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# POPULATION BIOLOGY OF THE URBAN MOUSE (*MUS DOMESTICUS*) IN THE UK

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**Abstract** Chronic infestations of house mice (*Mus domesticus*) are a common problem in urban areas within the UK, but little is known about the population dynamics of such populations. As a result of the high number of mouse infestations reported by local residents, an inner city area of Manchester, UK, was selected as a study site. The study area contained 254 domestic properties that varied in age and property type, but was representative of a typical inner city area. Intensive trapping of mice in domestic properties was undertaken as part of a control programme and 200 mice were captured. DNA samples were extracted from the mice and analysed using eight mouse microsatellite markers. Analysis of heterozygosity frequencies, Hardy-Weinberg equilibrium and Bayesian clustering methods indicated that each block represented individual breeding units and that migration rates between blocks were very low. Mice were easily moving between adjoining properties (such as semi-detached houses or terraces-defined as housing blocks) but that between the housing blocks there was very little movement. These results have important implications for the approaches to control of house mouse infestations in areas suffering from chronic infestations and confirm that reactive treatment regimes, targeting individual properties within a block, are unlikely to result in long term control as migration from adjoining properties is probable, enabling mice to exploit the niches opened up by the removal of mice during control programmes. Whilst 'block' control may be more resource intensive in the short term, without such a strategic approach chronic infestations are likely to persist in urban areas.
**Key Words** *Mus domesticus*, population dynamics

## INTRODUCTION

The continued survival and proliferation of house mice (*Mus domesticus*) owes much to their capacity to adapt to life in close association with man. In the UK, house mice tend to live almost entirely indoors and are often found infesting domestic properties. Niches available in a typical urban dwelling provide a relatively undisturbed habitat for them (Rowe, 1973; Shenker, 1973) and foraging activities can go largely unnoticed due to their nocturnal habits. Effective control of mouse infestations in the urban environment requires a thorough understanding of their biology, behavior and the factors affecting their population dynamics.

The English House Condition survey (EHCS) is undertaken every 5 years and in 1996 included, for the first time, details relating to rodent infestations and provided an important indication of the levels of rodent infestations associated with domestic properties. It reported modest infestation rates of 1.83% for mice living indoors (Langton et al., 2001). In addition, previous research (Murphy and Oldbury, 2002) found that domestic mouse infestations were most likely to occur where there was poor structural maintenance, poor hygiene and ample internal harbourage.

Generally, there is little public awareness of the presence or magnitude of disease potential within rodent reservoirs, although there has been debate about the potential threats urban rodents may pose to public health (Murphy, 2003). There are other factors that justify control programmes, just as the wastage of cereals and other crops has required the development of pest control strategies in agricultural areas, so the damage done to the fabric of buildings and commodities in urban centres is not trivial. Rodents have been implicated in fires, floods and explosions as a result of their gnawing activities. Equally, it should not be forgotten that the fear and distress caused by rodent infestations can be considerable (McNally and Steketee, 1985).

To understand the public health risks posed by mice, it is necessary to understand the nature and frequency of interactions between human and mouse populations. The challenges faced in attempting to study rodent populations which are primarily indoor pests in an urban environment are considerable. The methods such as removal techniques and mark release-recapture, adopted regularly to study the dynamics of small wild mammal

populations proved to be almost impossible to apply in the urban context. Residents want domestic infestations eradicated as quickly as possible and are often unwilling to facilitate intensive trapping over a period of time and the issues around releasing mice which may not then be recaptured and which may pose a public health risk make this technique untenable. Operationally, it is often difficult to gain daily access to domestic properties to check live traps and it is a labour intensive process.

Advances in DNA technology have led to developments that allow population studies to be facilitated. Microsatellite genotyping allows individual organisms to be 'DNA-fingerprinted' (reviewed by Ashley and Dow, 1994), facilitating the study of the population structure, gene flow and migration patterns of individuals within that population. These techniques have been applied to examine the population dynamics of house mouse populations infesting domestic properties in an urban area in the UK.

## MATERIALS AND METHODS

Cheetham Hill is a typical inner city area of Manchester, UK. The boundaries of the study area were drawn to ensure that it had a typical mix of property types (including terraced, semi-detached/detached properties and flats) and ages (from pre-1919 to post-1964). The study area contained 253 residential properties and covered an area of 6 hectares.

