Are bed bug infestations on the increase within Greater London?

L Richards[1] MSc BSc, C J Boase[2] BSc, Dr S Gezan[3] PhD BSc, Dr M M Cameron[1] PhD BSc

[1] Department of Infectious and Tropical Diseases, London School of Hygiene & Tropical Medicine.
[2] The Pest Management Consultancy, Haverhill, Suffolk, CB9 9AF, UK
[3] Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ, UK

Correspondence: Dr Mary Cameron, Department of Infectious and Tropical Diseases, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT, UK.
Telephone +44 (0) 207 927 2337 Email: Mary.Cameron@lshtm.ac.uk

Abstract

The objective of the study was to determine whether the number of properties infested with bed bugs in Greater London is increasing. Data sets for seven boroughs within Greater London containing the number of telephone calls received by pest control teams from members of the public seeking treatment for bed bug and other major domestic pest infestations (cockroaches, fleas, mice, rats and Pharaoh's ants), from January 2000 to June 2006, were analysed. The absolute increase of calls concerning bed bugs increased from 2000-2006 by an average of 28.5 (95%CI: 6.9-50.3) per annum and the proportion of calls concerning bed bugs, as opposed to other major domestic pests, increased by an average of 24.7% (95%CI: 17.2-32.7) p.a. Calls followed up during July across each of the seven boroughs confirmed bed bug infestations. Twenty two adult specimens were collected and identified as the common bed bug, *Cimex lectularius*. Monthly data obtained from six boroughs identified the greatest number of bed bug calls in late summer (August and September) and cyclic peaks with periods of twelve, six and two months were also identified. In conclusion, the number of calls concerning bed bugs increased in Greater London from 2000-2006. This reflects a trend found in other major national and international developed cities. Contributing factors are likely to be passive dispersal owing to a growth in international travel and second-hand furniture sales, lack of awareness of bed bug infestations owing to the crevice-dwelling behaviour of bed bugs, and ineffective control owing to resistance to insecticides and a move from broad-spectrum insecticides. Within the UK, there is a need for additional monitoring and a code of practice for the control of public health pests including bed bugs.

Key words: Bed bugs; *Cimex*; Environmental health; Infestations; Pest control; London

Introduction

Bed bugs are blood-sucking ectoparasites that infest human habitations, and usually feed during the night when the host is sleeping (Thomas *et al*., 2004). They are capable of carrying typhus, kala-azar, anthrax, plague, relapsing fever, tularaemia, Q fever, hepatitis B virus and HIV; but are not incriminated vectors of disease (Usinger, 1966; Webb *et al*., 1989; Silverman *et al*., 2001). Clinical symptoms from bed bugs are caused by the bites, which can result in severe irritation, large weals, itching, inflammation and swelling of the skin (Tharakaram *et al*., 1999; Fletcher *et al*., 2002; Liebold *et al*., 2003; Thomas *et al*., 2004). Reaction to the bites varies with the individual ranging from no symptoms to hyper-allergic conditions, in a few cases (Sansom *et al*., 1992; Tharakaram *et al*., 1999; Fletcher *et al*., 2002; Liebold *et al*., 2003). Additional problems associated with bed bug infestations include lack of sleep, and psychological and social distress from society's stigma concerning pests (Thomas *et al*., 2004). Further difficulties occur because of the intrusive control measures that are used for treatment (Cleary & Buchanan, 2004).

Bed bug infestations were almost eliminated from properties in developed countries during the 1980s (Boase, 2004). The decline was thought to have been owing to decreases in people's tolerance of household pests, improvements in hygiene, and the widespread use of DDT in the 1940s and 1950s (Boase, 2004). Recent observations, however, suggest that the number of infested properties in urban settings has increased in the last 10 years (Paul & Bates, 2000; Boase, 2004; Doggett *et al*., 2004; Ryan *et al*., 2004; Hwang *et al*., 2005).

