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Managing habitats on English farmland for insect pollinator conservation

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ABSTRACT

Agri-environment scheme habitats can support declining pollinators, but optimum approaches for deployment remain uncertain. The impact of three management treatments (project-, farm-managed and organic farming) alongside habitat type, quantity of uncropped land removed from production and spatial configuration (strips or blocks) on wild bees, butterflies and hoverflies were investigated. Pollinators were assessed on 28 sites over three years, along boundaries representing site scale (*ca.* 100-ha) and within project-managed (floristically enhanced grass, wild bird seed mix, insect rich cover and natural regeneration) or farm-managed wildlife habitats (typically grass margins or game cover). Project-management resulted in the creation of the most widely utilised habitats (floristically enhanced grass and wild bird seed mixtures), but these may attract wild bees away from boundaries whereas butterfly abundance (Lycaenidae and Pieridae) was enhanced along field boundaries. Organic management and spatial configuration of habitats had little impact. Proportion of uncropped land per site was positively related to Cuckoo bee, Lycaenidae and Satyridae density and butterfly species richness at site scale and on the density of several bee species, total wild bees, Pieridae and total butterflies in wildlife habitats. The mean abundance of uncropped land was 3.6% and at least double this was required to double the abundance of wild bees and butterflies. Wild bee densities were highest in field boundaries and floristically enhanced grass and positively correlated with flower cover. Butterflies sought habitats containing their larval food plants and high flower cover. Hoverflies were most abundant in the insect rich cover. Wildlife habitat in agricultural landscapes may be insufficient and additional, diverse habitats are needed to encourage pollinators.

1. Introduction

Pollinators are declining globally (Goulson et al., 2008; van Swaay et al., 2010) on farmland, attributed to agricultural intensification leading to a reduction in flower-rich habitats and associated fragmentation in the landscape, lack of nesting habitat, pathogens and sub-lethal effects of pesticides (Potts et al., 2010; van Swaay et al., 2010). Pollinator diversity is instrumental in determining pollination service levels (Albrecht et al., 2012) and we cannot rely on honeybees to substitute adequately for wild pollinators (Garibaldi et al., 2013). With declines in hoverfly and wild bee species richness in NW Europe (Biesmeijer et al., 2006) there is a need to find solutions to protect pollinator communities and the ecosystem service they provide.

Flower-rich habitats to enhance pollinator abundance in farmland have been supported through agri-environment schemes (AES) and private initiatives across Europe and aim to supplement or replace lost natural and semi-natural habitats that support pollinators. Schemes were more successful in simple than complex landscapes and when additional floral complexity was provided (Scheper et al., 2013; Shackelford et al., 2013). Newly created flower-rich habitats are utilised by pollinators (Pywell et al., 2005, 2006), however, it is unclear whether these additional resources increase populations locally or cause redistribution (Dicks et al., 2010). If the latter, then pollination of wild plants may be reduced which has implications for their survival (Biesmeijer et al., 2006) and for other wildlife that depends on the resources they produce (fruits and seeds). Some wild plant species are already pollen-limited (Jacobs et al., 2009) therefore the quantity and arrangement of additional floral provision must be considered carefully, taking into account flowering periods and location in relation to local wild floral resources and mobility and foraging preferences of pollinators.

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Farming systems can also have a profound impact on pollinators; bumblebees, other wild bees and butterflies showed a negative relationship with farming intensity (Gabriel et al., 2013). Organic farming can benefit pollinators (Holzschuh et al., 2008; Rundlöf and Smith, 2006; Hodgson et al., 2010; Birkhofer et al., 2014), although there is also conflicting evidence (Hole et al., 2005; Dicks et al., 2010).

Pollinator richness is known to decline with increasing distance from source habitats (Garibaldi et al., 2011) thus the spatial configuration of AES habitats may be critical if pollination services to crops are to be maximised. Interactions between surrounding landscape complexity and configuration with farming intensity have also been detected in a global synthesis of bee research, but overall the key driver was provision of high-quality habitat within their foraging range (Kennedy et al., 2013). The analyses of landscape complexity and configuration was inconclusive and highlighted the need for more detailed investigations of pollinator distributions and the importance of foraging and nesting habitats.

The success of Agri-environment Scheme (AES) habitats is variable and depends on their type and quality, determined by their management (Pywell et al., 2011) and consequently the quality of advice provided by farm advisors is critical. Overall, the adoption of AES exemplifies the land sparing approach to mitigating the impact of intensive farming on wildlife whereas organic farming is a land sharing option (Green et al., 2005). Whether conventional farms utilising AES options to create appropriate habitats can achieve pollinator levels found on organic farms has not been explored (Hole et al., 2005).

