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# A national scale inventory of resource provision for biodiversity within domestic gardens

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## ABSTRACT

The human population is increasingly disconnected from nature due to urbanisation. To counteract this phenomenon, the UK government has been actively promoting wildlife gardening. However, the extent to which such activities are conducted and the level of resource provision for biodiversity (e.g., food and nesting sites) within domestic gardens remains poorly documented. Here we generate estimates for a selection of key resources provided within gardens at a national scale, using 12 survey datasets gathered across the UK. We estimate that 22.7 million households (87% of homes) have access to a garden. Average garden size is 190 m<sup>2</sup>, extrapolating to a total area of 432,924 ha. Although substantial, this coverage is still an order of magnitude less than that of statutory protected areas. Approximately 12.6 million (48%) households provide supplementary food for birds, 7.4 million of which specifically use bird feeders. Similarly, there are a minimum of 4.7 million nest boxes within gardens. These figures equate to one bird feeder for every nine potentially feeder-using birds in the UK, and at least one nest box for every six breeding pairs of cavity nesting birds. Gardens also contain 2.5–3.5 million ponds and 28.7 million trees, which is just under a quarter of all trees occurring outside woodlands. Ongoing urbanisation, characterised by increased housing densities, is inevitable throughout the UK and elsewhere. The important contribution domestic gardens make to the green space infrastructure in residential areas must be acknowledged, as their reduction will impact biodiversity conservation, ecosystem services, and the well-being of the human population.

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## 1. Introduction

For the first time in recorded history, over half of the global human population live in urban areas and are, therefore, becoming progressively disconnected from the natural world (Wilson, 1984; Pyle, 2003; Miller, 2005). In developed countries

this proportion is much higher and, on average, is expected to rise to 84% by 2030 (United Nations, 2007). In fact, urban areas are presently expanding at a faster rate than any other land use type (Meyer and Turner, 1992; McKinney, 2002), with approximately 4% of global land cover being defined as urbanised (characterised by high human population densities or

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significant commercial or industrial infrastructure; United Nations Development Programme et al., 2000).

Whilst the world's population is growing increasingly isolated from biodiversity as a result of urbanisation, evidence is rapidly accruing as to the advantages that people gain from experiencing and interacting with nature (Katcher and Beck, 1987; Kaplan and Kaplan, 1989; Irvine and Warber, 2002; Maller et al., 2005). The personal and societal benefits to human health and well-being are wide ranging, but include quicker recovery rates from ill-health (Ulrich, 1984), self-reported general health (Stilgoe, 2001; de Vries et al., 2003; Maas et al., 2006), longevity (Takano et al., 2002), stress-relief (Moore, 1981; Leather et al., 1998; Parsons et al., 1998; Stigsdotter and Grahn, 2004), reduced mental fatigue (Hartig et al., 1991; Kuo, 2001), opportunities for reflection (Herzog et al., 1997; Fuller et al., 2007), degree of social interaction (Sullivan et al., 2004) and reduced crime rates (Kuo and Sullivan, 2001). Similarly, lack of access to green space has been associated with higher levels of depression and anxiety (Macintyre et al., 2003).

Improving urban environments for biodiversity will not only be beneficial to human individuals and communities inhabiting those areas, but will also be advantageous for biological conservation. In developed regions where intensive use of the wider landscape, particularly through agriculture, has resulted in population declines of species, urban areas are becoming increasingly important for sustaining regional abundances. Indeed, substantial proportions of the populations of some previously widespread and common species now occur in urban environments (e.g., Beebee, 1997; Gregory and Baillie, 1998; Mason, 2000; Bland et al., 2004; Peach et al., 2004).

A variety of options is available to increase the environmental quality of urban areas and, thereby, the degree of interaction between people and nature, including creating green networks and corridors, developing urban forests, improving the management of public parks, and encouraging householders to participate in 'wildlife gardening' (e.g., Baker, 1997; Tyrväinen, 1997; Good, 2000; Savard et al., 2000; Beebee, 2001; DEFRA, 2002). Wildlife gardening can be broadly defined to encompass any actions conducted in private or domestic gardens to increase their suitability for wildlife, and thus includes the provision of a diversity of resources (e.g., substrates, food, breeding and overwintering sites). A significant proportion of urbanised areas comprise domestic gardens (Loram et al., 2007), so one of the attractions of such an approach to improving urban environments is the potential for mass participation by householders. The multiple ownership of the domestic garden resource should be viewed as an opportunity to be exploited, rather than the complication that it commonly presents in the context of other land uses (Lepczyk et al., 2004; Gaston et al., 2005a; Warren et al., 2008).

