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Assessing the efficacy of artificial domiciles for bumblebees

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ABSTRACT

Bumblebees have suffered declines as a result of reduction in habitat availability associated with agricultural intensification. Although several conservation strategies for bumblebees address forage availability, other aspects of bumblebee ecology are often ignored. Availability of sufficient nest sites is a key requirement of bumblebee populations and since nesting habitat is likely to have become reduced on intensively farmed land, lower nest site availability may contribute to bumblebee declines. The use of artificial domiciles for bumblebees has been proposed as a potentially useful tool for conservation and for improving pollination services for crops, providing a method of boosting nest site availability where it is otherwise limiting. Here, six different artificial domiciles for bumblebees are trialled in different habitats in southern England and central Scotland. Of these, only one domicile design at one particular site achieved reasonable uptake rates, whilst all other combinations of domicile and site achieved low success. Overall, only 23 of 736 domiciles deployed were occupied by bumblebees (3.1%). Based on current knowledge, attempts to use domiciles for conservation or research in the UK are likely to be ineffective. Commercially available domiciles for bumblebees performed poorly in these trials and the implications of these findings for manufacturers are discussed.

Introduction

The nesting habits of bumblebees are an understudied aspect of bumblebee ecology. However, since reduction in habitat availability is implicated in declines of many bumblebee species worldwide (Goulson et al. 2008), a detailed understanding of the ecological requirements of nesting bumblebees may be vital to ensure the well-being of this important pollinator taxon. Most bumblebee conservation studies focus on counts of individuals foraging in the field, but there is an urgent need for studies at the colony level in order to improve our understanding of colony level responses to alterations in environmental conditions (Williams & Osborne 2009).

Artificial domiciles for bumblebees have been used with some success in Canada, New Zealand and the US (Donovan & Weir 1978; Frison 1926; Fye & Medler 1954; Pomeroy 1981; Richards 1978, 1987) but success has been very limited in similar trials conducted in recent years in the UK (Carvell 2000; Fussell & Corbet 1992; Gaston et al. 2005). Habitat, position relative to the ground and timing of placement are all important factors in determining occupancy rates and the species most likely to occupy domiciles (Frison 1926; Hobbs 1967; Hobbs et al. 1962; Richards 1978), but there appears to be little effect of the materials used or the shape and size of the domicile on their attractiveness to bumblebee queens (Pomeroy 1981; Richards 1978). Since timing and site selection appear to be so important in influencing uptake rates it is possible that poor siting and/or timing may be responsible for the comparatively low occupancy rates achieved in the UK.

If design and placement of artificial domiciles could be optimised, these might provide a useful tool for the conservation and study of bumblebees and could also provide additional economic benefits. The use of artificial domiciles by bumblebees would allow monitoring and management of colonies founded within them, facilitating detailed observation of colony fate for both common and rare bees. This could provide new and much-needed insights into colony-level responses of wild bumblebees to differing environmental conditions, as well as allowing artificial protection and supplementary feeding of these colonies (Fye & Medler 1954; Hobbs et al. 1960, 1962; MacFarlane et al. 1983; Sladen 1912). Additionally, artificial domiciles could be used as a method of procuring wild bumblebee colonies for experimental studies or for crop pollination, for use as an alternative for artificially reared colonies currently used for pollination of several flowering crop plant species (Ings et al. 2005, 2006). If nest site availability limits bumblebee populations, as may be the case in some parts of the US (Greenleaf & Kremen 2006; McFrederick & Lebuhn 2006), the provision of artificial domiciles to coincide with the emergence of (generally later emerging) declining species could significantly boost their population sizes.

