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Utilisation of agri-environment scheme habitats to enhance invertebrate ecosystem service providers

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ABSTRACT

The impact of habitat management (project-managed, farmer-managed or organic), quantity (proportion of uncropped land) and spatial configuration of habitats (arranged as strips or blocks) on the density and biomass of invertebrate functional groups was studied at the farm (100-ha block) and plot scale. At the farm scale, invertebrate abundance and biomass per unit area of uncropped land, responded positively to the presence of project-managed habitats for a number of invertebrate groups (including parasitoids and chick food). The abundance of different invertebrate functional groups varied considerably between habitat types; no single habitat provided the highest densities of all groups, suggesting that a diversity of habitats is beneficial for ecosystem service delivery. Grassy habitats supported the highest densities of predatory invertebrates, wild bird seed the most parasitoids and annual plant habitats the highest levels of chick food for farmland birds. Vegetation characteristics influenced total invertebrate biomass and levels of chick food, but not the total number of invertebrates or the abundance of those providing biocontrol.

1. Introduction

The decline in farmland biodiversity and the link to intensive agriculture over the last 40 years is now well documented (Potts, 1991; Chamberlain et al., 2000; Stoate et al., 2001; Benton et al., 2002; Storkey et al., 2012). Such changes in the biodiversity are also upsetting the balance of the agroecosystems and there is increasing concern that ecosystem services are being disrupted. Much attention has focused on pollination (Kremen et al., 2002; Steffan-Dewenter and Westphal, 2008; Wratten et al., 2012) although a wider range of services may also be threatened including biological control (Bianchi et al., 2006). There is also evidence that the impact of intensive farming is affecting wildlife that can be regarded as a cultural service, through the disruption of the food chain. The most comprehensive evidence for this comes from the research on the grey partridge (*Perdix perdix*) in which the link between invertebrate food supplies and chick survival, and chick survival and bird abundance has been demonstrated (Potts, 1986; Potts and Aebischer, 1995). Likewise, the breeding success of skylarks (*Alauda arvensis*), corn bunting (*Miliaria calandra*) and yellowhammer (*Emberiza citrinella*) were all dependent on invertebrate food supplies (Poulsen et al., 1998; Brickle et al., 2000; Boatman et al., 2004) and it is likely that many other farmland species will suffer from low levels of invertebrates given their dependence on them for food (Wilson et al., 1999; Holland et al., 2006).

The widespread adoption of agri-environment schemes was seen as the route by which farmland biodiversity could be restored (Anon, 2009) yet to date there is conflicting evidence of their effectiveness in the UK (Davey et al., 2010) and across Europe (Kleijn and Sutherland, 2003; Kleijn et al., 2006). In the UK this may have been because agri-environment options were initially chosen by farmers for their convenience or economic return (Boatman et al., 2007) rather than for biodiversity benefits or ecosystem service enhancement. This has led to the large-scale adoption of a limited number of options, particularly grass buffer strips, and consequently few new habitats. It has also become apparent that all the necessary complementary resources to support a particular wildlife group must be in place if they are to be successful, hence the promotion of the farmland bird package in the English AES (Anon, 2013). The provision of invertebrate-rich foraging habitats for farmland birds is especially important because modern agriculture leaves few arable weeds upon which many invertebrate species are dependent (Potts, 1986; Storkey et al., 2013) and as a consequence levels of chick-food invertebrates are insufficient in most crops (Holland et al., 2012b).

Although uncropped land and the biodiversity it supports is necessary for the provision of ecosystem services on farmland (Scherr

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and McNeely, 2008), the need to produce 70% more food by 2050 (UN, 2010) will put further pressure on agriculture land through drives to increase productivity and reduce land taken out of production via AES. Consequently, AES habitats may need to become multifunctional, delivering a range of ecosystem services and supporting greater biodiversity if we are to optimise their value and ensure they remain funded through the Common Agricultural Policy. However, to achieve this requires knowledge of the ecosystem service providers, which is rare (Kremen, 2005). This is especially true for invertebrates which provide several important ecosystem services (pollination, biological control) or support them as is the case with chick food. Some AES habitats have been designed to support particular beneficial invertebrates through the selection of appropriate plant species, for example flower-rich habitats for pollinators (Pywell et al., 2005; Decourtye et al., 2010), conservation headlands for chick food (Chiverton and Sotherton, 1991) and beetle banks for natural enemies (Collins et al., 2003). Moreover, pollinator and conservation biocontrol habitats also have the potential to provide other ecosystem services including cultural services and protection of soil and water (Fiedler et al., 2008; Wratten et al., 2012). For other habitats providing alternative resources, e.g. wild bird seed, little is known of their contribution to other ecosystem services. In addition, the surrounding landscape composition is known to impact on within-crop ecosystem services (e.g. Bianchi et al., 2006; Tscharntke et al., 2007; Holland et al., 2012a; Chaplin-Kramer and Kremen, 2012; Veres et al., 2013) and the service providers (Schmidt et al., 2005), but these studies must extend to identify the value of different types of uncropped land to invertebrates providing ecosystem services (Duelli and Obrist, 2003; Bianchi et al., 2006; Griffiths et al., 2008a).