Awareness of changing pest dynamics is currently limited to anecdotal reports from private pest control companies, local council authorities, clinical reports and other involved in the control of public health pests. Although reports suggest there has been an increase in the number of bed bugs in the UK (Paul & Bates, 2000; Boase, 2004; Ter Poorten & Prose, 2005), there have been no precise data to attempt to quantify the extent of the resurgence (Harlan *et al*., 2008). The present study aims to provide quantitative evidence to support the hypothesis that bed bug infestations are increasing in Greater London.

Method

Data collection

Local authority pest control teams were chosen as the source of data, as each team is responsible for a fixed geographical area within Greater London and has statutory powers to enter infested properties. Furthermore, a direct comparison could be made with preliminary data on bed bug infestations collected from 1995 to 2000 from one Borough (Boase, 2004).

There are 32 boroughs within Greater London that are individually governed by local government council authorities. Each has a pest control team that independently deals with pest-related issues for residential and commercial properties within the borough. All 32 London Borough pest control teams were initially approached in July 2006 at a biannual pest control seminar for councils in Greater London. Data were obtained from seven London Boroughs (just over 20% of all boroughs) that initially responded and agreed to participation. Participating boroughs represented a wide geographical distribution across Greater London, from the north, east, south and west. There was little variation in population size between boroughs (200,000 average total number of people) (National Statistics Office, 2004) and little variation in recommended pest treatment policies described in borough websites at the time of the study (Direct Government UK, 2006).

From borough records, the annual and monthly telephone calls received for pest enquiries from members of the public (predominantly residential) seeking information on pest identification and control were collected from January 2000 to June 2006. The records contained the caller's name and address, pest/s of concern, date of enquiry and date of appointment.

Additional monthly data were obtained for: average temperature (°C) (Intellicast, 2009), numbers of overseas visitors to the UK (National Statistics Office, 2002), and number of UK residents going abroad (National Statistics Office, 2002).

Statistical analysis

Two analyses were performed: (1) to test whether there has been a significant increase in the absolute number of bed bug calls in all boroughs, and (2) to test whether any increase detected was independent of any general trends in calls concerning all pest types, i.e. in order to address the possibility that any increase in the number of calls recorded may simply be owing to improvements in public awareness or willingness to contact the pest control teams. Both analyses tested for interactions with boroughs to test whether trends differed significantly between boroughs.

In the first analyses, the outcome data were the monthly number of bed bug enquiries/borough (available for Boroughs 1-4, 6 and 7, see Table 1.0). Using repeated measures analysis the following components were tested: (1) a quadratic regression for trend, (2) trigonometric functions to describe cycles of different period lengths, and (3) interactions between both of these components. Specific regression parameters were estimated for each borough by incorporating interactions with a categorical borough effect and all non-significant terms were eliminated from the model using the Wald test (Payne *et al.*, 2005). No transformation of the counts was required in order to approximate normality of residuals. Later, covariates for monthly values for average temperature (°C), number of overseas visitors to the UK, and number of UK residents going abroad were tested to verify their influence by individually incorporating them as a last component into the individual borough models and the general model using data from the six boroughs.

In the second analyses, the outcome data were the proportion of bed bug calls/borough/year, i.e. using the number of bed bug calls and the total number of calls for all pests per year (Boroughs 1-5 from Table 1.0). Logistic regression analysis, with a logit link, was used to test whether the proportion of bed bug calls had changed with time, making the assumption that the number of calls followed a binomial distribution, and interactions were incorporated in order to allow for differences between boroughs and years. The significance of each effect and their interaction was tested using an approximated F-test (Payne *et al.*, 2005).

In all tests a significance level of 1% was used, and analysis was performed using GenStat 8 (Payne *et al.*, 2005).

