# Living with Mammals: an urban study

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# LIVING WITH MAMMALS: AN URBAN STUDY

A Hedgehog exploring an urban garden. Paul Hobson/FLPA

**David Wembridge and Steve Langton**

**A 12-year study has cast new light upon mammal population trends in urban areas, demonstrating the important role that citizen-science monitoring can play.**

Most of us live in urban landscapes. The word 'urban' is variously defined in different countries, but typically it refers to population centres with more than 2,000 inhabitants (UN 2014). Globally, more than half of the human population (about 52%) lives in urban areas (UN 2012); in the UK – where, in England and Wales, the Office of National Statistics (ONS) uses 'urban' to describe settlements with more than 10,000 inhabitants – four-fifths of us are urban-dwellers (Defra 2012), occupying about a tenth of the land area (Davies *et al.* 2011). Within these urban regions, domestic gardens, recreational grounds, cemeteries, allotments, brownfield sites and other areas provide a mosaic of habitats with environmental benefits for local communities. The importance of this 'green infrastructure' in providing what are sometimes called 'ecosystem services' and in wildlife conservation is increasingly recognised (e.g. Alcock *et al.* 2014; Goddard *et al.* 2010; Pugh *et al.* 2012), but the extent of green space is largely unquantified (CABE 2010) and it is not systematically monitored (UNEP 2011). Notwithstanding this, obligations exist under domestic and European law to monitor the protected species such as Hedgehog *Erinaceus europaeus*, bats, shrews and Badger *Meles meles* that make use of these spaces.

The value of interactions between people and the wildlife alongside which they live is difficult to quantify (Soulsbury & White 2015), but there is some evidence to suggest that the health and well-being benefits of green space increase with greater biodiversity (Fuller *et al.* 2007). Increased urbanisation, however, generally reduces species richness across taxa (McKinney 2008). In Melbourne, Australia, a study of indigenous mammals found that, of 54 species present prior to European settlement, fewer than half had a 95% chance or more of surviving to the turn of the current century, and the effect of urbanisation was most marked for small, ground-dwelling species, with only two of 15 species likely to be extant in 2000 (van der Ree & McCarthy 2005). In the UK, changes in the urban environment continue to put pressure on populations: the recent *State of Nature report* (Burns *et al.* 2013) found that 59% of the 658 urban species assessed had declined in the previous 40 years and that 35% had declined strongly (i.e. the population had at least halved over the period monitored or would do so at the current rate over 25 years).

The significance to wildlife of domestic gardens and brownfield sites has received considerable attention (Gaston *et al.* 2007; Gibson 1998; Head 2011; Macadam & Bairner 2012; Owen 2010; Woodward *et al.* 2003), and the potential of volunteer-based surveys to monitor this wildlife has been demonstrated (Toms & Newson 2006), but few surveys have recorded mammal species in the built environment and few data on population trends exist.

## Citizen science and wild mammals

Identifying such trends in monitoring projects is necessary in order to assess the success or otherwise of conservation efforts and to inform conservation decisions (Danielsen *et al.* 2005), but professional monitoring is often costly and, as such, unlikely to be sustained over time. Moreover, it can fail to engage stakeholders, which, in urban areas, include the many people who live or work there. Natural-history recording in Britain has a long history, and large-scale, public surveys date back to those organised by the British Trust for Ornithology (BTO) in the first half of the last century, collecting records of paper-tearing and pecking of foil milkbottle-tops by birds. More recently, the potential for 'citizen science' has become apparent with the growth of the internet and mobile devices with GPS, large displays, cameras and the ability to run specialised applications (Jones 2013).

The survey described here started before such 'apps' were commonplace, but the advantages of volunteer-based, citizen-science monitoring extend beyond its particular format, not least that it is generally cost-effective. Taking the National Bat Monitoring Programme as a case study, Battersby (2005) estimated the annual running cost to be less than a fifth of what it would have cost had a similar level of data collection been carried out by professional surveyors. The built environment is a patchwork of separately owned and managed sites, which presents challenges for professional surveys. Residential areas, however, are naturally suited to citizen-science approaches.

Mammals are usually discreet neighbours. Occasionally, activities such as howling, digging or gnawing can raise the hackles of some human residents, but, for the most part, mammals are unobtrusive (typically active at twilight or at night) and only infrequently encountered by people. Surveys therefore require a degree of commitment; moreover, to identify how populations are changing, repeated surveys over time are necessary,

**A Fox foraging in a London park at night.** Jamie Hall/FLPA

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demanding a long-term commitment from volunteers. A lot is asked of survey participants and much can be gained.