In 2006, the Farm4bio project (Holland et al., 2007) was initiated to investigate some as yet unanswered fundamental questions regarding the type and scale of habitat enhancement for biodiversity (birds, plants and invertebrates), namely: (1) Are there relationships between the proportion of uncropped land (defined here as land taken out of production for AES habitats) and levels of biodiversity? (2) How should this land be arranged spatially in the landscape? Furthermore, the project also tested whether the management approach impacted on levels of biodiversity found on uncropped land. In England AES (Environmental Stewardship) has two tiers: a lower tier, the Entry Level Scheme in which farmers select the habitats and a Higher Level Scheme for which on-farm advice is normally provided. These approaches were replicated by prescribing the habitat types on some farms (project-managed) in contrast to the farmer's choices (farmer-managed). The biodiversity taxa recorded included farmland birds (reported in Henderson et al., 2012), plants and groups of invertebrates providing or supporting key ecosystem services (natural enemies and food items for farmland birds). Here we present the findings for these invertebrate functional groups and invertebrate pests within the dominant uncropped habitats, and also investigate the impact of vegetation characteristics within each habitat type on their numbers.

2. Methods

Twelve conventional and two organic study sites each comprising 100 ha of predominantly winter-sown arable crops were selected in each of the two regions of southern (Wessex) and eastern (East Anglia) England in 2006 giving a total of 28 sites. These were considered representative of typical arable farms, landscapes and cropping systems found in England. Crop rotations were dominated by winter cropping (wheat, barley and oilseed rape) although the organic farms had a high proportion of rotational grassland. Six treatments were then allocated at random to the 12 conventional sites, with two replicates per treatment per region as an incomplete factorial design. The six treatments imposed in spring 2007 were:

1. each site with 6 ha of project-managed uncropped land arranged in strips;
2. each site with 1.5 ha of project-managed uncropped land arranged in strips;
3. each site with 6 ha of project-managed uncropped land arranged in one or two blocks;
4. each site with 1.5 ha of project-managed uncropped land arranged in one block;
5. each site with 6 ha of farmer-managed uncropped land;
6. each site with 1.5 ha of farmer-managed uncropped land.

In addition, each organically managed site had ca. 1.5 ha of farmer-managed uncropped land.

The project-managed uncropped blocks or strips were each split into four equal areas.

i. Floristically Enhanced Grass mix (FEG) (six uncompetitive grasses and eight flowering plant species, A1) to encourage pollinating insects.
ii. Insect-Rich Cover (IRC) (cereal and common vetch *Vicia sativa*) to provide invertebrate chick food for breeding farmland birds in summer and seed in winter.
iii. Wild Bird Seed mixture (WBS) (cereals, brassicas and quinoa *Chenopodium quinoa*) to provide food for farmland birds in winter.
iv. Natural Regeneration (NR) (annual spring cultivation) to encourage annual arable plants and provide more open foraging areas for farmland birds and mammals.

Failure of autumn sowings and abnormally dry spring weather meant that seed mixes in some project-managed areas had in some cases to be resown or a different mix used that was better suited to the conditions (Appendix 1). The farmer-managed sites included grass margins, other Environmental Stewardship habitats, cross-compliance margins and habitat managed for game bird species (predominantly maize, occasionally with other seed-producing species).

2.1. Invertebrate sampling

A Vortis sampler with a modified nozzle (diameter 20 cm) was used to sample invertebrates both on the ground and in vegetation reflecting invertebrate availability for farmland birds and species that contribute to biological control, although there may be some bias owing to species different phenologies. Sampling was done annually from 2008 to 2010 in late June/early July when natural enemies of phytophages and invertebrates important for chick food were abundant. The modified nozzle was attached to a flexible hose and consequently could be placed over the vegetation. A standard Vortis nozzle would have been inappropriate for sampling taller vegetation. For each sample, the nozzle was placed over the vegetation and held for five seconds in each of 15 sub-sampling points, spaced at least 1 m apart sampling a total area of 0.47 m^2. A total of 16 samples were taken on each site per year. On project-managed sites with strips (treatments 1–2), two samples were taken in each managed habitat type in each of two different fields. On project-managed farms with blocks (treatments 3–4) four samples were taken in each managed habitat type, two at either end of a block. On farmer-managed sites, samples were taken from each uncropped habitat in proportion to their relative abundance but with a minimum of four samples per habitat type. Whenever possible the same areas were used each year. Owing to the large numbers and diversity of species collected and the resources available for