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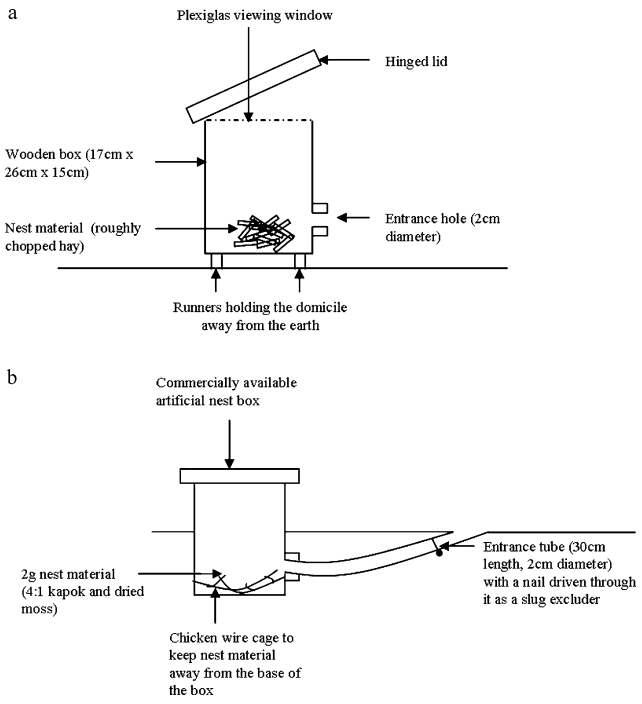


Fig. 1. Commercially available artificial domicile for bumblebees (a) installed as recommended by the manufacturers and (b) adapted as a wooden semi-subterranean domicile.

Here, we assess the efficacy of different artificial domicile designs trialled in a range of different habitat types in the south of England and central Scotland (UK).

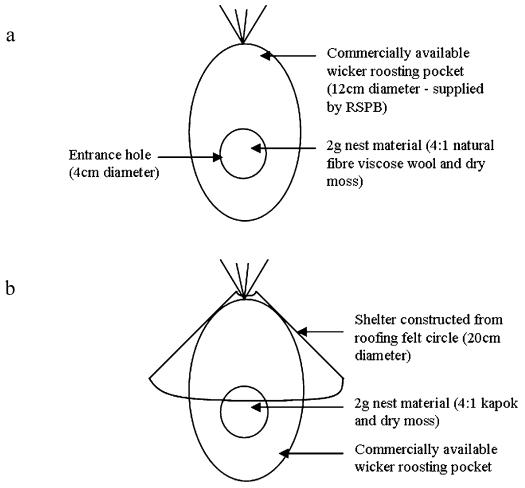
Methods

Garden habitat in central Scotland

In order to test the efficacy of commercially available artificial domiciles for bumblebees (RSPB, UK) (Fig. 1a), 26 were taken home by staff at the University of Stirling and placed in 13 suburban gardens in central Scotland in the spring of 2008. These remained in place throughout 2008 and through the summer of 2009. Boxes were placed out exactly as supplied and were located in sheltered locations along linear features in areas thought to be likely bumblebee nesting habitat. Participants were asked to provide details of any occupancy in June of each year.

Botanical gardens

The Sir Harold Hillier Gardens in Romsey is a botanical garden situated in the south of England, covering 180 acres and incorporating a wide range of native and non-native plant species with a broad range of flowering periods. Domiciles were placed in an area of mixed woodland containing a high density of *Rhododendron* spp. Twenty pairs of domiciles (designs shown in Figs. 2a and 5) were placed out at the end of February 2007, coinciding with the emergence of *Bombus terrestris* (Linnaeus) from hibernation. Each pair was placed at least 10 m away from any other pair and all were placed in locations where nest site searching queens had been observed in abundance the previous year (Lye, pers. obs.). Domiciles were checked monthly from March until May and the entrance holes cleared of any obstructions. They were collected in early July and the contents examined for any signs of occupancy by bumblebees or other animals.



* Roosting pockets were placed on upright features (e.g. trees, fence posts etc.) at a height of between 1.5m and 2m above ground level.

Fig. 2. Commercially available 'roosting pocket' domicile * (a) as sold and (b) with the addition of a protective roofing felt cover.