Specimen collection

During July 2006, properties of members of the public who called borough pest control teams with concerns about bed bug infestations were visited by the first author (LR) to (1) confirm whether calls concerning bed bugs could be interpreted as true bed bug infestations, and (2) determine which species of bed bugs were present in Greater London. The properties visited included those that were about to receive an initial treatment, and those that had previously been treated without success but where a re-treatment was required. Evidence of bed bug infestations included faecal spots, eggs, shed skins and live specimens found in cracks and crevices (Boase, 2004; Cleary & Buchanan, 2004). Live bed bugs were collected by brushing them into collection tubes from areas such as bed frames, sofas, mattresses and sheets, using a small paint brush, and an adult from each collection was later identified using appropriate diagrams or keys (Usinger, 1966; Newberry, 1989a).

Results

A summary of the data collected from pest control teams across Greater London is shown in Table 1.0. For anonymity, boroughs that provided data are numbered 1-7. The data demonstrate a significant increase in both the number of bed bug calls and the proportion of bed bug enquiries from 2000-2006. There was no increase

Borough	Year						Monthly data
	2000	2001	2002	2003	2004	2005	
1	58 1.85%	85 2.66%	92 2.56%	137 4.07%	0-1173 5.74%	191 6.39%	January 2000 to June 2006
2	- -	- -	143 1.60%	190 2.08%	200 2.33%	315 3.02%	April 2001 to March 2006
3	- -	93 1.65%	147 2.64%	251 4.78%	271 4.39%	263 4.43%	October 2000 to June 2006
4	29 0.82%	46 1.25%	80 1.70%	94 2.40%	124 2.98%	143 3.56%	January 2000 to June 2006
5*	- -	- -	240 8.63%	367 13.38%	806 17.39%	859 14.6%	- -
6	- -	- -	- -	- -	- -	104 2.03%	September 2004 to June 2006
7	- -	- -	- -	- -	- -	134 6.59%	September 2004 to June 2006

Table 1.0
Total number of bed bug calls per annum and the percentage of calls for bed bugs received by seven London Borough pest control teams for 2000-2005. Where available, monthly data for each borough are also presented.

** Monthly data were not available for this borough.*

for the total number of calls for the six main pests and no significant increase in the individual number of calls for fleas, Pharaoh's ants, mice and rats from 2000 to 2006; there was, however some suggestion of an increase in calls for cockroaches by an average of 12% p.a. (95% CI intervals:1-24%; p=0.030).