This said, the extent to which wildlife gardening activities are undertaken, and hence the level of provision of important resources to enhance biodiversity, remains poorly documented (but see Cowie and Hinsley, 1988; Lepczyk et al., 2004; Gaston et al., 2005b, 2007; Buczacki, 2007). In the UK, an assortment of estimates has been published for different regions, most frequently in the popular media,

but seldom with any indication of how they were originally derived (e.g., Baines, 1985; Moss and Cottridge, 1998; Owen, 1991; Bevan, 2001; Packham, 2001; Ryrie, 2003; Burton, 2004; Glue, 2006). In this paper we seek to redress this situation, generating estimates for a selection of key resources provided within domestic gardens across the country. This is the first time that such a comprehensive dataset has been assembled to address this issue at a national scale.

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## 2. Materials and methods

### 2.1. Urban and suburban household/garden surveys

Twelve datasets were used to generate estimates of the domestic garden resource in the UK (Table 1). Eleven of these were collected as part of seven recent projects that have been conducted within urban and suburban areas throughout the country (Fig. 1). They are highly representative of the UK population as approximately 90% of people live in towns or cities (ODPM, 2001), with over 40% distributed in London and other major cities (DETR, 2000). Some of the surveys were household focused, whereas others were more specifically aimed at garden users (Table 1; the survey methods for the unpublished data can be found in Appendix A of the Supplementary material).

### 2.2. Survey of English Housing

The remaining dataset used in the calculations of garden resources across the country was the Survey of English Housing (SEH). It is an annual survey of approximately 20,000 households, stratified across the counties of England. The SEH covers all types of household, from those in rural areas and small towns through to city centres, therefore accounting for potential variation at regional scales. It is conducted for the UK government's Department for Communities and Local Government (formally part of the Department for Transport, Local Government and the Regions) by the National Centre for Social Research. The primary purpose of the survey is to collate reliable information on the main features of each household and the opinion of the respondents in relation to their personal housing circumstances. In its entirety, the survey consists of approximately 800 questions, comprising a core of factual questions that remain largely unchanged from year to year (e.g., regarding factors such as tenure, housing costs, housing history), in addition to a set of questions on attitudes and intentions that are revised annually (see <http://www.esds.ac.uk/> for details).

The 2001/2002 survey (National Centre for Social Research and Department for Transport, Local Government and the Regions, 2004) included a small set of questions investigating the degree to which households participate in wildlife gardening activities. Respondents were asked: (i) whether they had access to a garden or patio area and, if so, (ii) whether they provided food for birds, (iii) if they had a nest box and (iv) whether the garden contained a pond.

**Table 1 – Characteristics of each household/domestic garden survey included in this study, and the relevant garden resource data extracted. Details of the survey methodologies for unpublished data can be found in Appendix A of the Supplementary material.**

