in the proportion of takes (referred to as the underlying trend), and substantial fluctuations around this decline. It was found that an exponential curve provided the most realistic fit to the data indicating a gradual decline in the number of bait takes over the 13-year period. Figure 1 illustrates the observed proportion of takes over the study period fitted with an exponential curve together with a five-year forecast. This curve was chosen as it gave a good fit to the data ($\text{MSD} = 0{\cdot}0011$) and did not indicate that the proportion of bait takes would be reduced to zero (i.e. eradication of the population). Over the study period the proportion of bait takes decreased significantly from approximately 0·17 in 1986/7 to 0·03 in 1998/9 ($F = 17{\cdot}75$, $P < 0{\cdot}001$: D.F. 1, 11).

Trend analysis was combined with decomposition analysis to produce a model that enabled both the

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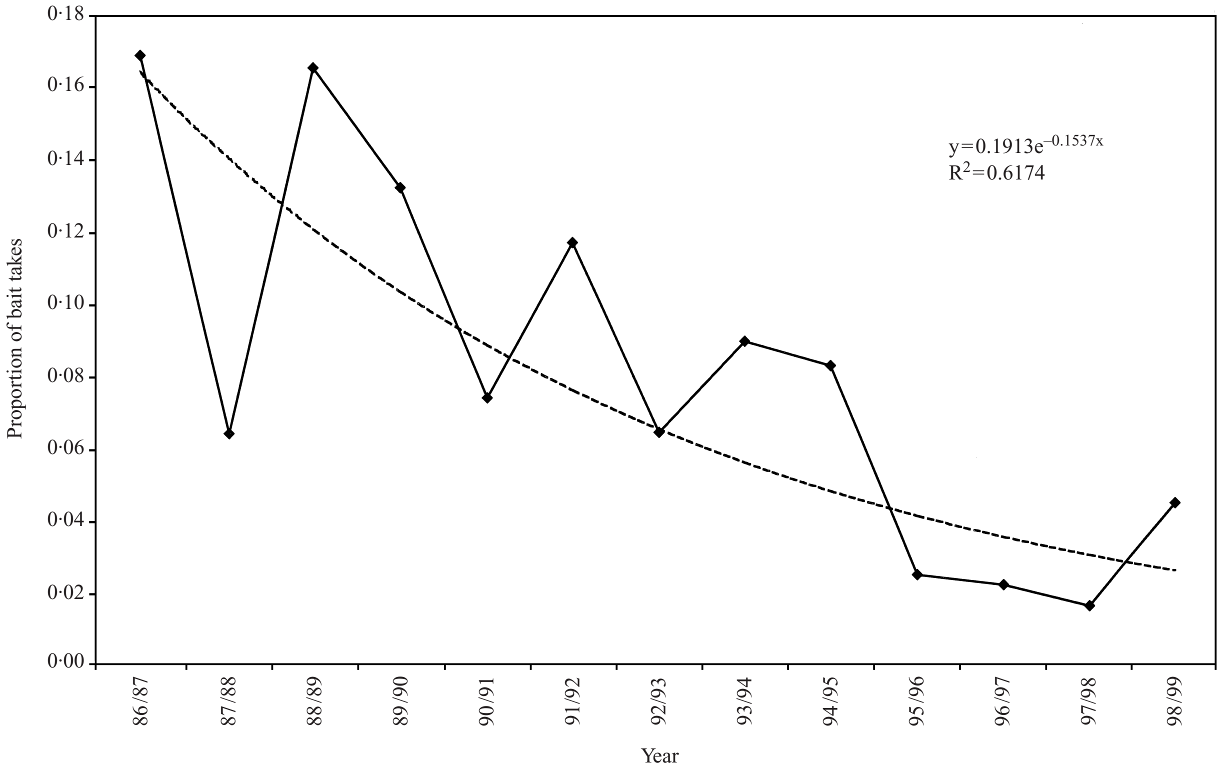

Fig. 1. The proportion of manholes at which rodent bait was taken over a thirteen year period in a London sewerage area. The exponential curve indicates the underlying trend in the data.