**Table 1.** Characteristics of the domestic properties (n = 117) and association with mouse infestation.

| **Fitness of property ($\chi^2$ = 15.04, 1 df, P = <0.001)** | | |
|---|---|---|
| **Variable** | **N** | **% infested** |
| Unfit/Defective | 30 | 87% |
| Acceptable / Satisfactory | 87 | 38% |
| **Date of construction ($\chi^2$ = 0.15, 2 df, P = >0.05)** | | |
| Pre 1919 | 60 | 77% |
| 1919-1964 | 9 | 67% |
| Post 1964 | 48 | 15% |
| **Dwelling type ($\chi^2$ = 46.06, 2 df, P = <0.001)** | | |
| Terraced | 65 | 78% |
| Detached/ semi-detached | 43 | 16% |
| Flats | 9 | 11% |

Following intensive publicity about the project, strong support from local politicians and work with local groups, the residents were supportive of the aims of the project and willing to allow regular access to their properties. Tracking plates were placed in 202 properties to establish the distribution of house mouse activity (see Taylor and Quy, 1973 for technique). In order to comply with strict UK Home Office requirements, live traps could only be laid in properties where daily access to check the traps was guaranteed and only 27 properties met these criteria. Traps were checked daily and trapped mice were despatched using cervical dislocation. Tail samples were taken and used for DNA analysis. Genomic DNA was prepared from the tails using an ammonium acetate variation of previously published method of DNA extraction (Gross-Bellard et al., 1973). DNA quantity and quality was measured by spectrophotometry. The results of the microsatellite data typing were analysed using the bioinformatics software Popgene 1.32 and Structure 2.0 (Pritchard et al., 2000).

A construction proforma was developed and used to record general information about the type of property (semi/detached; terraced; flats), the approximate age (pre 1919; 1919-1964; post 1964) and the fitness standard (unfit/defective; acceptable/satisfactory).

## RESULTS

Positive evidence of mouse activity was found in seventy-three of the 202 properties where tracking plates were placed, representing an infestation rate of 30%. Two hundred mice were caught in the live traps placed in 27 properties. The number of mice captured per property ranged from 1 to 34, with a mean of 7.4.

Construction surveys were undertaken in 117 properties by a qualified surveyor. Analysis of mouse activity and construction surveys confirmed that mice were not randomly distributed in the domestic properties within the study site (Table 1). The dwelling type and fitness standard had a significant influence on infestation status, however property age did not.

**Table 2.** A summary of the Hardy-Weinberg and heterozygosity data (as determined by Popgene 1.32).

| Block number | No. of alleles that conform to Hardy-Weinberg Equilibrium | Mean Observed Heterozygosity | Mean Expected Heterozygosity | P (for Chi-squared) |
|---|---|---|---|---|
| 1 | 5/8 | 0.717525 | 0.7176 | 0.257791 |
| 2 | 6/8 | 0.610638 | 0.628925 | 0.529707 |
| 3 | 8/8 | 0.445825 | 0.487238 | 0.770852 |
| 5 | 6/8 | 0.5727 | 0.668338 | 0.063678 |
| 6 | 6/8 | 0.668225 | 0.556875 | 0.000785 |
| 7 | 4/8 | 0.379013 | 0.557638 | **>0.05** |
| 8 | 8/8 | 0.734038 | 0.635563 | 0.86699 |
| 9 | 3/8 | 0.4261 | 0.6443 | **>0.05** |
| 10 | 6/8 | 0.458338 | 0.508325 | NA |
| **Composite** | **52/72 (72%)** | N/A | N/A | NA |

To investigate the population structure of the Cheetham Hill mice, microsatellite genotyping was carried out at eight loci for each of the 200 mice. Popgene 1.32 was used to determine whether populations conformed to Hardy-Weinberg equilibrium and to calculate heterozygosity frequencies. When the mice were analysed as a single population, a high level of significant deviation from Hardy-Weinberg equilibrium was observed, and the mean heterozygosity frequencies for each locus was found to be significantly lower ($P<0.001$) than the expected frequency (calculated using Levene, 1949). These factors indicate that the mice of the study area were not a single population, and significant barriers existed to prevent interbreeding.

Results were then reviewed at the 'block' level (a 'block' was defined as a group of houses, equivalent to an 'island' which were joined together (such as two semi-detached properties, or a row of terraced houses). The ten block populations (as shown in Figure 1) were shown to conform to Hardy Weinberg equilibrium in a high proportion of alleles (Table 2). Analysis of heterozygosity concurred with this, and only two of the ten populations exhibited a significantly reduced frequency of heterozygosity ($P>0.05$), indicating that these 'block-populations' were more defined individual breeding units.

The microsatellite data was then analysed using the software Structure 2.0 (Pritchard et al., 2000). This program infers population groups based on genetic similarities between individuals, using Bayesian clustering analysis. The results of this were shown to correlate well with the block-population structure of the urban mice. Clusters of mice were grouped together and given a probability of being from a certain population. These values were high indicating that each block does appear to represent individual breeding units, as suggested by Hardy-Weinberg analysis. The results of this clustering are summarised in Figure 1.