Grounds of the University of Stirling, Scotland

The campus at the University of Stirling consists of 300 acres including grassland, woodland, lakes and gardens. Domiciles were placed in woodland or woodland edge habitat across the entire campus. One hundred sets of four domicile designs (shown in Fig. 1b, 2b, 3 and 4) were placed out at the end of March 2007, approximately the time of commencement of nest site searching behaviour in bumblebees in this region. Each domicile was positioned at least 1 m from neighbouring domiciles and domicile sets were positioned at least 10 m away from neighbouring sets. The order in which these were placed was randomised. Each set was sited along a linear feature in areas believed to be good bumblebee nest site searching habitat based on the experience of the investiga-

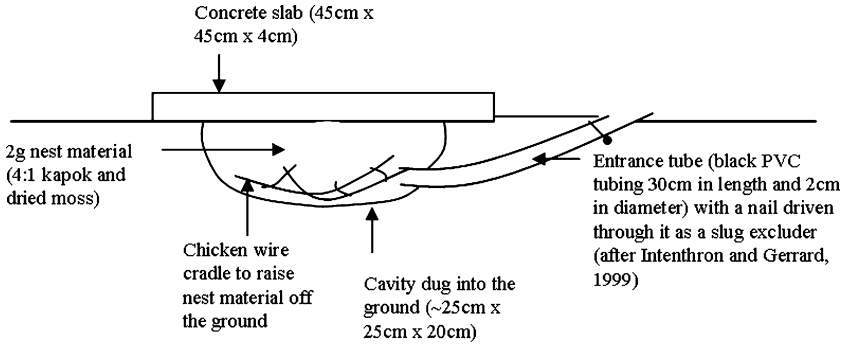


Fig. 3. Slab domicile.

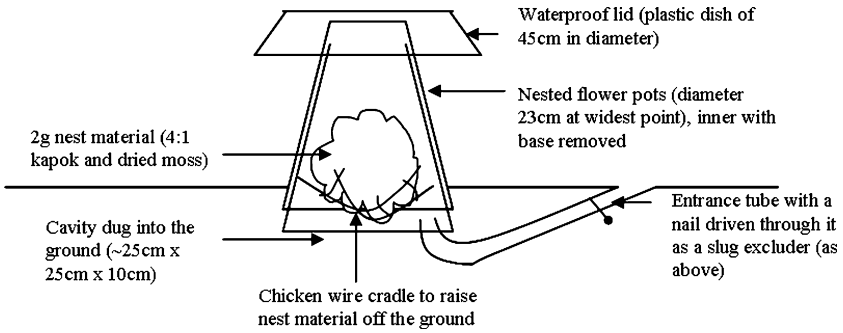


Fig. 4. Flower pot domicile.

tors. Domiciles were checked at fortnightly intervals through April and May and the entrance holes were cleared of any obstructions. If evidence of occupancy was observed, domiciles were checked weekly until late August, at which time all of the domiciles were collected and examined for evidence of occupancy by bumblebees or other animals.

In order to look for an effect of entrance type, fifteen new sets of eight domiciles were placed out in the grounds of the University of Stirling in mid March 2008. Each set consisted a pair of each of the domicile designs shown in Figs. 1b and 3–5. One of each pair of domiciles had a 'standard' tube entrance (as in Figs. 1b, 3 and 4) and the other included the more sophisticated 'tile' entrance (as in Fig. 5). The domiciles were checked fortnightly as above. They were excavated in late August and any evidence of occupancy by bumblebees or other organisms recorded.

Agricultural land in central Scotland

Domiciles were placed in ten arable or mixed farms across central Scotland. Five of these were participants of the Scottish Rural Stewardship scheme, designed to enhance and protect habitat features by encouraging the implementation of environmentally sensitive land-management practices. Rural Stewardship farms were selected based on their implementation of three management prescriptions that could benefit spring bumblebees and therefore may attract nest site searching bumblebee queens. These prescriptions consisted of hedgerow management, field margin management and species-rich grassland, all of which were developed to promote a complex vegetation structure and increase floral abundance. The remaining five farms were chosen as pairs for the five Rural Stewardship participant farms based on location and farm type (see Lye et al. 2009).