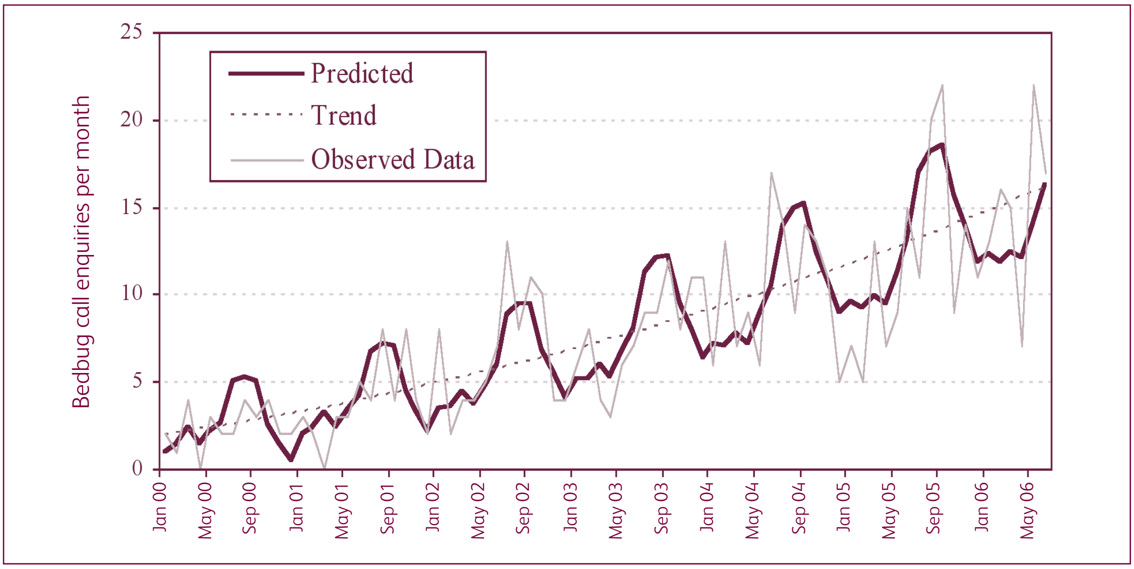

Figure 1.0
Borough 4, chosen as an example of observed data compared to the predicted monthly number of bed bug calls from January 2000 to June 2006. Lines were obtained using multiple linear regressions with repeated measures.

Table 2.0 Estimated parameters, followed by their standard errors, for the average model of monthly bed bug counts by London Borough pest control teams since 2000, based on six Boroughs (1-4, 6 and 7). The model considered a linear trend, and trigonometric functions to describe cycles and their interactions.

Parameter	Estimate	S.E.	Comment
α_0	1.1350	(4.7531)	Intercept
α_1	0.1978	(0.0763)	Linear trend
a_1	-1.3980	(0.3099)	12 months cycle
a_2	-0.6822	(0.3165)	6 months cycle
a_3	-0.6526	(0.6307)	2 months cycle
b_1	-0.4099	(0.6880)	12 months cycle
b_2	1.1120	(0.3169)	6 months cycle
d	-0.0493	(0.0136)	Amplitude with 12 month cycle

Figure 1.0 shows the observed data and the predicted trend in the absolute number of bed bug calls/month for Borough 4, as an example, as this was one borough that had complete monthly data available from 2000-2006. Interactions were found between boroughs and trends. The specific trend parameters for the five other boroughs for which monthly data were available (graphs not presented) suggest a similar positive linear trend for four boroughs (1, 3, 6 and 7) but a quadratic increase in two boroughs (2 and 4).

The predicted average trend for all six boroughs (figure 2.0), calculated using the parameters presented in Table 2.0, shows a steady monthly increase of bed bug calls between 2000-2006, which corresponds to an annual increase of 28.49 bed bug calls (95% CI: 6.88-50.30). This value was obtained by averaging the predictions for a given year: i.e. multiplying the average slope for each month by 144 (12 times the annual prediction sums times 12 months/year). There were also significant cycles with periods of 2, 6 and 12 months, and an interaction between the 12 month cycle and time. The 12 month cycle peaks around August, and its range increased in later years. Furthermore, interactions were found between boroughs and trends and the 2 month cycle, but the average value of this parameter was not relevant.

The second set of analyses found that the proportion of all calls that were for bed bugs increased significantly between 2000 and 2006 by 24.7% (95% CI: 17.2-32.7; $p<0.001$) per annum. There was no significant effect of additional covariates for all boroughs used in the general model. However, when tested against single borough models, there were statistically significant positive associations with average temperature ($p<0.001$, $\beta=0.882$ calls/°C) and with UK residents going abroad ($p=0.003$, $\beta=2.391$ calls/million people) in Borough 3, and with overseas visitors to the UK for Borough 4 ($p=0.002$; $\beta=3.699$ calls/million people).

Bed bug infestations were confirmed in all 22 properties visited, and samples collected were all later identified as *C. lectularius*.

