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Pollinator-friendly management does not increase the diversity of farmland bees and wasps

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ABSTRACT

In order to reverse declines in pollinator populations, numerous agri-environment schemes have been implemented across Europe, predominantly focused on increasing the availability of floral resources. Whilst several studies have investigated how bees and wasps (aculeates) respond to management at the scale of the scheme (i.e. within the flower patch) there has been little assessment of how schemes affect diversity at the farm scale. In the current work we assessed whether farms implementing flower-rich schemes had richer aculeate communities than farms without such habitats. A total of 104 species of bee and 44 species of aculeate wasp were recorded. Farms providing flower-rich habitats had significantly greater floral abundance but there were no differences in the total number of aculeate or flowering plant species recorded compared to farms without these habitats. After accounting for differences in sample size, and contrary to expectations, farms without flower-rich habitats were significantly richer in aculeate and flowering plant species. Bumblebees (*Bombus* spp.) and honeybees (*Apis mellifera*) foraged strongly from sown flowers, but the majority of bee species preferred wild plants that are not included in flower-rich schemes such as *Heracleum sphondylium*, *Hypochaeris radicata* and *Tripleurospermum inodorum*. The creation of pollinator-friendly habitats has not increased the diversity of flowering plants and such schemes will consequently only benefit a limited suite of aculeate species. If diverse aculeate communities are to be retained and restored on farmland, agri-environment schemes that provide foraging and nesting resources for a wider range of pollinator species must be developed.

1. Introduction

The process of agricultural intensification has resulted in simplified and less heterogeneous landscapes across Europe and North America and it is the primary driver behind long-term declines in farmland biodiversity (Benton et al., 2003; Tscharntke et al., 2005). As with many taxa, wild bees have been negatively affected with serious declines across Europe and North America (Biesmeijer et al., 2006; Williams and Osborne, 2009; Potts et al., 2010), though there is evidence that rates of decline are slowing (Carvalheiro et al., 2013). These declines are of serious concern as pollinators, particularly bees, provide an important pollination service which both supports wild plant communities (Ashman et al., 2004) and affects the yield for approximately 70% of crop species worldwide, representing around 35% of total global food production (Klein et al., 2007). Up to 80% of this pollination service has been attributed to honeybees *Apis mellifera* L. (Carreck and Williams, 1998), but more recent studies have highlighted the importance of the service provided by wild pollinators. The quality of this service depends on the diversity of the pollinator community, with richer assemblages improving yields in many crop species (Westerkamp and Gottsberger, 2000; Klein et al., 2003; Hoehn et al., 2008). Wild bee pollinators can provide the majority of crop visitation, even in contemporary intensive farming systems (Winfree et al., 2008), and enhance fruit set regardless of honeybee abundance (Garibaldi et al., 2013), leading to suggestions that the role of honeybees as agricultural pollinators has been overstated (Breeze et al., 2011; Ollerton et al., 2012). Pollinator communities are sensitive to habitat loss (Kremen et al., 2002; Steffan-Dewenter et al., 2002), and consequently the service they provide can reduce as agricultural intensification degrades the semi-natural environments upon which they depend (Garibaldi et al., 2011).

In order to reverse the decline in farmland biodiversity, agri-environment schemes are now funded across the European Union as part of the Common Agricultural Policy. These schemes offer opportunities to create pollinator-friendly habitats with the

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objectives of increasing both pollinator abundance and diversity. In England, two tiers of environmental stewardship were established in 2005. Entry Level Stewardship (ELS, Natural England, 2013a) was open to all farmers. Higher Level Stewardship (HLS, Natural England, 2013b) which was targeted to high priority areas provided greater financial rewards for more substantial and rigorous agri-environmental schemes. Most agricultural land in England is under some form of environmental stewardship with 72% of land under at least ELS management and around 21% of this total under HLS management as of 2014. (JNCC, 2014). There are three main pollinator-focused HLS options. HF4 pollen and nectar mixes are rotational plots or strips sown with a mixture of predominantly leguminous plants such as *Trifolium pratense* L. and *Trifolium hybridum* L. which tend to be resown within a 5 year period. HE10 floristically enhanced grass buffer strips are non-rotational grassland alongside fields and are composed of a mixture of grasses and plants such as *Centaurea nigra* L. and *Lotus corniculatus* L. HK6/7/8 focus on the maintenance, restoration and creation of species-rich grassland.