Survey name	Year(s) of survey	Area surveyed	Survey methods (variables)	Survey strategy	Type of households surveyed	Number of households/gardens surveyed (response rate, if applicable)	Resources recorded (measurement)	Reference
BUGS 1 (a)	2002	Sheffield	GIS analysis (garden areas)	Random	All residential households	250 households	Garden (presence/absence) Garden area (m <sup>2</sup> )	Gaston et al. (2005b)
BUGS 1 (b)	2002	Sheffield	Telephone questionnaire (garden features)	Random	All residential households	250 households (85%)	Garden (presence/absence) Nest boxes (presence/absence) Ponds (presence/absence) Trees >3 m tall (count)	Gaston et al. (2005b)
BUGS 1 Extension	2002	Sheffield	Telephone questionnaire (garden features)	Random	All residential households	500 households (83%)	Garden (presence/absence) Supplementary bird food provision (yes/no) Nest boxes (presence/absence) Ponds (presence/absence) Trees >3 m tall (count) Garden area (m <sup>2</sup> )	K.J. Gaston et al. (unpublished data)
BUGS 2 (a)	2005	Belfast Cardiff Edinburgh Leicester Oxford	GIS analysis (garden areas)	Random	Detached, semi-detached and terraced households	3643 gardens	Rear garden area (m <sup>2</sup> ) Supplementary bird food provision (yes/no) Bird feeders (presence/absence) Nest boxes (presence/absence) Ponds (coverage m <sup>2</sup> ) Trees >3 m tall (count) Garden area (m <sup>2</sup> )	Loram et al. (2007)
BUGS 2 (b)	2004–2006	Belfast Cardiff Edinburgh Leicester Oxford	Garden visits (garden features)	Informally stratified sample, representative of the range of households, from a pool of volunteered gardens	Detached, semi-detached and terraced households with rear gardens	267 gardens	Rear garden area (m <sup>2</sup> ) Supplementary bird food provision (yes/no) Bird feeders (presence/absence) Nest boxes (presence/absence) Ponds (coverage m <sup>2</sup> ) Trees >3 m tall (count) Garden area (m <sup>2</sup> )	A. Loram et al. (unpublished data)
CityForm Project (a)	2004	Edinburgh Glasgow Leicester Oxford Sheffield	GIS analysis (garden areas)	Census	All residential households	84,136 households	Garden (presence/absence) Supplementary bird food provision (yes/no) Bird feeders (presence/absence) Nest boxes (presence/absence) Ponds (presence/absence)	R.A. Fuller et al. (unpublished data)
CityForm Project (b)	2004	Edinburgh Glasgow Leicester Oxford Sheffield	GIS analysis (tree coverage)	Census of 149 km <sup>2</sup> area	All residential households	Not determined	Tree coverage (m <sup>2</sup> )	R.A. Fuller et al. (unpublished data)
CityForm Project (c)	2005	Edinburgh Glasgow Leicester Oxford Sheffield	Postal questionnaire (garden features)	Random, stratified by city area (inner, middle and outer)	All residential households	4381 households (37%)	Garden (presence/absence) Supplementary bird food provision (yes/no) Bird feeders (presence/absence) Nest boxes (presence/absence) Ponds (presence/absence)	Gaston et al. (2007)
British Urban Domestic Cat Survey	2004–2005	Twenty urban areas across England and Wales (Fig. 1)	Telephone questionnaire or household visits (garden features)	Random census of twenty 1 km <sup>2</sup> squares	All residential households	1000 households (33–71%)	Garden (presence/absence) Supplementary bird food provision (yes/no) Nest boxes (presence/absence)	Sims et al. (2008)
Sheffield Urban Domestic Cat Project	2003–2005	Sheffield	Telephone questionnaire or household visits (garden features)	Census of two 1 km <sup>2</sup> squares (one middle and one outer city area)	Detached, semi-detached and terraced households	2782 households (61%)	Garden (presence/absence) Supplementary bird food provision (yes/no) Bird feeders (presence/absence)	V. Sims et al. (unpublished data)
Valuing Open Space Questionnaire	2006	Sheffield	Postal questionnaire (garden features)	Random, stratified by socioeconomic grouping	All residential households (those without access to a garden were excluded)	2016 gardens (33%)	Bird feeders (presence/absence) Nest boxes (presence/absence) Ponds (presence/absence)	K.N. Irvine et al. (unpublished data)
Survey of English Housing (SEH)	2001–2002	England	Household visits (garden features)	Random, stratified by Government Office Region and socioeconomic grouping	All residential households	19,913 households (67%)	Garden (presence/absence) Supplementary bird food provision (yes/no) Nest boxes (presence/absence) Ponds (presence/absence)	NCSR and DETR (2004)