Discussion

Increase over time

The study demonstrates that the number of bed bug calls has increased in London, and supports findings from other major cities in developed countries including Australia, Canada, Denmark and the USA (Doggett *et al*., 2004; Hwang *et al*., 2005; Kilpinen *et al*., 2008; Potter *et al*., 2008). The fact that there is an increase in the proportion of bed bug calls, as well as in the absolute number of calls concerning bed bugs, supports the hypothesis that the increase is caused by true changes in bed bug infestations rather than general improvements in public use rates of the borough pest control teams. The general trend was linear apart from two boroughs where there was a quadratic increase, presumably owing to the variation in either: 1) property infestation densities

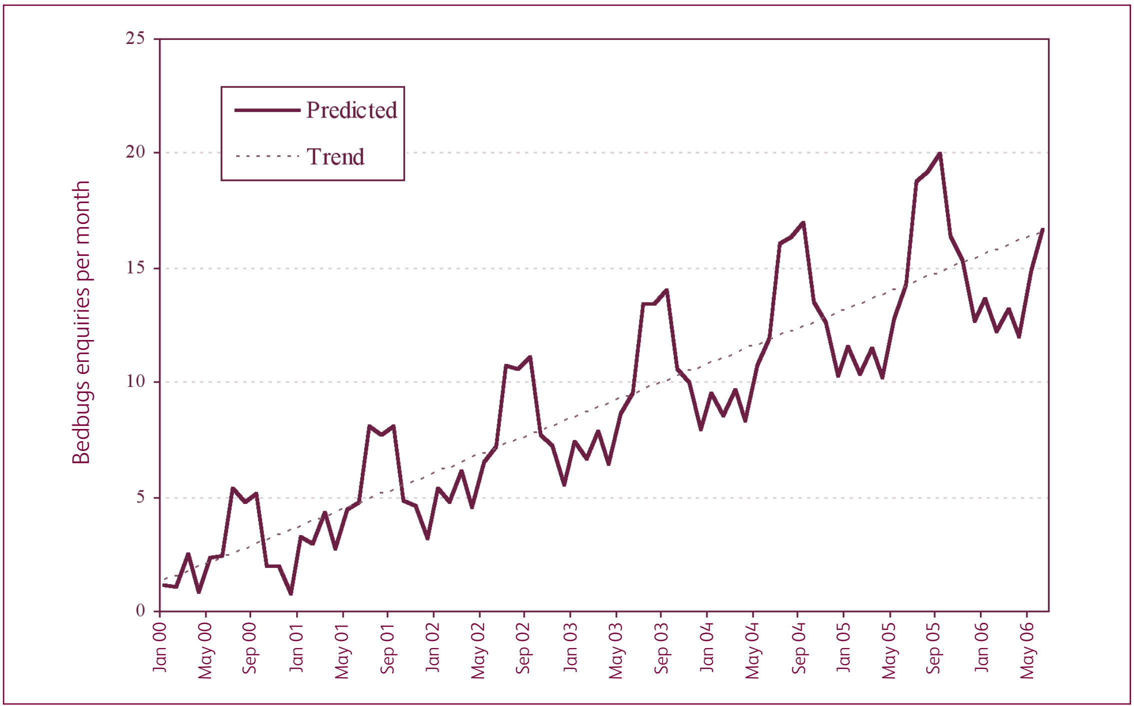

Figure 2.0
The general model for six Boroughs 1-4, 6 & 7 showing the predicted and linear trend using average monthly data for bed bug enquiries. Lines were obtained using multiple linear regressions with repeated measures. The predicted line was obtained using the model:

$$y_t = \alpha_0 + \alpha_1 t + a_1\cos(\frac{2\pi t}{12}) + a_2\cos(\frac{12\pi t}{12}) + a_3\sin(\frac{4\pi t}{12}) + b_1\sin(\frac{2\pi t}{12}) + b_2\sin(\frac{4\pi t}{12}) + d\,t\sin(\frac{2\pi t}{12}) + \varepsilon_t$$

where y_t and ε_t are monthly count, and residual at time t (with t=1 corresponding to January 2000), and α_0, α_1, a_1, a_2, a_3, b_1, b_2, d are the model parameters. The residual variance structure consisted of using a first and second order autocorrelation, which was estimated separately for each borough in a combined analysis.

