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Evaluating the effectiveness of wildflower seed mixes for boosting floral diversity and bumblebee and hoverfly abundance in urban areas

LORNA M. BLACKMORE[1] and DAVE GOULSON[2] [1]Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling, Scotland and [2]School of Life Sciences, University of Sussex, Brighton, UK

Abstract. 1. There is growing interest in improving the biodiversity of urban and suburban areas. Here we report on the effectiveness of a very simple intervention that may be used to boost flower and pollinator abundance; the sowing of plots of wildflowers in amenity grasslands. The abundance of flowers, bumblebees (*Bombus* spp.), and hoverflies (Syrphidae) was surveyed in 30 such plots, either 1 or 2 years after they had been sown.

2. Overall, sown plots had 25 times more flowers, 50 times more bumblebees, and 13 times more hoverflies compared to paired control plots. Floral abundance and bee abundance increased from year 1 to year 2, but hoverflies were more abundant in plots in their first year, reflecting their preference for shallow annual flowers.

3. Our data demonstrate that flower-poor amenity grasslands can be readily converted to flower-rich areas that are highly attractive to pollinators, providing a simple tool for pollinator conservation in urban areas.

Key words. Pollinator, *Bombus*, Syrphidae, conservation, amenity grassland, restoration, suburban.

Introduction

The primary driver of pollinator declines is thought to be loss of flower-rich habitat, driven by intensification of farming systems (Goulson *et al.*, 2005, 2010; Carvell *et al.*, 2006). Urban areas generally contain many patches of unused land (e.g. road verges, roundabouts) and also amenity areas (e.g. parks, lawns) that are typically managed by regular mowing, and are often of low value to biodiversity. There is the potential to alter the management of these areas to improve habitat provision for pollinators, simultaneously creating an attractive flower-rich landscape and boosting opportunities for urban dwellers to engage with wildlife. A popular conservation method to boost floral availability for pollinators in agricultural areas is to sow wildflower strips/patches, and these have been shown to be effective in attracting many pollinators, particularly bumblebees (e.g. Pywell *et al.*, 2011). The effectiveness of this strategy in providing forage for pollinators has not been examined in an urban context.

A Scottish voluntary group known as 'On the Verge' has, since 2010, sown over 50 urban wildflower patches in the county of Stirlingshire, UK. In this study, we investigate the efficacy of these urban wildflower plots in terms of their provision of floral resources and the numbers of bumblebees and hoverflies feeding within them compared to controls.

Methods

Thirty wildflower plots were surveyed, ten in their first year after sowing and twenty in their second year (Appendix 1). Prior to sowing, all consisted of mown grassland, and they were prepared by removing the existing turf and rotavation. Plots were all sown in spring (28 sites) or autumn (2 sites) with a wildflower seed mix (Appendix 2). Plots were subsequently managed with an autumn cut.

Control sites were areas that continued to be subject to the same management regime that the wildflower plots had experienced before they had been sown (i.e. mowing at

Correspondence: Dave Goulson, School of Life Sciences, University of Sussex, Brighton BN1 9QG, UK.
E-mail: D.Goulson@sussex.ac.uk

variable intervals). Each control plot was matched to a wildflower plot, was of the same size and shape, and was situated between 5 and 20 m distant from the wildflower plot.

Each wildflower plot and its control pair were surveyed once in July or August 2012. Stratified random 1 m^2 quadrats were used to survey the vegetation cover, with a minimum of 10 quadrats per plot. Plots that had an area greater than 100 m^2 had one extra quadrat for every additional 10 m^2. The number of flower units was estimated for the entire plot (following Carvell *et al.* 2004). Bumblebees, hoverflies, and day-flying Lepidoptera were surveyed by walking the margin of the plot at a steady speed between 10:00 and 17:00 on dry, warm days. Bumblebees were identified to species, and the forage species on which they were feeding was recorded. Syrphidae and solitary bees were also recorded but not identified to species.

The natural log of the total number of floral units per plot was analysed in SPSSv21 using a GLM with normal errors, time since sowing (1 or 2 years), and treatment (sown vs. control) as explanatory factors, with plot size included as a covariate. The number of bumblebees per plot (all species pooled) and hoverflies per plot were each analyzed using a similar approach but using Poisson errors. Plot size squared was also included to examine whether there were non-linear relationships between insect numbers and plot size. Models were simplified by stepwise removal.