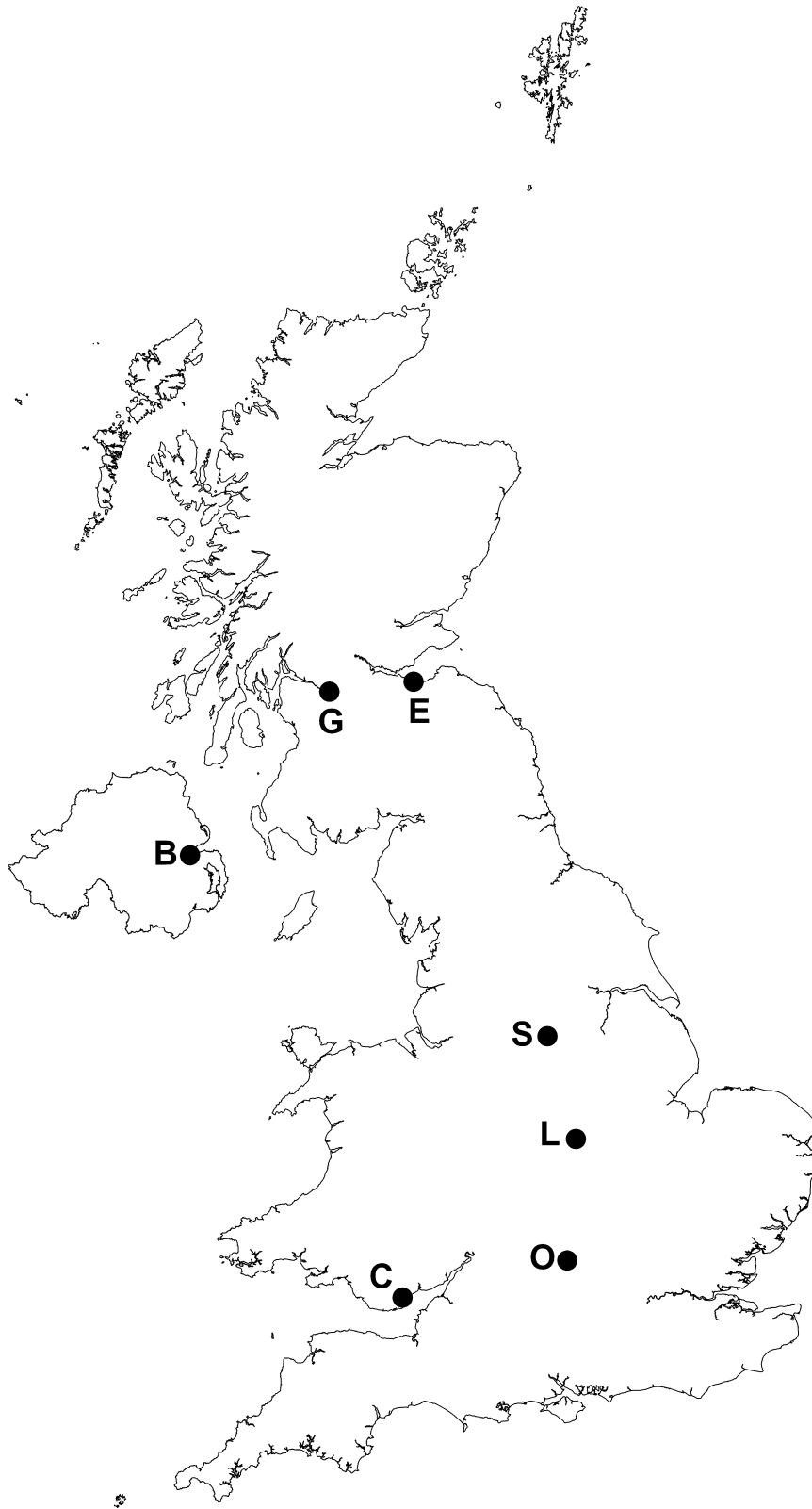


Fig. 1 – The location of the urban and suburban areas sampled in seven of the household/domestic garden projects (Table 1), the relevant survey data from which were collated for this study: (a) the UK cities targeted in six of the projects: B, Belfast; C, Cardiff; E, Edinburgh; G, Glasgow; L, Leicester; O, Oxford; S, Sheffield; (b) the 20 1 km × 1 km areas sampled, in England and Wales, for the British Urban Domestic Cat Survey: Bas, Basingstoke; Bd, Bridgend; Bs, Bristol; Bt, Bath; Ca, Cardiff; Ch, Chester; Con, Conisbrough; Cov, Coventry; Cr, Croydon; Ep, Epsom; Gr, Greenwich; Ol, Oldham; Pl, Plymouth; Po, Pontypool; Pr, Preston; Re, Reigate; Ru, Ruislip; Ur, Urmston; Wo, Woking; Wt, Walton-on-Thames.