Up to 43 mammal species have been recorded in a questionnaire-based survey of gardens (Ansell *et al.* 2001) but, more typically, around two dozen (Baker & Harris 2007; Toms & Newson 2006) are recorded, including seven of the 11 non-bat species formerly designated priority terrestrial-mammal species in the UK Biodiversity Action Plan (Hedgehog, Brown Hare *Lepus timidus*, Red Squirrel *Sciurus vulgaris*, Water Vole *Arvicola amphibius*, Otter *Lutra lutra*, Pine Marten *Martes martes* and Hazel Dormouse *Muscardinus avellanarius*). Only six species or species groups, however (bats, Red Fox *Vulpes vulpes*, Grey Squirrel *Sciurus carolinensis*, Hedgehog, mice and voles), are recorded in a fifth or more of gardens (Baker & Harris 2007).

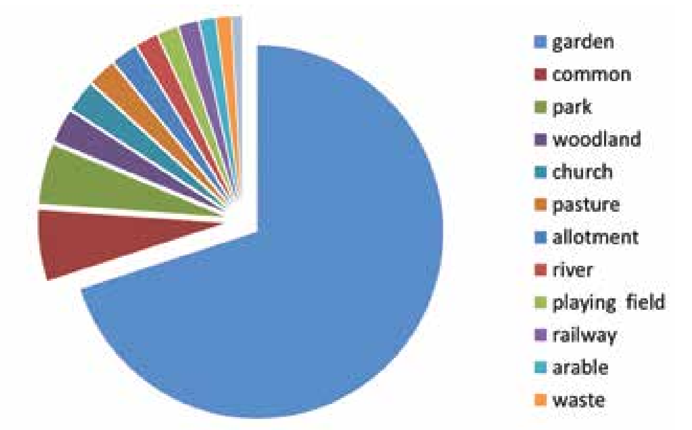



**Figure 1 Composition of site types in the survey. The site type of 2,895 sites was identified, gardens comprising 70.0%.**

Two surveys, the BTO's *Garden BirdWatch*, described by Toms & Newson (2006), and the People's Trust for Endangered Species' (PTES) *Living with Mammals*, described here, have produced long-term datasets of mammal records in gardens and, in the latter case, other urban green spaces.

For some mammals, urban green space is an important resource. Species that have shown declines in the wider countryside (notably in farmland), such as the Song Thrush *Turdus philomelos* and the Hedgehog, are found in significant numbers in urban areas (Hubert *et al.* 2011; Mason 2000). A better understanding of these relationships and of how species are faring in the built environment will be important in the provision and development of green infrastructure in towns and cities, to improve the lot not only of our wild neighbours but of ourselves as well.

## Living with Mammals

The *Living with Mammals* survey started in 2003, with the aim of producing effort-based indices of mammal abundance across the built environment, and has run annually ever since. It was developed by Paul Bright, at Royal Holloway, University of London, and its ongoing management is undertaken by PTES.

Weekly records of sightings and field-signs of mammals are collected by volunteers during a 13-week period each year between the end of March and the start of July, recording the largest group of animals seen at one time. Sites are chosen by participants and identified as one of 13 types, described either by use (e.g. 'allotment' or 'churchyard') or by predominant habitat type (e.g. 'riverbank' or 'woodland'). Information about the site, as well as species records, are recorded in a 'tick-box' format and captured by optically scanning survey forms.

Sites can be any green space within 200m of buildings or wholly within a town or city (for example, within a large civic park). Nature reserves or urban farms are excluded. The pattern of distribution of sites closely mirrors that of built land, indicating that the survey's coverage is predominantly 'urban' in the sense used by the ONS.

In total, 7,500 surveys of wild mammals were collected over the 12-year period, providing data from more than 3,000 sites. Domestic gardens make up the majority of sites in the survey (Fig. 1) and are the largest single category of urban land use, typically making up about a quarter of the area of cities (Loram *et al.* 2007; Smith 2010). The extent of the resource represented by gardens has been characterised in Sheffield University's *Biodiversity in Urban Gardens in Sheffield* (BUGS) and BUGS II projects. Gardens in the eponymous city were estimated to be home to 360,000 trees, 50,750 compost heaps and 25,200 ponds (Gaston *et al.* 2005b), far more than in other forms of suburban and urban green spaces such as parks and recreational areas.