A total of 150 complex subterranean domiciles (Fig. 5), were installed between late March and early April 2008. Fifteen domiciles were placed out per farm, five each in a grassland, hedgerow and field margin habitat context (prescribed features within Rural Stewardship farms or equivalent habitats within the conventional farm pairs). Each domicile was positioned at least 3 m away from adjacent domiciles and domiciles on each farm pair were installed on the same day or on consecutive days. Domiciles were checked once a week for three weeks between late May and early June and were removed at the end of August 2008. The contents of the domiciles were then examined for evidence of activity by bumblebees or other animals.

Results

Garden habitat in central Scotland

None of the 26 commercially available wooden domiciles placed out in urban gardens were occupied by bumblebees in 2008 or 2009.

Botanical gardens

At the Sir Harold Hillier Gardens, high occupancy rates were recorded for the complex subterranean domicile design (Fig. 5) with 9/20 domiciles (45%) showing evidence of bumblebee activity. Four of these (two *B. terrestris*, one *Bombus lucorum* (Linnaeus) and one *Bombus hortorum* (Linnaeus)) were still active at the time of col-

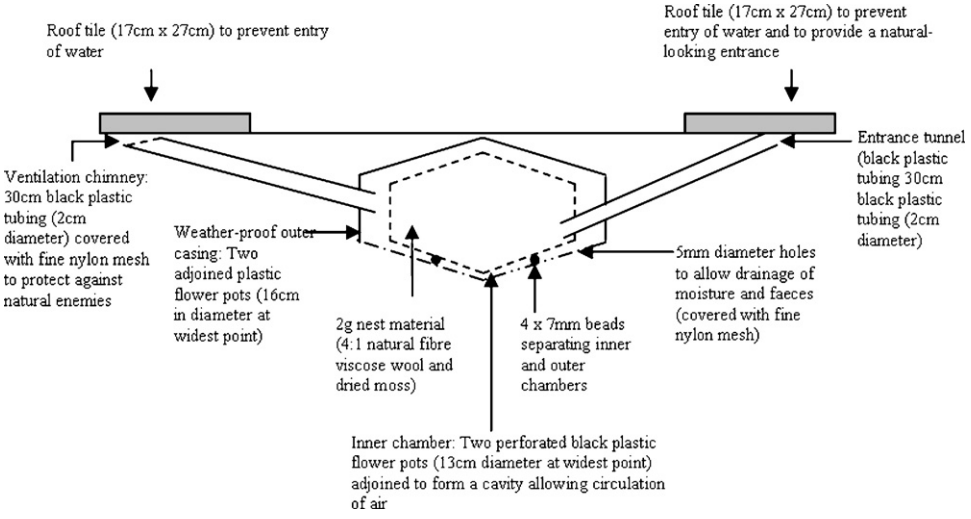


Fig. 5. Complex subterranean domicile.

lection and of these, two had commenced queen production. One domicile contained the intact remains of a colony of *B. terrestris* but no queen cells were present. There was no evidence to suggest the reason for the demise of the colony, but it is likely to have happened very close to the time of collection as other previously occupied boxes contained material in advanced stages of decay. Three other domiciles showed evidence of reasonably large colonies, but the remains were highly degraded and it was only possible to deduce that the colonies had belonged to *B. terrestris* or *B. lucorum*. A further domicile contained nest material that had been shaped in such a way as to suggest manipulation by a queen bumblebee as well as the yellow faeces associated with bumblebee activity, but no cells were present, indicating that the queen either deserted the domicile or perished very early on in colony foundation. Of the remaining complex subterranean domiciles, two were flooded, one contained a large colony of vespid wasps, one was inhabited by ants and a further one showed evidence of occupancy by mice. Lower occupancy rates were observed for the roosting pocket domiciles with only 2/20 (10%) showing evidence of bumblebee activity. One of these was occupied by a colony of *Bombus pratorum* (Linnaeus), which progressed to queen production. The other contained around six cells but no bodies so that the identity of the species that the comb belonged to could not be ascertained. No queen cells were present. One of the remaining roosting pockets also showed evidence of occupancy by birds.