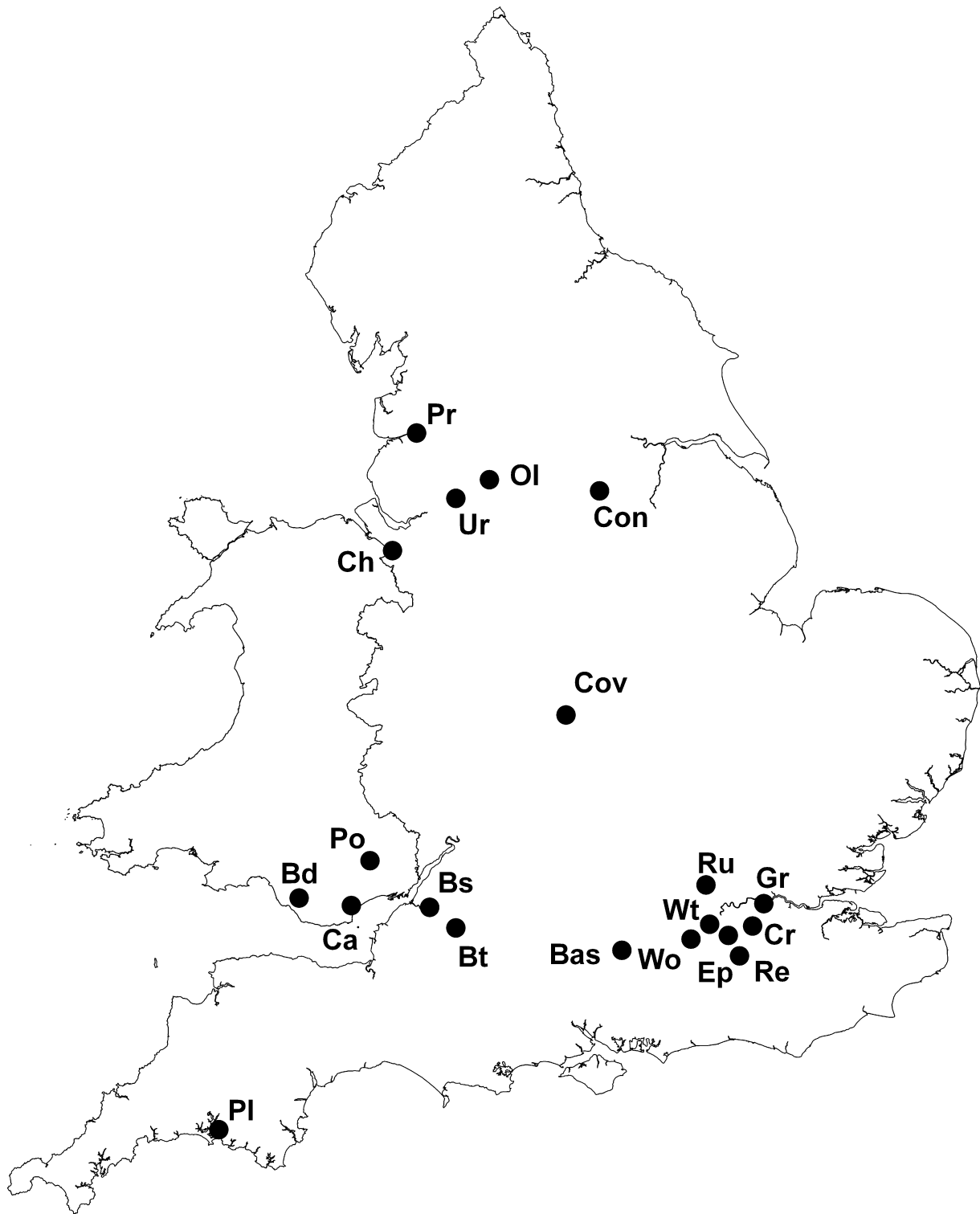


Fig. 1 (continued)

2.3. Estimating the extent of the garden resource

All surveys were weighted equally, although we acknowledge that each individual survey will potentially have associated biases. However, a broad range of research questions motivated the different studies and a variety of methodological techniques were used to collect the datasets. As such, there

is no reason to suspect that the garden resource estimates derived from the surveys will be systematically biased. In addition, the purpose of this paper is not to produce a highly accurate figure for each resource, but to provide approximate, robust and transparent estimates that can be used to assess the value of domestic gardens to biodiversity conservation.



**Table 2 – Number of households across the UK according to the most recent census conducted in 2001.**

Country	Number of households
England	21,262,825
Northern Ireland	1,311,860
Scotland	2,308,939
Wales	1,275,816
UK	26,159,440

The garden resources examined were supplementary bird feeding, provision of nest boxes, and the occurrence of ponds and of trees taller than 3 m. For each dataset, the proportion of households and/or gardens in the survey providing each resource was calculated, in addition to the average of any recorded quantitative measure (e.g., garden area, number of trees). Data were then averaged across all studies to generate a mean proportion and confidence interval for each resource type (see [Appendices B–F](#)).

The number of households in the UK with access to a garden was calculated by multiplying the mean proportion (generated using all surveys with relevant data) of households with a garden by the number of households recorded in the most recent UK census conducted in 2001 ([Table 2](#)). Subsequently, the area of all gardens across the country was extrapolated using the average garden size, which was recorded in some of the surveys, and the previously estimated number of gardens across the country. The number of households/gardens in the UK providing each resource (e.g., supplementary food for birds, a pond) was calculated using the same simple assumptions; all household-based estimates were scaled up using the 2001 census data, and all estimates of resources specifically within gardens were extrapolated using the number of UK gardens derived above. The garden resource estimates are hereafter presented as whole numbers, but were calculated using exact figures.

### 3. Results

#### 3.1. Garden sizes and total garden area

On average, 87% of households had a garden area associated with the dwelling ([Appendix B](#)). Mean garden size, excluding zero values within each survey, was 190 m<sup>2</sup> (95% CI = 173.0–207.8). Extrapolating to the 26,159,440 households in the UK, this equates to 22,738,563 (95% CI = 21,768,735–23,708,391) domestic gardens with a total area of 432,964 ha (95% CI = 393,391–472,537).

#### 3.2. Supplementary food provision for birds

The average proportion of households and, more specifically, households with a garden providing supplementary food for birds were 48% and 51% respectively ([Appendix C](#)). Scaling up, using the known number of households in the UK, this gives an estimate of 12,581,718 (95% CI = 10,469,000–14,694,435) homes across the country participating in bird feeding activities. Similarly, using the proportion of households with a garden providing food for birds and the esti-

mated number of gardens in the UK, the extrapolated number of gardens containing supplementary bird food is 11,640,921 (95% CI = 9,907,575–13,374,266).