## Species correlation across sites

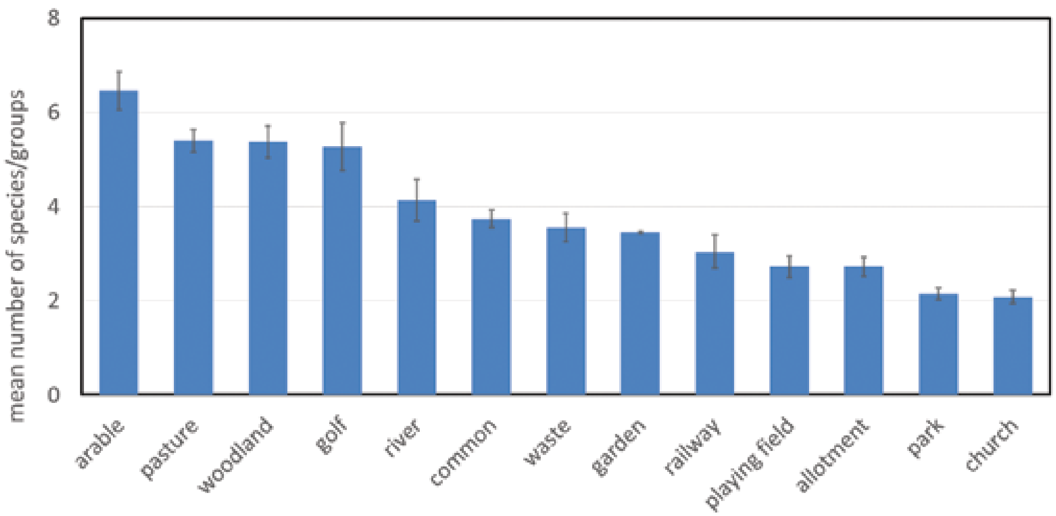
The value of individual efforts to enhance biodiversity in gardens ('wildlife gardening') is generally seen as real, but there is limited evidence for the effectiveness of particular measures to increase diversity. Gaston *et al.* (2005a) found that artificial nest sites for solitary bees and wasps were readily used by the target species, while nettle patches and bumblebee nest sites had a low probability of success (nettles supported few Nymphalid butterfly larvae, but did encourage other nettle-feeding invertebrates). There is evidence that the providing of food sources – berry- and fruit-bearing plants, birdfeeders, ponds, compost heaps, etc. – or features offering shelter – flowerbeds, trees, woodpiles, hedgehog boxes, etc. – in gardens increases the number of mammal species using the site (Ansell *et al.* 2001). Meanwhile, Baker & Harris (2007) found that Hedgehogs and mice were recorded more frequently in gardens with greater numbers of habitats and food-bearing plants; Hedgehogs appeared to respond to increasing food availability more than to increasing habitat diversity.

One aim of the *Living with Mammals* survey, similarly, is to identify features associated with a greater species richness of mammals at sites in the built environment, and participants record 40 characteristics of a site, including its size and age, the type of boundary, and whether features such as trees, compost heaps and nocturnal lighting are present, along with the type of habitats close to the site.

Teasing apart the separate contributions to biodiversity of the different microhabitats that characterise green spaces is difficult, but it is apparent that types of site differ in the mean number of species (or species groups) recorded. After allowing for differences in recording effort and other explanatory variables, significantly more species were recorded on average in gardens than in churchyards or cemeteries, allotments, parks and road or railway verges (Fig. 2). Grey Squirrels and mice were relatively frequent in gardens and, together with bats, Red Fox and Hedgehog, were the most commonly recorded garden species. Derelict or wasteland sites recorded a similar number of mammal species to that in gardens, but Red Fox and deer (Muntjac *Muntiacus reevesi* and Roe Deer *Capreolus capreolus*) were more common at these sites.

The more bucolic sites, those identified as woodland, pasture or arable sites, showed the greatest number of species, and significantly more than gardens did. This was due to higher recording rates of Red Fox and Rabbit *Oryctolagus cuniculus*, and, in the case of arable sites, Brown Hare *Lepus europaeus*.

**Figure 2 Mean number of mammal species (+/- SE) at each type of site over the 12-year dataset.**



**A young Brown Long-eared Bat clinging to a brick wall.** Hugh Clark/FLPA

The most ubiquitous species – those for which 'site type' was not a significant factor in explaining their presence – included Hedgehog and Badger, although the latter was only rarely recorded at wasteland or allotment sites. The current fortunes of these two species, discussed below, differ markedly, and an understanding of how each uses and moves about an urban environment may be important in preserving both.

Older sites, particularly those established before 1900, were significantly more species-rich than more recent ones. Grey Squirrel and bats were proportionately more common on older sites, whereas Hedgehog was more likely to be found on sites established in 1950 or later.