Results and Discussion

Sown wildflower plots contained approximately 25-fold more floral units than control plots ($F_{1,56} = 90.6$, $P < 0.001$; Fig. 1c). There were also 1.4 times more flowers in wildflower plots in the second year after sowing, compared to the first ($F_{1,56} = 6.89$, $P = 0.011$). There was a positive but non-significant relationship between plot size and number of flowers ($F_{1,56} = 2.40$, $P = 0.127$). The two autumn-sown plots were not obviously different from spring-sown plots, but statistical analysis was not possible.

Most plant species included in the seed mix successfully established (Appendix 2). Twenty three flowering dicots were recorded in the 1-year old plots, dominated by *Centaurea cyanus*, *Glebionis segetum*, and *Triplospermum inodorum*, all three of which had almost entirely disappeared by the second year. Thirty-two flowering dicots were recorded in second-year plots, dominated by *Daucus carota*, *Leucanthemum vulgare* and *Trifolium pratense*. Fourteen flowering dicots were recorded in the 30 control plots, with *Trifolium repens, Bellis perennis* and *Ranunculus repens* the most abundant species. Clearly this approach is effective at increasing the diversity and abundance of wild flowers in urban settings.

Five species of bumblebees were observed: *B. pascuorum* (55.6%), *B. hortorum* (21.8%), *B. terrestris* (14.3%), *B. lucorum* (8.27%), and *B. lapidarius* (0.75%) (Table 1). The number of bumblebees was, on average, approximately 50 times higher in sown plots compared to controls (Fig. 1b, $\chi^2_1 = 47.3$, $P < 0.001$). The abundance of bumblebees in plots in their second year was nearly double that found in first year plots ($\chi^2_1 = 19.3$, $P < 0.001$). More bumblebees were found in larger plots ($\chi^2_1 = 4.99$, $P = 0.026$), but there was no evidence for a non-linear relationship between plot size and bee abundance ($\chi^2_1 = 0.648$, $P = 0.421$). Fifty-four solitary bees were also recorded, all in wildflower plots, but the numbers were too low for statistical analysis.

