Agriculture, Ecosystems and Environment 140 (2011) 62–67

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Ecological restoration on farmland can drive beneficial functional responses in plant and invertebrate communities

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ARTICLE INFO

Article history:
Received 26 July 2010
Received in revised form
15 November 2010
Accepted 16 November 2010
Available online 14 December 2010

Keywords:
Agri-environment schemes
Beneficial arthropods
Ecosystem services
Field margin strips
Pollinators
Seed addition
Sustainable agriculture

ABSTRACT

This study contrasted the effects of the most widely implemented, low cost restoration prescriptions promoted by the English AES with more demanding and costly options on plant and invertebrate community composition, and their functional traits. In all cases these prescriptions were compared to intensive crop management. The plant community regenerating from the seed bank was species-poor, highly dynamic and had a high proportion of undesirable crop weeds. Sowing a low-cost, simple mix of tall grasses resulted in a stable community dominated by competitive grasses. Creation of these habitats resulted in negligible shifts in the functional composition of the associated invertebrate community. Sowing a diverse mix of wildflowers resulted in a stable, perennial vegetation community with both legumes and regulating hemi-parasitic plants that supported significantly more pollinator and herbivore species, as well as higher abundances of beneficial arthropod predators. There were no measured synergies when a mix of tall grass and wildflower habitats were created adjacent to each other on the same margin. The results confirm the value of ecological restoration as a potentially useful means of enhancing ecosystem function within intensive farmland systems.

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1. Introduction

There is growing evidence that ecological restoration of appropriate habitats on farmland increases habitat heterogeneity and can mitigate some of these damaging effects (Tscharntke et al., 2005; Wade et al., 2008; Rey Benayas et al., 2009). In the context of this study we refer to restoration as the creation of habitats of increased floristic and faunistic diversity on land that had been previously used for crop production. The European agri-environmental schemes (AES) are voluntary agreements with farmers which reward environmentally-sensitive land management often associated with traditional, extensive farming practices (Ovenden et al., 1998). They are increasingly seen as a means of planning and implementing the large-scale ecological restoration required to deliver sustainable agriculture and ensure the continued provision of ecosystem services. However, the effectiveness of these policies remains poorly monitored (Kleijn and Sutherland, 2003). In 2005 a new agri-environment scheme (Environmental Stewardship) was launched in England (Natural England, 2010). The key component of this is the Entry Level Scheme (ELS) which is voluntary and aims to deliver simple and effective environmental benefits over large areas. The ELS currently covers 5 million ha (55% of the utilisable farmland with a target of 70% by 2011) and has an annual budget of €193 million (Natural England, 2010). The scheme has a broad range of objectives including conservation of biodiversity, protection of resources, climate change adaptation and mitigation, and increasingly, the delivery of ecosystem services. To receive support payments participating farms are encouraged to both manage cropped land more extensively, and remove marginal areas from production for the creation of wildlife habitat.

Previous studies have focused primarily on the benefits of habitat restoration as part of the agri-environment schemes for the conservation and enhancement of biodiversity (e.g. Pywell et al., 2004, 2006; Carvell et al., 2006; Marshall and Moonen, 2002). However, considerably less is known about the effectiveness of these restoration prescriptions in promoting key ecosystem functions and services, and enhancing the stability of agro-ecosystems. A pragmatic approach to this problem would be to classify species assemblages in terms of their functional traits which more closely reflect their potential role in determining and regulating ecosystem processes, and through this the provision of agro-ecosystem services (Balvanera et al., 2006; Moonen and Bàrberi, 2008). This paper describes a multi-trophic study examining the effects of a range of habitat restoration strategies (differing in both cost and

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0167-8809/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2010.11.012

complexity) on plant and invertebrate functional traits. It contrasts the observed effects to those recorded in an intensively managed crop treatment. It specifically focuses on the agro-ecosystem services for production provided by functional groups, namely food web services and gene flow services (pollination) (after Moonen and Bàrberi, 2008).

Using this approach the following hypotheses were addressed:

H1: removing areas from agricultural production causes large shifts in the functional composition of plant and invertebrate communities that have the potential to benefit food web and gene flow (pollination) services;
H2: creating two contrasting habitat types on the same field margin enhances the potential for multi-functionality by having complementary beneficial effects on traits associated with agro-ecosystem services for production.

2. Materials and methods

The experiment was carried out at Manor Farm, Eddlethorpe, near Malton, UK (000°49′W 54°05′N). This is an intensively managed arable enterprise of 164 ha growing cereals, oilseed rape and beans on clay and loam soil. In September 1999, five field margin management treatments were applied at random to contiguous plots within one of three replicate blocks. Each field margin plot was 6 m × 72 m. The treatments were:

(1) Intensively managed crop with conventional inputs of pesticide and fertiliser (control; see Supplementary Table 1 for details of management);
(2) Natural regeneration following a final autumn cultivation (natural regeneration);
(3) Tall grass seed mixture comprising five grass species sown at 20 kg ha^{-1} (tall grass);
(4) 3 m tall grass margin adjacent to hedge and 3 m wildflower margin (see 5 below) adjacent to crop (split margin);
(5) Wildflower mixture comprising eight grass and 17 forb species sown at 37 kg ha^{-1} (wildflower).