Table 1. *The fit of models combining the exponential curve with either a 3, 4 and 5-year cycle* (*indicated by the Mean Square Deviation*, *MSD*)

Multi annual cycle length	Combined model trend and cycle MSD
3-year	0·000888
4-year	0·001117
5-year	0·000460

underlying trend and the population cycles to be forecast. This was achieved by performing decomposition analysis on the residuals of the exponential curve to examine the fluctuations around this curve. Decomposition analysis was performed to examine the fit of a 3, 4 and 5-year cycle. By combining the underlying trend (obtained from trend analysis) and the population cycle (obtained from decomposition) an overall model was produced. A model combining a 5-year cycle with the exponential trend was found to explain more of the variation in the data than any other cycle (Table 1). Figure 2 shows the actual proportion of takes together with the combined 5-year model with a 5-year forecast.

DISCUSSION

The long-term study indicated that the proportion of bait takes decreased significantly over the period, from a proportion of 0·17 bait takes in 1986/7 to 0·03 in 1998/9. This suggests that the rat population also declined during this period. The decline in the proportion of bait takes over the study period was found to level off at around one to two percent bait takes. This suggests that with continued baiting the population would not have been eliminated from the system. This finding is consistent with the widely held view that it is not practically possible to eradicate rat populations in sewers [10].

Although it is not possible to assume a strictly linear relationship between the level of bait takes and the rat population level, it is difficult to find any other reason for the decline in bait takes over the period than a reduction in the population. If the pattern observed in this area of London is representative of the rest of the sewer network, sewer rat populations may have decreased during the periods spanned by the National Rodent Survey. The findings suggest that the perceived increase in the sewer rat population [2] may be unfounded at least in London. Further as surface and sewer populations appear to show

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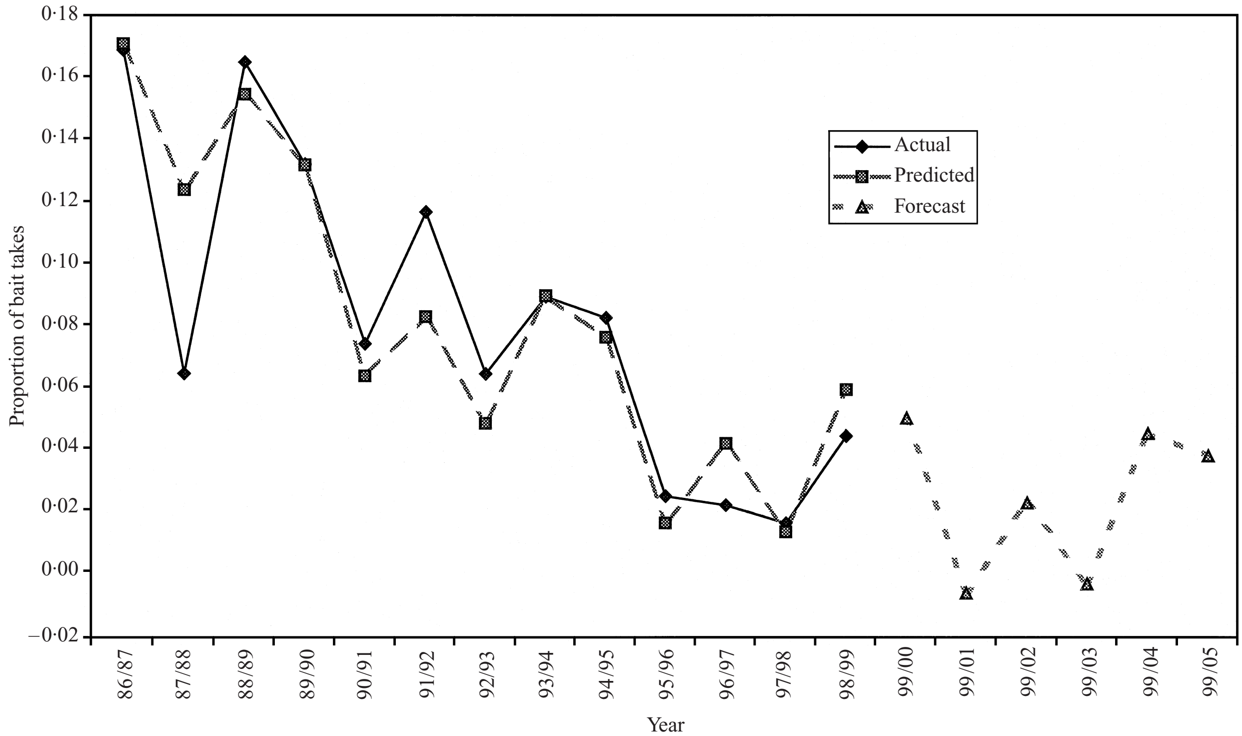