Several other site characteristics also had a significant impact on the number of species found, supporting the findings of earlier surveys. One characteristic, the proportion of the site covered by trees or shrubs, is interesting because it follows a finding of the BUGS project, namely that the single feature of gardens most strongly linked to a rich invertebrate fauna is the abundance of trees more than 2m tall (Smith *et al.* 2006). Hedgehog, Grey Squirrel, Red Fox, bats and shrews were all less likely to be recorded at sites with low levels of trees and shrubs. Bats and shrews feed almost exclusively on invertebrate prey; insects and earthworms make up a half or more of the diet of Hedgehogs, and a fifth of that of urban foxes. While it is not surprising that trees are a good habitat for squirrels, this suggests that their impact on biodiversity may extend through the brushwood and leaf-litter habitats which they create, and the invertebrate fauna which these support, to increase mammal abundance.

The patchwork of different sites that make up the built environment, and the diversity of micro-habitats within them, collectively can support a rich mammal fauna – so long as sites are accessible and connected. The single factor that was significant for most species, however, was the extent of built land in the 1km grid-square of the site. Those sites with the greatest amount of built land (those in the highest quartile) had on average only 60% of the number of species at sites in grid-squares with the lowest amount of built land (those in the lowest quartile).

## Population trends

Each year between 1998 and 2008, London lost on average an area of domestic-garden land (consisting of lawn, tree canopy or other vegetation) equal to two-and-a-half times that of Hyde Park (Smith 2010). Brownfield sites are prioritised for development, and redevelopment of residential housing tends to decrease the area of garden land and increase that of hard features. Given the changing land use in urban areas, how are wildlife populations faring?

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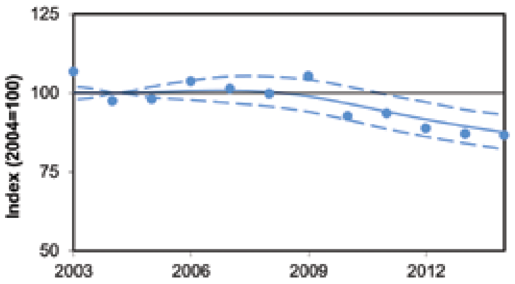


**Figure 3 Proportion of sites recording bats. A smoothed curve (solid blue line), for sites surveyed in two or more years, was fitted by using a Generalised Additive Model, and 95% confidence limits (broken lines) estimated by bootstrapping at the site level. Results are based on 400 bootstrap samples.**

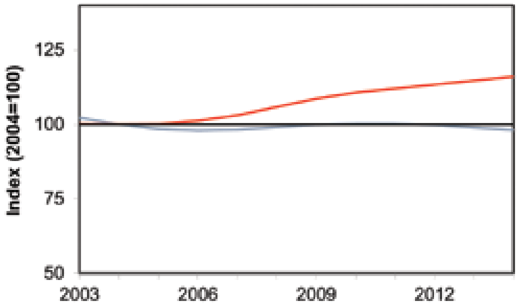


**Figure 4 Records of Red Fox. The blue line shows the proportion of sites recording Red Fox; the red line shows the proportion of weeks in the survey period in which Red Fox was reported. For the sake of clarity, annual estimates and confidence limits are not shown.**

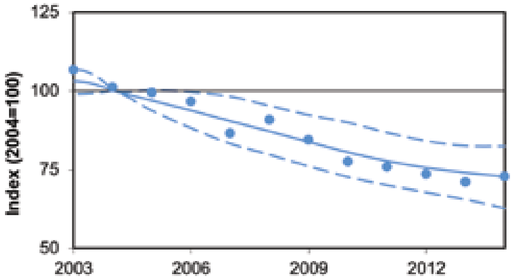


**Figure 5 Proportion of sites recording Hedgehog.**

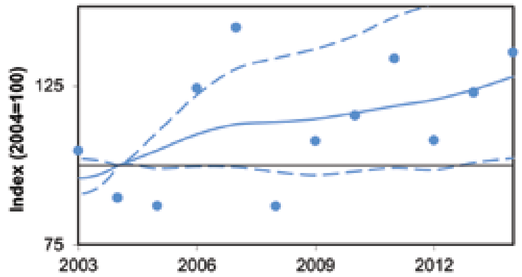


**Figure 6 Proportion of sites recording Badger.**

Four species or species groups showed a significant change in the proportion of sites occupied between 2003 and 2014: Hedgehog, Badger, bats and mice. Nominally, the trend for Grey Squirrel was also significant, the upper confidence limit for 2014 dipping below the baseline, but this should be treated as provisional until further years' data are available.