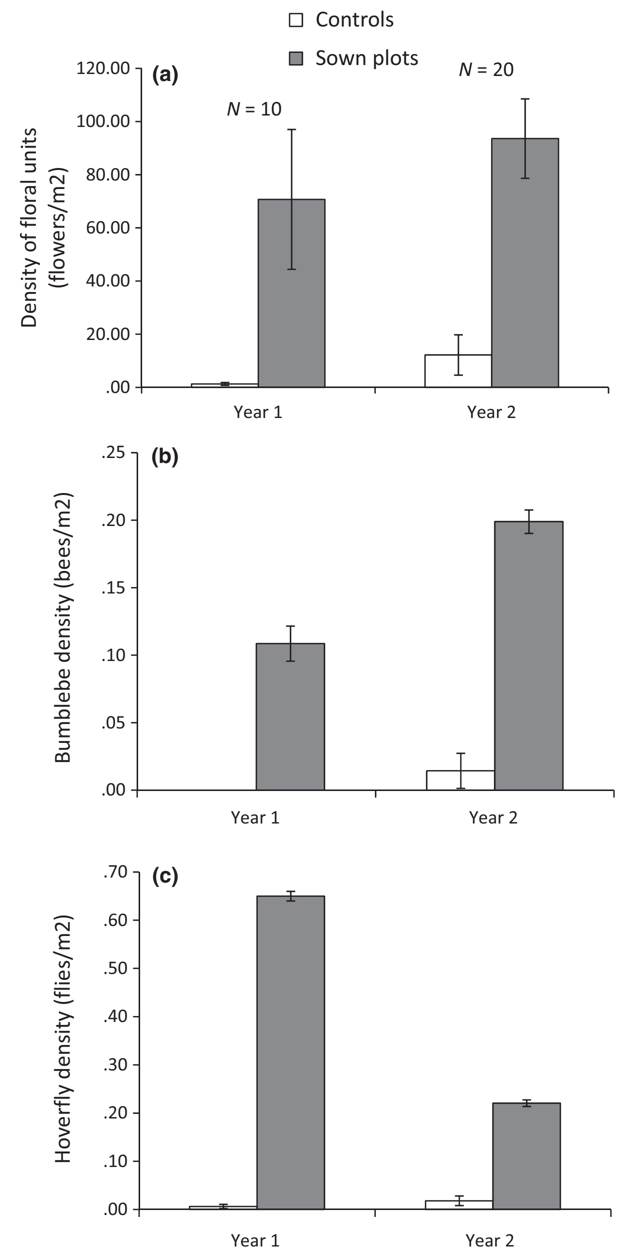

Fig 1. Densities of (a) floral units, (b) bumblebees, and (c) hoverflies in urban sites sown with wildflower seeds versus paired control plots, 1 or 2 years after sowing (mean ± SE).

Table 1. Insect visits to flowers in sown wildflower plots.

	Bombus lapidarius	*Bombus hortorum*	*Bombus lucorum*	*Bombus pascuorum*	*Bombus terrestris*	Total bees	Hoverflies
Anthyllis vulneraria		1				1	
Centaurea cyanus	1		3	2	11	17	15
Centaurea nigra			1	3		4	
Daucus carota			3		5	8	131
Echium vulgare		2		2		4	
Glebionis segetum							109
Leucanthemum vulgare							6
Lotus corniculatus		1	1	1		3	
Papaver rhoeas					3	3	8
Prunella vulgaris		1		2		3	
Rhinanthus minor				1		1	
Silene dioica		1				1	
Trifolium pratense		23	2	51		76	5
Trifolium repens				9		9	
Tripleurospermum inodorum							38
Vicia cracca				3		3	

The bulk of bumblebee visitors to sown plots were of medium tongue length (*B. pascuorum*) or long-tongue length (*B. hortorum*) species (Goulson *et al*., 2008b), and these were mainly visiting *T. pratense* (Table 1). *T. pratense* has long been known to be favoured by long-tongued bumblebees (e.g. Goulson *et al*., 2005), and this group includes the majority of the endangered and declining species (although none was detected in this study) (Fitzpatrick *et al*., 2007; Goulson *et al*., 2008a). If more such flower-rich habitat were created in urban areas, it is conceivable that rarer species might move in to cities. Visits by the other three bumblebee species (all short-tongued) were scattered across a range of plant species, with the annual *C. cyanus* receiving the most visits.

Hoverflies were approximately twice as abundant as bumblebees, overall, and there was a ~13 fold increase in hoverfly abundance in sown plots compared to controls (Fig. 1c, $\chi^2_1 = 150.7$, $P < 0.001$). Unlike bumblebees, hoverflies were more abundant in plots in their first year ($\chi^2_1 = 45.2$, $P < 0.001$). There was no significant linear or quadratic relationship between plot area and hoverfly abundance ($\chi^2_1 = 2.18$, $P = 0.14$, and $\chi^2_1 = 0.271$, $P = 0.602$ respectively). Hoverflies predominantly visited three plant species, *D. carota, G. segetum,* and *Tripleurospermum inodorum* (the latter not included in the seed mix), thus exhibiting little overlap with bumblebees in floral resource use.

Sutherland *et al*. (2011) surveyed the views of 44 practitioners in pollinator conservation to ascertain where research priorities and knowledge gaps lay: evaluating the effectiveness of boosting floral abundance in urban areas emerged as a high priority. We demonstrate that sowing of small wildflower patches into amenity grassland can significantly increase numbers of flowers, and provide forage for bumblebees and hoverflies in urban areas. Although these results could readily be predicted, nonetheless this is to our knowledge one of the first studies to demonstrate this. Future investigations might examine what population-level impacts such flower patches have on pollinators.

We did not survey plots beyond 2 years of age, but clearly it would be useful to establish whether they remain rich in flowers and pollinators over the longer term, or whether occasional reseeding is necessary. The high value of annual flowers for hoverflies in the first year after sowing suggests that reseeding some plots regularly would be of value to this insect group.

Urban areas contain substantial areas of regularly mown amenity grassland and, as our results show, this habitat is low in floral abundance and insect visitation. Although close-mown turf is necessary in some situations (e.g. playing fields), many areas are mown regularly for aesthetic reasons only. Outreach and education is needed to raise awareness that such areas can readily be converted to more biodiverse habitats that are attractive to wildlife and, arguably, are also more attractive to the human eye.