The treatments were replicated on the margins of three separate fields (blocks) with the crop treatment assigned randomly to either end of each replicate to enable farming operations. Details of the seed mixtures are given in Supplementary Table 2. In year 1 and 3 the crop treatment and the rest of the field was winter wheat (*Triticum aestivum* L.) for all replicates. In year 2, two replicates were winter oilseed rape (*Brassica napus* L. ssp. *oleifera*), and the other winter wheat. The wildflower vegetation was managed by cutting and removal of the biomass in May and August of year 1, and in late August of each subsequent year according to the scheme guidelines (Natural England, 2010). The other non-crop treatments were left unmanaged as per guidelines.

2.1. Monitoring

Vegetation composition was recorded in July each year (2000–2002) from six randomly located 1 m × 1 m quadrats located within each treatment plot. The percentage cover of all vascular plants, bare ground, litter and bryophytes was estimated as a vertical projection. Litter and bryophyte cover were a very small component of the vegetation and so was not reported further.

Transects were walked through the centre of each plot (72 m) to record the abundance and species richness of butterfly and bumblebee (*Bombus* spp.) species using a modified version of the Butterfly Monitoring Scheme (BMS) methodology (temperature above 13 °C with at least 60% clear sky, or 17 °C in any sky conditions) (Pywell et al., 2006). Butterfly transects were walked on 15 occasions between May and August in 2000, on 14 occasions in 2001 and 13 times in 2002. Bumblebees were recorded on 12 occasions in 2000, on 10 occasions in 2001 and 11 times in 2002. Pitfall traps were used to sample surface active epigeal invertebrates. Pitfall traps (diameter 8 cm, depth 11 cm) were placed in lines of eight along the centreline of each plot, 5 m apart. Each trap was half filled with a 50% solution of propylene glycol (antifreeze) and water, combined with a small volume of detergent to reduce surface tension. Propylene glycol was used as a preservative (instead of the more commonly used ethylene glycol) as it is less poisonous to badgers (*Meles meles*) and foxes (*Vulpes vulpes*) which are attracted to the traps. The traps were open for a four week period from late April to late May in each year from 2000 to 2002. The contents of the traps were emptied after a two week period and then again at the end of the trapping period. The entire contents of all pitfall traps was retained for subsequent identification and summed within an individual year for a particular treatment. All adult individuals collected within the pitfall traps were identified to the level of species. This included spiders (Araneae), harvestmen (Opiliones), beetles (Coleoptera), true bugs (Heteroptera), ants (Formicidae), centipedes (Chilopoda), millipedes (Diplopoda) and woodlice (Isopoda). To sample the complementary fauna of canopy dwelling arthropods, sweep netting on a single occasion in early July of each year was undertaken. A standard sweep net of 0.5 m diameter with a 0.7 m handle was used. One sample unit comprised all material collected from a single plot by sweeping vigorously from side to side through the canopy while walking a standardised, figure-of-eight transect (length 90 m), keeping the speed and spatial extent of sweeping as constant as possible. All sweeping was carried out by the same person during warm, dry weather (>15° C) between the hours of 10.00 and 16.00. Species identification was taken to the same resolution as described for pitfall traps.

Finally, overwintering invertebrates were sampled in each habitat with the exception of the split tall grass and wildflower margin. Twelve randomly positioned soil cores, each measuring 16 cm × 16 cm and 12 cm deep, were collected at equal intervals along the centre line of each plot in January 2002. Each sample was placed in a sealed and labelled polythene bag, and stored in a cold room at 4° C. Batches of samples were removed to a room at between 18 and 22° C for 24 h prior to sorting. This was to encourage invertebrate activity and therefore increase the probability of catching individuals by hand sorting. Each sample was broken up by hand and thoroughly searched for invertebrates for a fixed period of 10 min (Pywell et al., 2005). Adults and larvae of the order Coleoptera (with the exception of the Staphylinidae from the subfamily Aleocharinae) were identified to species level. Finally, larvae of the orders Diptera and Thysanoptera, and adult Hymenoptera were counted, but not identified to species.

2.2. Classification into guilds and functional groups

Following Blondel (2003) sown and unsown plant species were classified into the following ecological guilds to describe how they share resources and for explaining the structure of the communities: grasses (27 species), forbs (77), legumes (6) and hemi-parasites (1). The single hemi-parasitic plant species (*Rhinanthus minor*) was included as it is well known to have an important role in the regulation and maintenance of plant diversity through the reduction of competitive species (Bullock and Pywell, 2005). It also attained a high (>30%) cover in some plots. In addition, we applied a further economic and cultural classification based on the potential to reduce the yield of crops and the undesirability of species (weeds: 9 species). This group included serious weeds of agriculture (e.g. *Alopecurus myosuroides*) and species that must be controlled by law under the UK Injurious Weeds Act of 1959 (e.g.

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