Grounds of the University of Stirling, Scotland

Domiciles trialled in the grounds of the University of Stirling received low occupancy rates. In 2007, no bumblebee colonies were founded within flower pot domiciles. Eight percent showed evidence of occupancy by small mammals (probably wood mice) and one contained a large colony of vespid wasps. Similarly, no successful colonies were founded within wooden semi-subterranean domiciles. A dead queen of *B. lucorum* was found within one box, but there was no evidence of an attempt at nest founding. It is likely that, having explored the domicile, the queen was unable to get out again, perhaps as a result of a tube blockage or simply of being unable to relocate the entrance tunnel. These domiciles also appeared to be unattractive to other organisms, with the majority of boxes remaining unoccupied (Table 1). Two slab domiciles were occupied by bumblebees, one by *B. lucorum* and one by *Bombus lapidarius* (Linnaeus). The former was first observed on April 26th and the latter on May 24th. Both colonies thrived and the colony of *B. lucorum* progressed to queen production. The colony of *B. lapidarius* was observed to be producing males on July 12th but at the next visitation, one week later, the nest was dead and the comb was some way outside the nest entrance. It is believed that this colony may have been attacked by a mammalian predator. No queen cells were evident in the comb that was retrieved, but this may not be representative of the state of the colony at termination. Small mammals and ants were also regular occupants of slab domiciles (22% and 7% respectively), and the slab domicile containing the colony of *B. lapidarius* contained nest material other than that provided by the experimenters suggesting occupancy by small mammals prior to colonisation by bumblebees. One roosting pocket was occupied by a bumblebee colony and this belonged to *B. pratorum*. The queen was seen to enter the roosting pocket on 12th April and queens and males were observed leaving the nest shortly before its expiration in the middle of June. Roosting pockets were also often occupied by vertebrates (31%), but in most cases, it was unknown whether this was by birds or by small mammals (which often make use of these domiciles – D. Beaumont, pers. comm.).

In 2008, just four of the 120 artificial domiciles showed evidence of queen activity (3%), and all of these incorporated the standard entrance styles rather than the novel 'tile' entrance style. On 20/04/08, a queen *B. lucorum* was observed to emerge from a slab domicile incorporating the standard entrance and commence rearrangement of moss and twigs around the entrance. This behaviour continued for at least 5 min. However, the queen was not seen again on subsequent visits and on later inspection of the material within the domicile, no evidence of nest initiation could be found. The bodies of two queens were discovered within one of the flowerpot domiciles. Both were degraded but belonged either to *B. terrestris* or *B. lucorum*. It is not known why these bees did not survive. Two colonies were established within wooden semi-subterranean domiciles. The first belonged to *B. lucorum* and produced workers, but expired in early June. No males or queen cells were found, suggesting that this colony did not progress to reproduction. The second colony initiated was of unknown species. The comb was discovered on 06/06/08 and consisted of nine cells and the larger honeypot. However, no complete bees were present within the domicile.

Small mammals occupied slab, wooden box and flower pot domicile designs (20%, 3% and 7% respectively), and the entrance style did not seem to influence likelihood of inhabitancy by these animals (tile: 8%, standard: 7%). Large vespid wasp nests were found in two of the complex underground domiciles, both of which were still active when the domiciles were dismantled in August.

Agricultural land in central Scotland

Occupancy of artificial domiciles placed on agricultural land was low and there was no evidence for a preference of either bumblebees or small mammals for any particular habitat type (grassland, hedgerow or field margin) or land management type (Rural Stewardship vs. conventional). Six (4%) of the domiciles showed evidence of inhabitation by small mammals and one (<1%) was colonised by vespid wasps. A further two were flooded and two were accidentally destroyed by farm machinery but showed no evidence to suggest occupancy prior to their destruction.