Fig. 2. The predicted proportion of bait takes over the 13 year period, produced by combining the underlying exponential curve, with a 5-year cycle, using decomposition analysis. A 5-year forecast is also given.

opposite trends, if the increase in surface activity is accurate, then it is unlikely to be due to movement of rats from the sewers.

Although it is important to control rats to prevent damage to the sewer infrastructure, their disease carrying potential should be a significant factor in control decisions. There is very little current data in the literature on the prevalence of rodent borne diseases in sewer rats. However in a recent UK survey of 509 specimens of *R. norwegicus*, surface trapped on agricultural land, a total of 13 zoonotic and 10 non-zoonotic parasitic species were found [11]. These included *Cryptosporidia parvum*, *Capillaria* spp. and *Listeria* spp. in 63% 23%, and 11% of rats sampled respectively. The study also found *Yersinia enterocolitica*, *Leptospira* spp., *Pasturella* spp., *Pseudomonas* spp. and *Toxoplasma gondii* in surface trapped rats. The wide range of pathogens found illustrates the continuing potential of rats to play a role in the transmission of infectious disease. However, as this population study suggests that the sewer rat population has declined, the threat to public health, which they present must also have declined.

In addition to the observed decline in rat numbers, as indicated by bait takes, the population also appeared to undergo multi-annual cycles (best described by a 5-year cycle) similar to that identified in a variety of other rodent populations [6–8]. The proportion of bait takes was found to fluctuate by up to 10% between one year and the next. The mechanisms driving multi-annual cycles in rodent populations are poorly understood [12]. The identification of such a cycle within a sewer population of *R. norvegicus* suggests, however, that long term trends may only be identified with confidence, if they are sampled consistently over a period of several years. In the present study if only two samples were taken, the first in 1987/8 and the second in 1991/2, it would have appeared that the population was increasing (see Fig. 2).

Large-scale sampling such as that of the National Rodent Survey are sufficiently statistically robust to draw conclusions on differences in rat population levels between sample years. However, rats have a high reproductive potential and their populations show an inherent variability. This type of study may not be sufficient, therefore, to indicate a long-term trend in rat populations. In addition, the variation observed in many rodent populations is cyclical, and there is evidence that these cycles can be synchronous over large geographical areas of up to hundreds of square kilometres [5, 13]. It may be considered important, therefore, in studies of rat population on any scale to survey repeatedly over several years in order to separate both cyclical and non-cyclical fluctuations from any underlying trend.

This study was not conducted as a controlled experiment, it is not therefore possible to determine if the observed decline in bait takes over the 13-year period was the result of sewer baiting. It is probable that this decline was the result of a combination of factors, which may include improvements in infrastructure affecting harbourage and also changes in food supply. Though baiting will play a role. With the addition of data on other variables such as climatic factors, changes in sewerage composition, improvements in infrastructure etc the data set could be expanded to form the basis of a model of the rat population. The final model would allow rat numbers to be predicted with greater accuracy. Control programmes could, as a result, be directed more effectively and their success monitored more closely.

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