In summary, if AESs are to be implemented in the most cost-effective way whilst maximising their value for pollinators there is a need to: (a) determine the importance of the farm management approach; (b) identify the quantity of uncropped habitats required to increase pollinator abundance and diversity at the farm level; (c) identify the importance of habitat type; (d) understand the importance of AES habitat spatial configuration to pollinators. Moreover, the adoption of organic farming offers the alternative land sharing approach to remedy the impact of intensive farming, however its value remains uncertain. These knowledge gaps were investigated in this study. The outputs were aimed to inform farmers and policy makers to help them target more effectively the allocation of land taken out of production for AES.

2. Materials and methods

2.1. Study design

The study compared the effect on pollinators of three management approaches: (1) project-managed sites representing farms receiving AES on-farm advice; (2) farm-managed where they selected the habitats and (3) organic farming that included AES habitats. In each of the project-managed treatments (1–4) four habitats were established in spring 2007 designed to support farmland birds, invertebrates and plants (see Appendix S1 in supporting information). The habitats were: (1) floristically enhanced grass mix (FEG), (2) insect-rich cover (IRC), (3) wild bird seed mixture (WBS), (4) natural regeneration (NR) by annual cultivation in spring. The four habitats were established together in a block and each was 3–6 m wide and of varying length depending on the land available and farm machinery dimensions. On farm-managed sites (treatments 5–7) the wildlife habitats comprised Entry Level Scheme options (usually grass margins, 45–61%) or game cover (usually maize, *ca*. 16%) (see Appendix S2, Fig. S1). The wildlife habitats were created on land taken out of production, termed here as "uncropped land", allowing the importance of habitat quantity to be assessed. In addition, the choice of management influenced their quality through the type of habitat and the subsequent flower density which is important for pollinators. We also compared the effect of having different proportions and configurations of wildlife habitats. In 2006, 24 conventionally farmed and four organic sites (each *ca*. 100 ha) of predominantly winter-sown arable crops, split equally between two regions of England (Wessex and East Anglia), were allocated to seven treatments (see Table 1). Six treatments were imposed in spring 2007, allocated at random to the 24 conventional sites, with two replicates per treatment per region as an incomplete factorial design. In addition, across all sites there were varying proportions of permanent habitats (e.g. woodland and hedgerows) and other uncropped land in addition to the experimental treatments (details in Henderson et al., 2012). The initial choice of 6 ha of wildlife habitats was considered the maximum acceptable to farmers and 1.5 ha sufficiently lower to provide contrasting results.

2.2. Pollinator assessments

Pollinators were assessed across two different scales, site and wildlife habitat, from 2008 to 2010. In each the standardised butterfly transect method (Pollard and Yates, 1993) was adopted recording hoverflies within 1 m, bees within 2 m, and butterflies within 5 m of the recorder walking along pre-marked 100-m transects, once early-season (mid-May to mid-June) and once mid-season (mid-July to early August).

For the site-scale assessments, three 'baseline' field boundaries in separate fields to project- or farm-managed habitats were surveyed at each site and year to quantify the impact of the habitat management interventions on pollinator numbers and diversity at the wider site scale.

In the project- or farm-managed wildlife habitats, a total of eight 100-m long transects were sampled on each site. On the project-managed sites, transects were split equally between the four habitats and on farm-managed sites (treatments 5–7) at least two transects were assessed in each wildlife habitat type with the remainder allocated in proportion to the area occupied by each habitat type. The following taxa were identified: (1) *Bombus lapidarius* L., *Bombus pascuorum* Scopoli, *B. pratorum* L., *B. terrestris/lucorum* L. *B. hortorum* L., cuckoo bees as a group and other bees including solitary bees but not *Apis mellifera* L.; (2) hoverflies as *Episyrphus balteatus* De Geer (common species important for biocontrol) or other species; (3) butterflies to species.

The level of dicotyledonous flower cover was recorded along each 100-m transect walk using a simple floristic index (Carvell et al., 2004): (1) rare (approx. 1–25 flowers per 100 m); (2) occasional (approx. 26–200 flowers); (3) frequent (approx. 201–1000 flowers); (4) abundant (approx. 1001–5000 flowers); (5) superabundant (more than 5001 flowers).

Table 1
Experimental design (Conv = Conventionally managed farm).

Treatments	1	2	3	4	5	6	7
Site management	Project	Project	Project	Project	Farm	Farm	Farm
Farming system	Conv	Conv	Conv	Conv	Conv	Conv	Organic
Proportion wildlife habitats (ha)	6	1.5	6	1.5	6	1.5	1.5
Spatial configuration	Strips	Strips	Blocks	Blocks	Unspecified	Unspecified	Unspecified