Only four (3%) of the domiciles showed any evidence of bumblebee activity. One of these, on a conventionally managed hedgerow, did not contain any cells, but the nest material had been rearranged in the characteristic manner that provides evidence of manipulation by a queen bumblebee. A further domicile, destroyed by farm machinery, contained a small comb (~eight cells and a honeypot), however no bees were present at the time of discovery so it was impossible to ascertain which species this colony had belonged to. This domicile was located on a Rural Stewardship field mar-

Table 1
Overall fate of each domicile style combined across trials (% in brackets).

Domicile design	Bumblebees	Bird/ small mammals	Other insects	Damaged/ missing	Unoccupied	Total
Commercially available domicile	0 (0%)	Unknown	Unknown	Unknown	Unknown	26
Wooden semi-subterranean domicile	3[a] (2%)	1 (1%)	2 (2%)	3 (2%)	121 (93%)	130
Roosting pocket domicile	3[a] (3%)	32 (27%)	0 (0%)	28 (23%)	57 (48%)	120
Slab domicile	3[a] (2%)	28 (22%)	7 (5%)	6 (5%)	86 (66%)	130
Flower pot domicile	1[a] (1%)	10(8%)	1 (1%)	9 (7%)	109 (84%)	130
Complex subterranean domicile	13[a] (7%)	7 (4%)	5 (3%)	6 (3%)	169(85%)	200

[a] For details see text.

gin. The remaining two colonies belonged to *B. lucorum* and both thrived and progressed to queen production. The first, located on a Rural Stewardship managed grassland site, had completed the colony cycle by the time of domicile removal in late August, but the second, located on a conventionally managed grassland site, was still very active. With such low rates of occupancy it is not possible to ascertain whether domicile uptake should be expected to differ between farms deploying agri-environment schemes and conventional farms (3% in each case), or between grassland, field margin and hedgerow habitats (4%, 2% and 2% respectively).

Discussion

Past studies conducted in the US, Canada and New Zealand report high uptake rates by bumblebee queens (often of between 30% and 50%) when trialling wooden boxes similar to the commercially available domicile used in this study (Fye & Medler 1954; Hobbs 1967; Hobbs et al. 1962; MacFarlane et al. 1983; Richards 1978). However, similar trials conducted more recently in the UK have failed to replicate these rates of success (Fussell & Corbet 1992; Gaston et al. 2005). The results of this study are consistent with those of the latter, demonstrating low uptake rates of wooden commercially available domiciles, whether used according to the manufacturer's guidelines or with the addition of more suitable nest material and modified for underground usage.

In the early 20th century, Sladen (1912) developed the 'Sladen cover' domicile design, which consisted of a hole in the ground supplied with suitable nesting material and covered by a wooden lid. When trialled in the UK between 1910 and 1912, these achieved an overall uptake rate of 30% and six different bumblebee species were represented (Sladen 1912). The slab domicile design used in this study was very similar to that of the Sladen cover domicile but occupancy rates achieved were much lower (2%). Slab domiciles were commonly occupied by mice, and since bumblebees are often found nesting in the abandoned homes of mice (Donovan & Weir 1978; Svensson & Lundberg 1977), it is possible that these domiciles might have been occupied more readily by bumblebees in subsequent years. Increasing occupancy across years is common in artificial domicile trials but the explanation for this is generally unclear (Barron et al. 2000; Donovan & Weir 1978; Hobbs et al. 1962).

Roosting pockets were the only aerial design trialled in this study. In past studies carried out in the US, Canada and the Netherlands, aerial designs have achieved occupancy rates of between 33% and 43% (Fye & Medler 1954; Hobbs 1967; Richards 1978; Wilcke 1953) and it has been suggested that the number of bumblebee colonies founded above ground may often be underestimated (Richards 1978), perhaps because such colonies are less likely to be observed. However, in the present study, roosting pockets yielded low occupancy rates. As with the slab domiciles, roosting pockets were frequently occupied by birds or small mammals so it is possible that uptake rates would have increased if the domiciles were left out over subsequent years.