and/or 2) effectiveness of treatments used between boroughs. There are a number of untested hypotheses suggesting reasons for the increase in bed bug infestations in developed countries (Boase, 2004; Reinhardt & Siva-Jothy, 2007, Boase, 2008). These include passive dispersal and control failure: bed bugs are dispersed passively (Paul & Bates, 2000; Newberry, 1989b), owing to business and holiday travel and purchases of used furniture (Harlan *et al*., 2008), on items including personal possessions such as furniture and suitcases (Doggett *et al*., 2004) aided by human migration (Doggett *et al*., 2004; Masetti & Bruschi, 2007), and there is also recent evidence for insecticide resistance in bed bugs in addition to ineffective application techniques (Temu *et al*., 1999; Myamba *et al*., 2002; Karunatne *et al*., 2007; Romero *et al*., 2007; Harlan *et al*., 2008; Potter *et al*., 2008). Both factors are likely to contribute to the annual increase.

Annual cyclic patterns

The results indicate 2, 6 and 12 month periodic cycles for the number of call enquiries for bed bugs. The 12 month cycle peaked in August-September and reflects data from other studies showing the number of bed bug calls increasing during the summer and declining in the winter (Cornwell, 1974; Cleary & Buchanan, 2004; Doggett *et al*., 2004; Ryan *et al*., 2004; Kilpinen *et al*., 2008). The 12 month cycle increased in amplitude for later years, which may suggest greater bed bug dispersal during the summer months, and greater optimal conditions for survival and reproduction (Omori, 1941). The 6 and 2 month cycles appear, however, to be specific to this study. There is evidence that suggests that some first and second time treatments may be ineffective (Ryan *et al*., 2004; Hwang *et al*., 2005). The 6 and 2 month cycles may reflect call back periods from members of the public to pest control services after initial treatment has failed, because the data did not differentiate between first time callers and subsequent calls received from the same household. Further studies would be necessary to confirm these findings.

Covariates

There was evidence for only one borough to suggest that outdoor temperature had an impact on the increase in calls concerning bed bugs. This is presumably because the majority of properties nowadays have central heating and double glazing, and maintain warm temperatures all year creating favourable conditions for breeding, survival and development of bed bugs.

In addition, although the effect of people's movements has been previously hypothesised to contribute to the cyclic numbers of bed bug infestations (Cornwell, 1974; Kilpinen *et al*., 2008), human movement only had a significant contribution in one borough. More evidence would be required to determine whether human movement influenced the number of bed bug infestations.

Specimen collection

All adult specimens collected were identified as the common bed bug *C. lectularius*. The dominance of *C. lectularius* in developed countries, rather than the tropical bed bug, *C. hemipterus*, has been found in other studies in the UK (Boase, 2001) and Australia (Doggett *et al*., 2003).

Conclusion

In conclusion, the study shows that for the selected seven boroughs investigated in Greater London, the number of call enquiries for bed bugs increased from 2000 to 2006. This rise is likely to arise from a combination of factors including greater dispersal of bed bugs and control strategies that are not fully effective. Cyclic patterns were identified every 12, 6 and 2 months with the greatest peak in August-September. This suggests that there is likely to be a higher number of reports for bed bugs during summer months. Current control of bed bug infestations relies on public recognition of the symptoms and recent evidence of widespread resistance suggests that public awareness will be important for control and dispersal. Members of the public, pest control operators and medical professionals should therefore be aware of typical symptoms and an integrated approach should be used for bed bug management involving inspection, detection, and education, and physical removal and exclusion as well as pesticide applications (Harlan *et al*., 2008). For example, the development and promotion of a Code of Practice for the control of bed bug infestations in Australia, and education of stakeholders, has been widely adopted in Australia (Doggett and Russell, 2008). Adequate surveillance of bed bug populations will be important for future monitoring and control, especially in Greater London in view of the possible increased movement of people predicted for the 2012 Olympic Games.

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