The response of bumblebees to the creation of flower-rich schemes has received a great deal of attention. From the initial designation of five UK bumblebees as Biodiversity Action Plan species of conservation concern, and the resulting research into their ecological requirements, it was argued that without landscape scale habitat restoration these species would continue to decline (Edwards, 1999). Many bumblebee species that have suffered substantial declines tended to collect a large proportion of pollen from Fabaceae (Goulson et al., 2005), and consequently leguminous plants became an important part of agri-environment scheme design. A number of studies have focused on the response of foraging bumblebees to these schemes and other agri-environment scheme habitats (Edwards, 2003; Pywell et al., 2006, 2011; Carvell et al., 2007; Holland et al., 2015), but the response of other bees to these options has received much less attention and is correspondingly less well characterised, both in the UK and abroad (Haaland et al., 2011). Studies suggest that the wider bee community can respond well to management at a local level, with higher species richness recorded in targeted areas, such as field margins or meadows, compared to unmanaged control areas (Knop et al., 2006; Albrecht et al., 2007). However, there has been little comparison of diversity between farms at a scale greater than that of the targeted area. It is not clear to what extent any positive benefits extend to the wider landscape, as species richness can drop off sharply outside target areas (Albrecht et al., 2007; Kohler et al., 2008). If schemes are effectively increasing species diversity we would expect farms implementing appropriate management to support significantly more diverse pollinator communities. Bees and wasps can be highly aggregative, congregating on appropriate habitat (Heard et al., 2007), but not all species will be attracted to agri-environment schemes, necessitating more extensive surveying within and between targeted areas to accurately capture the community present at any one site.

In a recent survey of insect pollination scientists and conservation practitioners, the top research priority identified was to understand how important the diversity of pollinator species was to the resilience and reliability of the pollination service (Dicks et al., 2013). Other than bumblebees, there is little knowledge as to which bee and aculeate wasp species (henceforth collectively referred to as aculeates) persist on agricultural land and how they respond to agri-environment schemes. Without an appropriate evidence base, conservation interventions generally, and agri-environment schemes in particular are unlikely to be effective (Kleijn and Sutherland, 2003; Sutherland et al., 2004). In this study we assess whether farms implementing pollinator-friendly management schemes support richer and more diverse aculeate communities at the farm level. Our results have clear implications for the future management of farmland aculeate populations.

2. Materials and methods

Nine HLS and nine ELS farms were selected in Hampshire and West Sussex, UK. A map of the study area can be found in Appendix A. On average, HLS farms were significantly larger (256.22 ± 37.80 ha) than ELS farms (156.67 ± 22.07 ha, *t*-test, $t_{16,17} = 2.565$, $p = 0.021$). The selected HLS farms had been implementing an average of 5.56 ± 0.13 ha of pollinator focused flower-rich options representing 2.17 ± 0.05% of the farm area by ownership for a minimum of three years. As the majority of farms in England are in some form of environmental stewardship, ELS management was chosen as the control group for this study. Whilst pollinator-focused flower-rich options are available as part of ELS management, the selected ELS farms were not implementing any such schemes, representing the approach of most ELS farms. Farms were predominantly arable or mixed arable/dairy with wheat, barley, oilseed rape and permanent/silage grassland as the major crops.

As the proportion of the landscape which is comprised of semi-natural habitat can affect the species richness of bees (Steffan-Dewenter et al., 2002; Holzschuh et al., 2010), the farms were mapped to ensure their overall similarity. A detailed land cover map to a resolution of 2 m^2 was constructed in Google Earth (Google Inc) based on detailed surveys during the field season and satellite imagery. A 1 km buffer was drawn around the centre point of each transect covering the majority of each farm and some of the surrounding area. Semi-natural habitats fell into four broad groups (i) flower-rich agri-environment scheme grassland, (ii) flower-poor general grassland (not including permanent pasture and silage grassland, categorised as intensive grassland), (iii) hedgerows and (iv) woodland (Table 1). There was no significant difference in the proportion of the landscape covered by semi-natural habitats between farm types (GLM, $t_{16,17} = 0.147$, $p = 0.885$). The presence of water and urban structures can also affect the species richness of bees and wasps by creating moisture gradients that increase floral abundance and by providing floral resources

Table 1
Habitat composition within a 1 km radius for selected farms in Hampshire and West Sussex, UK. Means ± 1 SE are given for nine study sites per farm type. Habitat types marked with a ∗ were categorised as semi-natural.

Habitat type	Area (%)	Minimum (%)	Maximum (%)
(a) Higher level Stewardship farms			
Arable land	59.73 ± 5.13	28.18	72.99
Flower-rich grassland*	1.77 ± 0.41	0.38	4.36
Flower-poor general grassland*	8.36 ± 1.43	3.02	16.19
Intensive grassland	14.15 ± 3.34	3.57	34.32
Water	0.34 ± 0.22	0.00	2.01
Hedgerows*	1.96 ± 0.24	0.77	3.12
Urban	4.89 ± 0.79	1.83	8.60
Woodland*	8.81 ± 3.06	0.84	24.96
(b) Entry level Stewardship farms			
Arable land	55.76 ± 6.06	25.08	78.23
Flower-rich grassland*	0.05 ± 0.05	0.00	0.47
Flower-poor general grassland*	5.73 ± 1.03	2.88	12.40
Intensive grassland	15.93 ± 3.18	0.68	30.77
Water	1.52 ± 1.49	0.00	13.44
Hedgerows*	2.26 ± 0.36	0.39	3.40
Urban	4.82 ± 0.58	2.68	7.44
Woodland*	13.92 ± 4.41	1.52	35.17