No bumblebee colonies were established in flower pot domiciles nor did these appear to be particularly attractive to small mammals. This type of domicile was also fragile and although most survived the first summer, the majority succumbed to bad weather and/or vandalism over the winter.

Overall uptake rates were low for the complex subterranean domicile but this design did show potential as a method of providing suitable nest sites for bumblebees. At the botanical garden site in southern England, uptake rates were comparable with those achieved by Richards (1978, 1987) and Hobbs et al. (1960, 1962) in Canada and three different bumblebee species were represented, suggesting that this domicile style could provide benefits for multiple species. However, in central Scotland in the agricultural environment and on Stirling University campus, the domiciles performed poorly and uptake rates were closer to those achieved with other domicile designs and in other British studies (Fussell & Corbet 1992; Gaston et al. 2005). Since other designs were not trialled in the botanical garden site, the effects of location and domicile design cannot be disentangled, thus there is no evidence that this design is more effective than other designs trialled in this study. However, the success of some colonies founded within the domiciles demonstrates that this design can provide suitable nest sites for bumblebees.

The domiciles trialled in this study were based on designs that have previously been used with some success (Hobbs 1967; Hobbs et al. 1962; Intenthron & Gerrard 1999; Sladen 1912) yet low occupancy rates were achieved for all. It should be noted that many of the successful artificial domicile studies carried out previously were conducted several decades ago. Given ongoing declines of bumblebee populations throughout most of their range (Williams & Osborne 2009) the lower occupancy rates observed here may be a direct reflection of lower bumblebee population sizes. This would also explain low levels of uptake reported in recent studies in other parts of the world (Barron et al. 2000; Elliot 2008).

The location of domiciles placed in the botanical garden site were selected based on the presence of an abundance of nest site searching queens in the previous year, a method of site selection which has also often yielded successful results in past studies (Frison 1926; Pomeroy 1981; Sladen 1912). It is possible that an abundance of nest site searching queens may reflect a deficit of nest sites relative to local bumblebee population sizes. This might be expected at the botanical garden site since it provides a succession of flowers throughout the spring and summer which is likely to promote bumblebee colony survival and reproduction. This would lead to high local abundances of bumblebees and could potentially cause nest sites to become a limiting resource.

Whilst population sizes were probably greatest at the botanical garden site, it is not likely that the very low rates of success at other sites were due to a lack of nest-site searching queens. Though many bumblebee species have shown range restrictions in recent years, some, for example *B. terrestris*, are abundant and are found throughout mainland Britain in most terrestrial habitat types (Edwards & Jenner 2005). In addition, since bumblebee queens have been shown to be able to disperse at least 5 km from the site of their maternal nest (Lepais et al. 2010), and may spend several weeks searching for a suitable nest site (Alford 1975), it is extremely unlikely that domiciles were not encountered by nest site searching queens. Indeed, several nest site searching bumblebee queens of six common British species (*B. terrestris*, *B. lucorum*, *B. lapidarius*, *B. pratorum*, *Bombus pascuorum* and *B. hortorum*) were observed at all sites during the years in which the investigation was carried out (G. Lye, pers. obs.). At the agricultural sites, spring queens were counted as part of a separate investigation (Lye et al. 2009). Eight hundred and fourteen spring bumblebee queens were recorded during around 50 h of observations made across the ten farms (see Lye et al. 2009 for details of methods used). At other sites, queen abundance was not formally recorded. However, intensive searches for bumblebee nests at the university campus in Stirling in 2009 gave rise to a nest density estimate of approximately 28 per hectare in some of the same woodlands as those used in this study (S. O'Connor, unpublished data). Whilst no data are available on bumblebee populations in the private or botanical garden sites, a similar study by Osborne et al. (2008) estimated nest density in gardens in England and Wales to be approximately 36 nests per hectare. It therefore seems unlikely that nest site searching bumblebee queens were scarce in any of the habitats trialled.