The discrepancy between these two values is likely to be due to the approximate nature of the calculations. However, it is also possible that it reflects the provision of bird food by householders living in flats, who may have access to an outside space (e.g., a balcony or roof terrace) or a bird feeder attached to a window in order to attract avian visitors, but were excluded from the garden surveys.

From the surveys, a mean of 28% of households and 23% of households with gardens specifically used bird feeders for supplementary food provision. Assuming that each household/garden only has one bird feeder, which is likely to be a conservative assumption, it is estimated that there are 7,376,105 (95% CI = 5,240,886–9,511,324) bird feeders associated with households at a national level and 5,299,590 (95% CI = 3,132,608–7,475,571) bird feeders within gardens across the UK.

#### 3.3. Nest boxes

On average, 16% of households had at least one nest box ([Appendix D](#)). Extrapolating this to the number of households in the UK gives a minimum estimate of 4,305,621 (95% CI = 2,658,848–5,952,394) nest boxes across the country. This figure is consistent with the 4,710,632 (95% CI = 3,869,926–5,551,337) nest boxes derived from a mean proportion of 21% of gardens containing a nest box.

#### 3.4. Ponds

The mean proportion of households with a pond was 10%, equating to 2,543,201 (95% CI = 1,487,803–3,598,599) ponds in the country ([Appendix E](#)). The garden surveys, on average, recorded 16% of gardens containing a pond, giving a total of 3,531,118 (95% CI = 2,496,205–4,566,031) ponds in UK gardens. The mean size of a garden pond was 1 m<sup>2</sup> (95% CI = 0.5–1.5). Scaling up to the 3,531,118 gardens in the UK with a pond, this corresponds to a total area of standing water of 349 ha (95% CI = 158.5–540.3).

#### 3.5. Trees

On average, 54% of gardens contained one or more trees taller than 3 m, equating to 12,200,863 (95% CI = 9,846,431–14,555,296) gardens across the UK ([Appendix F](#)). The mean number of trees within a garden was 2.4 (95% CI = 1.8–2.9), generating a national estimate of 28,730,986 trees within domestic gardens (95% CI = 22,196,978–35,264,995). One study examined the extent of tree cover in gardens, reporting that 11% of garden area was tree-covered; this figure translates to a national tree coverage of 47,402 ha.

## 4. Discussion

### 4.1. Gardens

In the UK, we estimate that 87% of households, or 22.7 million homes, have access to a domestic garden. These figures are

comparable to the 85% of households in the UK that have a garden according to *English Nature* (2004), but is somewhat higher than the outdated estimate of 80% of households in Britain quoted by *Hessayon and Hessayon* (1973) and subsequently cited in other ecological publications (e.g., *Owen*, 1991; *Buczacki*, 2007).

The average size of a garden in the surveys was 190 m<sup>2</sup>, equating to an area of 432,964 ha across the country. *Hessayon and Hessayon* (1973) give a mean area of 186 m<sup>2</sup> for gardens which is highly consistent with our calculation, as is the frequently quoted figure of over 400,000 ha of gardens in Britain (e.g., *Baines*, 1985; *Ryrie*, 2003; *Moss and Cottridge*, 1998). To illustrate the extent of this area, it is equivalent to the US state of Rhode Island and is larger than the English county of Suffolk. To a householder, the area of their individual domestic garden may seem limited, particularly for those living in terraced accommodation in urban centres, but the sum of all these gardens contributes substantially to the overall amount of green space in urban areas across the country. For example, *Loram et al.* (2007) found that domestic gardens accounted for approximately one quarter of urban land cover within five UK cities. Moreover, the total contiguous area, and heterogeneous nature, of all the gardens in a residential street or neighbourhood is of considerably more relevance to species requiring large areas over which to fulfil their niche requirements, than any one individual plot (e.g., *Cannon et al.*, 2005; *Knight et al.*, 2005). As well as providing habitat in their own right, domestic gardens may facilitate species moving between areas of public green space (e.g., parks) and/or the wider countryside, therefore increasing habitat connectivity at a landscape-scale (*Fernández-Juricic*, 2000; *Fernández-Juricic and Jokimäki*, 2001; *Rudd et al.*, 2002).