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Appendices

Appendix 1 Size, age, and location of experimental wildflower plots.

Site no.	Area (m^2)	Age of plot (years)	Yellow rattle sown?	Location (GPS)
1	37.2	2	No	NS 79381 97006
2	188.9	2	No	NS 80585 90996
3	68.9	2	Yes	NS 79309 92257
4	12.3	1	No	NS 80138 91956
5	47	2	No	NS 70581 96655
6	22.4	2	Yes	NS 79944 92234
7	20.3	2	Yes	NS 79944 92217
8	18.0	1	No	NS 77821 92367
9	57.1	2	No	NS 77547 92322
10	94.78	2	Yes	NS 79471 95095
11	130.3	2	Yes	NS 79370 95163
12	127	2	Yes	NS 79334 95229
13	12.0	1	No	NN 78097 00588
14	21.0	1	No	NS 78524 92534
15	71.6	1	No	NS 77900 92332
16	177.5	2	Yes	NS 78888 92713
17	49.0	2	No	NS 80426 93002
18	105.6	2	Yes	NS 78107 94545
19	65.3	2	Yes	NS 78338 94278
20	69.4	2	Yes	NS 78253 94374
21	22.1	2	Yes	NN 79031 01474
22	38.5	2	Yes	NS 79820 94532
23	125.8	1	No	NS 79986 94482
24	4.2	2	No	NS 79024 94755
25	15.9	2	No	NS 79046 94731
26	156.5	1	No	NN 78473 01248
27	27.6	2	No	NS 81613 93495
28	28.3	1	No	NS 79200 91874
29	27.9	1	No	NS 79196 91858
30	21.0	1	No	NS 79192 91835

Appendix 2 The seed mixture sown (% by weight), and the percentage of flowers within each treatment attributable to each plant species (averaged across replicates). Seeds were sown at a rate of 2–3 g m^{-2}. All sown species, with the exception of *Centaurea cyanus,* were of Scottish provenance. On 12 of the sites (Appendix 1), seeds of the hemi-parasitic plant *Rhinanthus minor* were added to the mixture at 1 g m^{-2}. Nevertheless, these failed to establish. The plants below *R. minor* in the list were not in the seed mix.

		Floral abundance (% of all flowers in treatment)		
Species	Seed mix composition	Year 1	Year 2	Controls
Annuals				
Centaurea cyanus	10	19.71		
Glebionis segetum	6	38.48		
Myosotis arvensis	1	0.61	0.35	
Papaver rhoeas	8	5.39	0.04	
Triplospermum inodorum	5	23.10	0.81	
Biennials				
Daucus carota	10	2.81	27.16	
Echium vulgare	9		0.70	
Digitalis purpurea	5			
Perennials				
Achillea millefolium	2	0.66	1.99	
Anthyllis vulneraria	10		2.72	
Centaurea nigra	10		0.85	
Knautia arvensis	2			
Leucanthemum vulgare	2	4.02	15.63	
Linaria vulgaris	2			
Lychnis flos-cuculi	5		0.06	
Silene alba	2	0.10	0.15	
Silene dioica	2	0.26	0.36	
Stachys sylvatica	2		0.05	
Trifolium pratense	1	1.34	30.36	0.13
Vicia cracca	2		0.96	
Lotus corniculatus	1	0.06	3.49	
Prunella vulgaris	1	1.25	3.89	1.83
Trifolium repens	1	0.15	2.68	50.89
*Lathyrus pratensis***	1		0.07	
Rhinanthus minor			0.45	
Bellis perennis			0.43	7.34
Cardamine hursuta		0.04	0.25	2.78
Cerastium glomeratum		0.21	0.08	0.23
Cirsium arvense		0.05	0.02	2.58
Cirsium vulgare			2.20	0.41
Epilobium montanum		0.29	1.35	
Leontodon sp.			0.03	0.24
Medicago lupulina		0.10	0.14	
Persicaria bistorta		0.10		
Ranunculus acris		0.28	2.11	0.23
Ranunculus repens				27.87
Senecio jacobea			0.05	0.01
Sonchus sp.		0.57	0.18	
Taraxacum officinale		0.52	0.40	4.90
Veronica chamaedrys				0.55