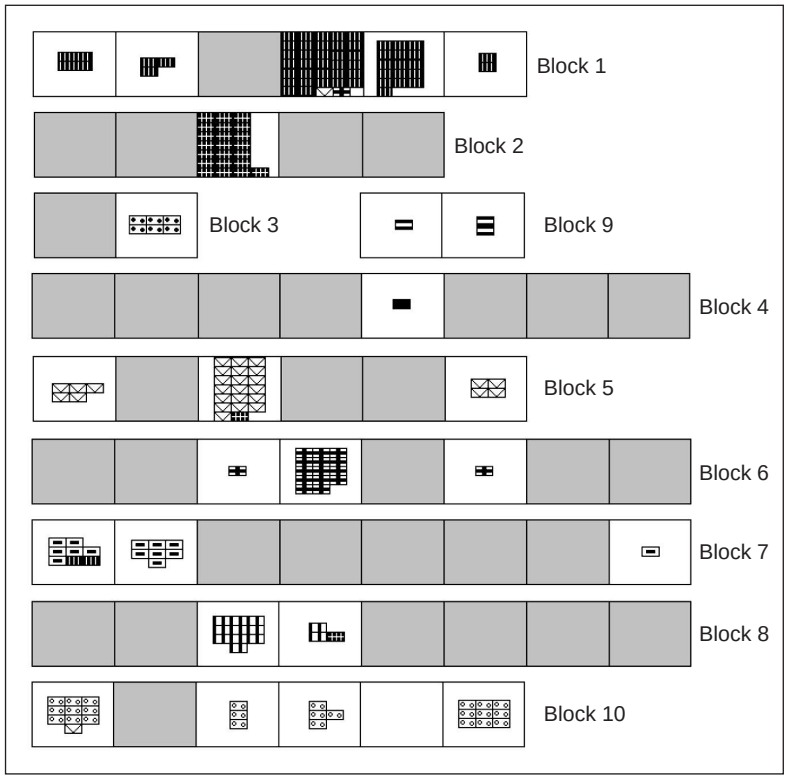


**Figure 1.** Population structure of the Cheetham Hill mice, over the 10 blocks investigated.

## DISCUSSION

The results of this study provided a valuable insight into the population structure and dynamics of house mouse colonies in the urban environment. The levels of infestation (30%) found in this study differ significantly ($\chi^2 = 573$; $p < 0.0001$) from the findings reported by Langton et al. (2001) and suggest that the movement of mice between properties in their study was not considered when weighing the levels of infestations and housing types.

The results from this study have reinforced the findings of other studies in that fitness, age and type of property have significant impacts on the presence and persistence of domestic mouse populations. Analysis of the tracking plate results confirmed that mice were not uniformly distributed within domestic properties, and older, attached properties were more likely to be infested than newer, detached properties. The DNA analysis undertaken in this study confirms what many working in pest management have suspected, that mice migrate freely between adjoining properties and do not map to individual houses, nor do they exist as a single interbreeding population within an urban area. Each housing 'block' represents a separate breeding unit or population island that is well-established. Mice move between properties within a block (an important aspect in terms of approaches to the control of house mouse infestations); however interbreeding between these blocks as result of migration does not appear to occur very often, if at all.

The spatial separation of populations between blocks of housing has important implications for the approaches adopted in attempting to control domestic mouse infestations. Providing a reactive mouse control service, where single properties are treated will certainly crop a proportion of the mice present in that property at the time of the treatment, but mice from adjoining properties may not be exposed to the bait during the treatment phase and will invade and colonise the vacated niches those mice which have been removed have occupied and numbers will quickly return to pre-treatment levels, rendering the treatment ineffective in the longer term. This would appear to be borne out by conversations with residents discussing their own attempts to control infestations. Many stated that they had tried to control the infestations in the past, using a variety of approaches, but that none seemed to be successful and they had learned to live with the infestations.

Following the results of this study, Manchester City Council's pest management service adopted a 'block' approach in the study area and treated all properties within a block where there had been any evidence of infestation. A follow-up tracking plate survey undertaken three months after this control regime was completed found that this had been an effective means of control and no evidence of activity in any of the properties was recorded. Residents were given advice on hygiene and control measures and no further complaints of infestations were reported to the Local Authority almost 18 months after the block treatments were completed. This strategic approach to control has been rolled out to other areas of the city. Whilst this approach is resource intensive in the beginning, it has enabled the pest management unit to become more strategic in its control program. Whilst reactive treatments are still an important part of the service, the focus is now on eradication of chronic mouse infestations neighborhood by neighborhood, with older terraced properties prioritized.

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