Nonetheless, the national coverage of domestic gardens is still an order of magnitude less than the 4.7 million hectares of statutory protected areas throughout the UK (*S.F. Jackson and R.A. Fuller*, unpublished analyses). In addition, these estimates of garden coverage may include large areas covered by temporary structures, such as garden sheds or greenhouses, or areas that have been converted to hard standing (e.g., concreted, paved, decked). Indeed, this is a growing phenomenon (*Goode*, 2006), and a recent report has suggested that nearly half of all households in North East England have paved over the majority of their front gardens to create off-road parking (*RHS*, 2007). Furthermore, the area of domestic gardens throughout the UK is likely to decrease as a result of increasing urbanisation. For example, the human population in England alone is projected to grow by a further 7%, from 49 million individuals in 1998, to 52.4 million by 2021 (*DETR*, 2000). In response, new houses are being built at an increased density of 40 dwellings per hectare, up from 25 dwellings per hectare before 2002 (*ODPM*, 2006). Meanwhile, existing gardens are frequently being built upon (commonly referred to as backland development or 'garden grabbing') and thus proportional coverage of green space within residential areas seems likely to decline in the coming years (*Goode*, 2006).

#### 4.2. Supplementary food provision for birds

Approximately 12.6 million households, or 48% of homes across the UK, were estimated to be participating in supple-

mentary food provision for birds. This compares well to a poll conducted in 2003 on behalf of the Royal Horticultural Society that showed that half of all households with a garden provide food for avian visitors (*Moss*, 2000).

Of the 12.6 million households supplying supplementary food for birds, 7.4 million specifically use bird feeders. The sheer scale of this resource estimate can best be illustrated by an undoubtedly simplistic calculation. There are 134,602,702 (SE = 3,751,514) breeding birds in the UK and 67,734,400 (SE = 2,165,000) of these belong to species that commonly use bird feeders (*R.A. Fuller*, unpublished analyses using national population estimates compiled by *Baker et al.*, 2006). Therefore, across the country, there is approximately one bird feeder for every nine potentially feeder-using birds.

In recent years, bird feeding has developed from just throwing food scraps out of the back door in winter to becoming a multi-million pound industry (*Moss and Cottridge*, 1998; *Moss*, 2000). Indeed, the *British Trust for Ornithology* (2006) estimates that the total annual expenditure on outdoor bird feeding in the UK is £200 million. The quantity of food held by specially designed bird feeders across the country can be roughly calculated as a typical small bird feeder contains approximately 350 g of bird seed (*R.A. Fuller*, unpublished data). Conservatively assuming that each household recorded as using bird feeders only has the one, there is a standing crop of 2580 tonnes of bird food. However, although this illustrates the extent of the potential resource, up to 80% of feeders are believed to be empty at any one time (*Toms*, 2003) and *Gaston et al.* (2007) found that 36% of bird feeding activity was carried out less frequently than once a month.

Moreover, supplementary feeding may not be universally beneficial to all avian populations. Despite some evidence that birds do not become dependent on food resources provided by householders (*Brittingham and Temple*, 1992), and that levels of bird feeding are positively correlated with the abundance of urban birds (*Fuller et al.*, 2008), the possible negative consequences still remain to be fully investigated (*Jones and Reynolds*, 2008). These may include reliance on an unpredictable resource, a reduction in diet quality, increased predation pressure, loss of natural foraging behaviours (*Brittingham and Temple*, 1992; *Robb et al.*, 2008) and an increase in the number and abundance of exotic species (*Daniels and Kirkpatrick*, 2006).

#### 4.3. Nest boxes

At a national level, we estimated that there is a minimum of 4.7 million nest boxes within domestic gardens. This figure is likely to be an underestimate as it assumes that each household only has one nest box, as none of the surveys collated data on the number of nest boxes per household.

A review of 46 studies by *Newton* (1998) determined that the availability of nesting sites can limit breeding bird densities for hole-nesting species. This can be a particular problem in urban areas, where public land managers remove dead and decaying trees and, along with them, the potential opportunities for nesting (*Moss*, 2000). As a result, it has been recommended that nest boxes should be provided in urban parks in order to increase the colonization by a greater variety of cavity-nesting birds (*Jokimäki*, 1999). Of the 134,602,702



(SE = 3,751,514) breeding birds in the UK, 53,098,498 (SE = 1,929,443) belong to species that may commonly use garden nest boxes as breeding sites (R.A. Fuller, unpublished analyses using national population estimates compiled by Baker et al., 2006). Using our conservative estimate of the number of nest boxes in UK gardens, this approximates to one nest box for every six breeding pairs of cavity-nesting birds in the country. Even accounting for the fact that some nest boxes will be structurally unsuitable, have been placed in inappropriate locations, or not be in a serviceable state of repair, this is still an impressive resource.