It is important to note that discrepancies between rates of occupancy reported in this study and those of other published studies

may be due to underreporting of unsuccessful domicile trials as a result of a bias toward the publication of positive results. The success of the trial using complex subterranean domiciles in the botanical garden site demonstrates that it is possible to attain reasonable uptake rates but with this exception, the results of the other trials indicate a poor return on the effort required to build and place domiciles.

Commercial nest boxes

Urban gardens appear to support strong populations of bumblebees (Goulson et al. 2002; Osborne et al. 2008) and the floral abundance and diversity present at the garden sites represented in this study are likely to have been similar to those within the botanical garden site. As a result, it might have been predicted that the commercially available domiciles placed in gardens should have achieved similar success. However, not a single commercial domicile became occupied or showed any sign of inhabitation by bumblebees. Whilst it is possible that bumblebee population sizes within the gardens in which the boxes were trialled were lower than those in the botanical garden, all available data suggest that private gardens in the UK do attract large densities of common bumblebee species (Goulson et al. 2002; Osborne et al. 2008) and since these domiciles are marketed to be used in a garden situation, the lack of occupancy is concerning. In the UK alone, a single manufacturer of artificial domiciles for bumblebees sells in excess of 10,000 of these in a single 12 month period (sales figures provided by Wildlife World, UK, 03/2010) and these are usually priced at between £15 and £35. Identifying modifications to increase the success of commercially available domiciles for bumblebees should be a key priority for those that manufacture and market these since at present they appear to provide very poor value to customers.

Recommendations for future domicile design

Whilst domiciles were largely unsuccessful in this study, chances of success can be optimised by following a few guidelines. Bumblebees require fine material with which to insulate the brood clump (Sladen 1912) so the nesting material supplied within any domicile must be suitable. Straw, as is often provided with commercially available domiciles, is too coarse to allow manipulation by bumblebee queens and any queen encountering this material is likely to reject the domicile regardless of other considerations. Any occupancy of domiciles supplied with straw is probably subsequent to previous occupancy by another animal capable of shredding or degrading the material to a finer substrate. Additionally, the majority of common bumblebee species in the UK (including *B. terrestris*, *B. lucorum* and *B. lapidarius*) show a tendency to nest below the surface of the ground (Sladen 1912). It therefore seems likely that subterranean-style domiciles will be more suitable for use in the UK than the surface-style domiciles most commonly available for purchase. This is supported by the small number of reports of the successful use of artificial domiciles for bumblebees in the UK (Intenthron & Gerrard 1999; Sladen 1912), all of which have involved subterranean domicile designs. A small modification such as the inclusion of a connecting hose (as used here) would allow users to adapt the domicile as a subterranean design, however, ventilation and drainage are important considerations for subterranean domiciles (Intenthron & Gerrard 1999) and these may need to be considered if a manufacturer wanted to maximise chances of domicile success.

However, given the current lack of understanding regarding the criteria used by a bumblebee queen to select a nest site, if nest site availability does not limit bumblebee populations in the UK it seems unlikely that a man-made domicile should be as attractive to bumblebee queens as available natural nest sites. In this case, only very low rates of occupancy might ever be expected in most habitat types.

Conclusions

Attempts at attracting bumblebees to nest in artificial domiciles generally yield very poor results in the UK. Here, it is shown that artificial domiciles can achieve high uptake rates, but that this appears to be uncommon. Factors influencing the likelihood of success of artificial domiciles are probably numerous and may include domicile design, local bumblebee abundance, nest site preferences of bumblebee species present, availability of natural nest sites and availability of local forage.

Findings presented here suggest that based on current knowledge, attempts to use artificial domiciles for obtaining colonies of wild British bumblebees or as a tool for bumblebee conservation are likely to be unproductive. It is also shown that commercially available domiciles for bumblebees are often ineffective and it is recommended that manufacturers should provide a more suitable nest material and consider investing further research towards the development of a more effective product.

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