The proportion of sites recording bats (Fig. 3) remained constant until 2008, but has declined markedly since then. The likelihood of observing bats was greater if the site was within 100m of a river. Most records are likely to be of pipistrelles, but Daubenton's Bat *Myotis daubentonii*, Brown Long-eared Bat *Plecotus auritus* and Serotine *Eptesicus serotinus* are also frequently encountered in built environments, and most of the 17 breeding bat species in Britain will make seasonal use of buildings for maternity roosts. In the National Bat Monitoring Programme, field surveys of Common *Pipistrellus pipistrellus* and Soprano Pipistrelles *P. pygmaeus* at rural as well as urban sites level off or (in the case of the latter) decline slightly after 2009–10 (BCT 2015), which may underlie the decrease found here.

Records of mice showed a similar pattern to those of bats, but the decline levels off from 2009–10.

The proportion of sites recording Red Fox has changed little since the first year of the survey (Fig. 4, blue line), but the frequency of sightings during the 13-week survey period has changed (red line), the proportion of positive weeks increasing by an average of 1.49% each year. There is some evidence, from an analysis of weekly counts of animals, to suggest that this is due to an increase in abundance (rather than in activity, for example) but, as yet, the current level of site occupation appears sufficient to support the population.

Evidence that the Hedgehog population in Britain is declining has been growing over the past ten years or so. At the time of the first report of the Tracking Mammals Partnership (Battersby 2005), limited data were suggestive of a decline. A better picture came in a report by Roos *et al*. (2012), commissioned by PTES and British Hedgehog Preservation Society (BHPS), which analysed data from five surveys between 1996 and 2010, including *Living with Mammals*. All the surveys showed declines: a conservative estimate suggests that a quarter of the population had been lost in the first decade of this century (Wembridge 2011). In urban areas at least, this trend appears to be continuing. Fig. 5 shows the proportion of sites recording Hedgehogs in *Living with Mammals*; the average decrease of the smoothed curve per year is 3.12%, exceeding the IUCN Red List criteria identifying species at greatest conservation risk.

Hedgehogs can be locally abundant in built environments. In suburban gardens or on amenity grassland, densities are typically greater than those in rural landscapes (e.g. Young *et al*. 2006), and it is likely that this is a result (at least in part) of the protection which such areas provide from Badger predation (Young *et al*. 2006; Hubert *et al*. 2011). Ansell *et al*. (2001) found that Hedgehogs were 2.5 times less likely to be present in gardens visited by Badgers than in those where Badgers were absent; and Hof & Bright (2009) showed a negative (but non-significant) correlation between Badger presence and Hedgehog presence at sites in the first four years of *Living with Mammals*. The current analysis of the survey shows that Badgers are becoming more common; the proportion of sites recording this species shows a significant increase of 2.49% each year on average (Fig. 6).

Badgers will eat Hedgehogs, but the relationship between the two is an example of asymmetric intraguild predation, in which predator and prey also compete for a shared food source, and the impact on Hedgehogs is more complex than predation and competition alone (Polis *et al*. 1989). The two species coexist in the built environment, and Badgers have a significant negative impact on Hedgehogs in the *Living with Mammals* survey: taking into account site characteristics and survey effort, sites recording Badger are less likely to record Hedgehog. The question is, however: how directly is an increasing Badger population the cause of declining Hedgehog numbers? At sites where Badgers are absent, the downward trend in Hedgehog records is as marked as that at sites where Badgers are present, suggesting that other factors are important. In an urban setting, multiple factors are likely to play a role in shaping the dynamics: the distribution of green spaces and the connectivity between them, the abundance of soil invertebrates and supplementary feeding may be as significant (food availability is balanced against predation risk in intraguild-predation theory). At sites where Badgers are absent, for example, their presence at neighbouring sites may have an effect by limiting the movement of Hedgehogs between areas (Young *et al*. 2006).

## Conclusions

The potential of gardens and urban green spaces to support biodiversity is substantial (Head 2011), and their importance in environmental education and engagement is paramount: they are where most of us experience nature day to day. Collectively, these spaces are home to most of our terrestrial mammal species and, as our countryside changes, they may be increasingly important to some. The pressure on wildlife – the loss, fragmentation and degradation of habitat – is, however, common to the built environment as well, and *Living with Mammals* shows that some species are faring better than others. The fall in Hedgehog records, a decrease of 30% since the survey began, is of particular concern as suburban areas are thought to represent refugia for this species.

Monitoring of urban wildlife is important if biodiversity in these environments is to be maintained and improved. Citizen-science surveys and projects such as PTES/BHPS' *Hedgehog Street*, which encourages neighbourhood-scale efforts to improve urban habitats, can be effective conservation tools and provide another level of engagement – an active connection – between human residents and our wild neighbours.

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**A Badger comes to the window of one of the survey participants.** S. Paterson

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