#### 4.4. Ponds

Across the UK, we estimate that there are between 2.5 and 3.5 million ponds in domestic gardens, equating to 349 ha of standing water. This corresponds to the over 2 million cited by Bevan (2001). To put these figures in context, the 1996 Lowland Pond Survey estimated that there were only 228,900 lowland ponds within the wider countryside of Great Britain (Williams et al., 1998). Such ponds are defined as a small water body between 1 m<sup>2</sup> and 2 ha, which holds water for all or part of the year, and collectively includes pools, marl and brick pits, bog pools, kettle holes and lagoons (Rouen, 2001). Following this definition, and excluding those within gardens, they comprise 97% of the standing waters in the country, but only 14% of the total surface area (Bailey-Watts et al., 2000). Nonetheless, meaningful comparisons between the numbers of ponds in gardens and those in the wider countryside are difficult because most garden ponds are generally much smaller (with a mean surface area of only 1 m<sup>2</sup>).

In the wider countryside, many ponds are threatened by natural succession, land drainage and development (Boothby and Hull, 1997). Despite the total surface area of garden ponds being so small, the resource is fragmented over a wide distribution and provides a haven for many amphibians, invertebrates and plants in residential areas, including some of specific conservation interest (e.g., the common frog *Rana temporaria* and common toad *Bufo bufo*; Beebee, 1997; Williams et al., 2000). Indeed, almost all ponds are used by aquatic organisms, irrespective of age or structure, as long as the water quality is maintained (Pond Action, 1994; Linton and Goulder, 2000; Wood et al., 2003), and they do not have to be large to be of high conservation value (Oertli et al., 2002). Garden ponds also provide birds with drinking water and a place to bathe, in addition to supporting a variety of invertebrates which are a possible food resource (Moss, 2000; Burton, 2004). The important habitat heterogeneity associated with domestic garden ponds is often lost due to the removal of vegetation and silt (Biggs et al., 1994). A balance therefore needs to be found between maintaining the pond and preventing succession without over managing the resource (Linton and Goulder, 2000).

#### 4.5. Trees

Over 12 million gardens across the country are estimated to contain at least one tree. Of these gardens, the average number of trees in each was approaching 2.4, giving a total esti-

mate of 28.7 million trees. According to the Forestry Commission (2003), there are just over 123 million live trees occurring outside woodland in Great Britain (England, 89,217,000; Scotland, 18,576,900; Wales, 15,334,000) and a further 2 million dead trees. Domestic gardens therefore contribute just under a quarter of this total.

Trees in residential areas can play a number of important roles. First, they contribute to ecosystem services such as microclimate regulation and air filtration (Bolund and Hunhammar, 1999). Second, garden trees may include rare species that have either disappeared, or been severely depleted, in the wider countryside, often as a result of changing land use (e.g., old varieties of fruit trees). Finally, they may provide important habitats for wildlife. For instance, the species richness of some taxonomic groups increases in urban areas in relation to the volume of available vegetation (Dickman, 1987; Jokimäki and Suhonen, 1993; Savard et al., 2000) and trees provide nesting sites, food and refuge from predators for many species (Fernández-Juricic and Jokimäki, 2001). Although the utility of trees within domestic gardens as habitats, particularly in urban centres, will frequently be limited by an array of factors such as human disturbance, stress as a result of pollution or heat, and whether they are exotic or native species, this is still a potentially substantial resource for biodiversity that has, so far, largely been overlooked in the conservation literature.

## 5. Conclusions

The potential importance of domestic gardens to biodiversity has been acknowledged in the popular media for many years (e.g., Hammond, 1974; Baines, 1985; Good, 2000; Packham, 2001; Ryrie, 2003; Buczacki, 2007). This assertion is supported by a small number of studies that have demonstrated that gardens play a substantial role in maintaining, and enhancing, biodiversity. They have included intensive investigations of the biodiversity of individual gardens (e.g., Owen, 1991; Miotk, 1996), the presence and abundance of particular taxonomic groups in one or more gardens (e.g., Morley, 1944; Barnes, 1949; Davis, 1978; Dickman, 1987; Rapoport, 1993; Vickery, 1995; Cannon et al., 2005; Daniels and Kirkpatrick, 2006; Smith et al., 2005a–c; Osborne et al., 2008), and the occurrence of multiple taxonomic groups across many gardens (e.g., Saville, 1997; Thompson et al., 2003, 2004; Gaston et al., 2005a). However, further research is required to better understand the complex interactions between wildlife, both native and exotic, and the habitat features provided within gardens. Knowing how best to manage these resources must be a priority if we are to maximise the retention of biodiversity within domestic gardens in the future. To date, information on the magnitude of the resource provision has also been lacking (Gaston et al., 2005b; Loram et al., 2007; Buczacki, 2007). This paper is the first to illustrate the sheer scale of the contribution that gardens make to possible habitat provision in a national context. Planning strategies which neglect the role of gardens within estimates of green space, particularly those in urban areas, undervalue the extent of the resource. This is particularly pertinent as further development and urbanisation throughout the world is likely to continue unabated.

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2008.12.016.

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